ALLIED PAPER, INC./PORTAGE CREEK/ KALAMAZOO RIVER SUPERFUND SITE DESCRIPTION OF THE CURRENT SITUATION

VOLUME I OF VII

Kalamazoo River Study Group

BBL
BLASLAND, BOUCK & LEE, INC.
engineers & scientists

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KALAMAZOO RIVER STUDY GROUP

JULY 1992

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SECTION 1 - INTRODUCTION

1.1 Background

The Remedial Investigation and Feasibility Study (RI/FS) of the Allied Paper, Inc./Portage Creek/Kalamazoo River Superfund Site is the essential requirement of the Administrative Order by Consent (Consent Order) between the Michigan Department of Natural Resources (MDNR) and Allied Paper, Inc./HM Holdings, Inc., Georgia-Pacific Corporation, and the Simpson Plainwell Paper Company. The Kalamazoo River Study Group (KRSG), comprising Allied Paper, Inc./HM Holdings, Inc., Georgia-Pacific Corporation, and the Simpson Plainwell Paper Company, is sponsoring an RI/FS of the Allied Paper, Inc./Portage Creek/Kalamazoo River Superfund Site. The Consent Order, which became effective on December 28, 1990, defines the activities of the Remedial Investigation (RI) and sets the course for the Feasibility Study (FS). The first milestone of the RI/FS process is the development of this report - a description of the current situation.

The general requirements of this report, including format and general topics, are prescribed in the Consent Order. The report is intended to assist in the identification of specific areas to be included in the RI and the nature of the RI/FS activities for those areas. It is also intended to draw into focus the major issues involved with the assessment of remedial needs and alternatives.

This document encompasses a significantly larger area to be investigated than that contemplated by the drafts which were submitted on February 26, 1991 and May 24, 1991, and which addressed the Site identified on the National

Priorities List (NPL). The second draft was issued in response to MDNR's May 16, 1991 comments. On July 24, 1991 MDNR directed that the RI address additional areas both upstream and downstream of the Site as described for the National Priorities List. MDNR issued further instruction on July 31, 1991 to revise this document to include those additional areas to be investigated.

The National Priority Listed Site, referred to as the "NPL Site", includes three miles of Portage Creek and 35 miles of the Kalamazoo River from the city of Kalamazoo to the city of Allegan. The entire area now subject to RI activities is referred to as the "Site." The Site encompasses not only the NPL Site but the entire downstream length of the Kalamazoo River, in addition to the other areas discussed below.

The specific areas to be investigated include:

- The Kalamazoo River from the Morrow Lake Dam to Lake Michigan;
- Portage Creek from Alcott Street to the Kalamazoo River;
- Performance Paper Mill and property;
- Former King Mill property;
- Georgia-Pacific Corporation Kalamazoo Mill and property;
- King Street storm sewer outfall; and,
- Simpson Plainwell Paper Company Mill.
- Allied Paper residuals disposal area including the former Bryant Mill Pond (Allied Paper Operable Unit);
- King Highway Landfill Operable Unit;
- Willow Boulevard and A-Site Operable Unit; and
- 12th Street Landfill Operable Unit.

Four of the areas to be investigated have been segmented into operable units to allow RI/FS activities to proceed along different schedules. These operable units include:

- Allied Paper residuals disposal area including the former Bryant Mill Pond (Allied Paper Operable Unit);
- King Highway Landfill Operable Unit;
- Willow Boulevard and A-Site Operable Unit; and
- 12th Street Landfill Operable Unit.

At the time of this report's preparation, a great deal more was known about the Allied Paper portion of the Site than the rest of the Site. This is largely due to the information generated in connection with litigation pending between the state and Allied Paper, Inc. (See Frank J. Kelly et al., vs. Allied Paper, Inc., et al., U.S. District Court, Western District of Michigan, Case #L87-89CAS).

1.2 Major Issues

Polychlorinated biphenyls (PCBs) are the main chemical of concern at the Site. The National Priorities List (NPL) scoring packet identified PCBs exclusively as the chemical of concern. According to the MDNR, a major source of the PCBs was the recycling of carbonless copy paper between the 1950s and the 1970s. Recycling of carbonless paper occurred at mills owned by members of the KRSG.

Creal (November 1983) reported a survey of PCBs in the Kalamazoo River and Portage Creek. It was stated that the sediments surrounding Bryant Mill

Pond, the Plainwell, Otsego, and Trowbridge impoundments, and Lake Allegan contained an estimated 227,910 pounds of PCBs.

The NPL scoring packet suggests that the major human health issue involves potential exposure to PCBs through the consumption of ground water (as drinking water) and, to a lesser extent, surface water. The Draft Preliminary Health Assessment for the NPL Site by the Agency for Toxic Substances and Disease Registry (ATSDR, 1991) expands the potential pathways to include: dermal contact with sediment and water; ingestion of soil, sediment, and biota; and inhalation of airborne PCBs. The Draft Preliminary Health Assessment also discounts the potential importance of ground-water contamination noting the limited mobility of PCBs in the subsurface, given their tendency to bind with soil and sediment. As required by the MDNR, ground water will, however, be investigated in the RI.

The protection of endangered species has been given special consideration by the Superfund program. According to the NPL scoring packet, there are no endangered species known to be within the required one-mile boundary of the NPL Site. However, a pair of nesting bald eagles, a threatened species, have been seen in the Ottawa Marsh and have been seen feeding in and near Lake Allegan. The Ottawa Marsh is located six miles downstream of the Lake Allegan Dam (Adams, 1991). While not within the NPL Site, this segment of the Kalamazoo River downstream of Lake Allegan has been added to the scope of the investigation.

Inquiries to the U.S. Fish and Wildlife Service (US FWS) and the Wildlife Division of MDNR generated information on the possible existence of threatened

or endangered species in the general vicinity of the Site. Information on threatened and endangered species is presented in Section 2.7.2.

Among the notable issues at the NPL Site are MDNR's prior and future management objectives for the Kalamazoo River upstream of the Trowbridge, Plainwell, and Otsego Dams. These state-owned dams have been removed to the sill level by MDNR. The MDNR claims that the complete removal of the dams is consistent with long-term fisheries management objectives for the Kalamazoo River, and contingent upon remediation of upstream PCB-contaminated sediments (MDNR, 1989).

The impact of PCB transport to areas downstream of the NPL Site is also a concern to MDNR. The section of the Kalamazoo River from Lake Allegan to Lake Michigan was designated an Area of Concern by the International Joint Commission in 1985. The resulting remedial planning has focused on remediation of the upstream sources of PCBs, primarily in-place contaminated sediments (MDNR, December 1987).

Estimates and estimated ranges of annual transport of PCBs from the Kalamazoo River to Lake Michigan have been made. These estimates include 104 to 439 lb/yr (Horvath, 1984), 57 to 220 lb/yr (Marti, 1984), 170 to 310 lb/yr (MDNR, December 1987), 251 lb/yr (NWF, 1991), and 275 lb/yr (Hesse, 1973; MWRC, 1972, 1973).

1.3 Description of Polychlorinated Biphenyls

1.3.1 Industrial Usage of PCBs

All of the major issues of this Site appear to be linked in some manner to the physical, chemical, and toxicological properties of PCBs and the history of their use and release to the environment. Consequently, a summary review of PCB properties and usage follows.

PCBs are a family of 209 possible compounds, referred to individually as congeners, differing in the number and arrangement of chlorine atoms on the biphenyl molecule. They are durable, thermally-resistant compounds which are good conductors of heat and poor conductors of electricity. These properties resulted in the widespread use of PCBs in the manufacturing of electrical components such as capacitors and transformers. In the United States, PCBs were produced for commercial purposes exclusively by Monsanto Industrial Chemicals Company (Monsanto).

Monsanto's base PCB products were mixtures sold under the trade name of Aroclor. The average chlorine content of a particular Aroclor product in most cases was evident in the specific product name. For example, Aroclor 1242 is comprised of 42 percent chlorine by weight. In other countries, PCBs were marketed under the trade names Clophen (Germany), Phenoclor and Pyralene (France), Kaneclor and Santotherm (Japan), and Fenclor (Italy).

In the United States, although most of the PCBs produced were used in electrical component manufacturing, portions were used in other applications including hydraulic fluids, cutting oils, plasticizers in synthetic

resins, heat transfer fluids, and carbonless copy paper. A review of PCBs in the paper industry (Carr et al., 1977) notes that only Aroclor 1242 was used in carbonless paper manufacturing. Aroclor 1242 comprises approximately 80 PCB compounds in widely varying abundance. Polychlorinated dibenzofurans are known trace contaminants of Aroclor mixtures and are collectively present in roughly a part per million level in Aroclor 1242 (Albro and Parker, 1979).

Carbonless paper containing Aroclor 1242 was manufactured under license to the National Cash Register Company (NCR) during the period of 1957 to 1971 (Carr et al., 1977). Dyes and Aroclor 1242 were contained within the hardened microcapsules on the back of carbonless paper. Approximately 44 million pounds of Aroclor 1242, roughly 6 percent of Monsanto's domestic sales of all Aroclors between 1957 and 1971, were sold for use in carbonless paper manufacturing.

By 1971, concerns regarding the persistence and bioaccumulation of PCBs in the environment led to a decision by Monsanto to restrict PCB sales to applications involving closed electrical systems. In 1971, PCBs were replaced by alkyl-biphenyls in the production of carbonless paper (Carr et al., 1977). The manufacture of PCBs was banned in Michigan and then nationwide in 1979.

Aroclor 1254 received some limited use within the paper industry in "flexographic" inks which were used on plastic packaging. Carr et al. (1977) estimated that a total of 50,000 pounds of Aroclor 1254 were used in these inks. Since the flexible packaging was plastic or paper containing

plastic adhesives (and contained negligible amounts of fiber), it would not have been an attractive stock for recycling. Consequently, Carr et al. (1977) concluded that these inks were unlikely to have made a significant contribution of PCBs to waste streams within the paper industry. Therefore deinking operations involving carbonless paper would have probably generated a waste stream containing Aroclor 1242, and no appreciable amount of Aroclor 1254.

1.3.2 Human Health Effects of PCBs

The following summary of human health effects was provided by the MDNR in a letter dated April 13, 1992, with instructions to include the text in this report. This summary does not reflect the opinions of the KRSG.

> PCBs were widely used in industry for over 40 years and, due to their chemical stability, have become widespread in the environment. PCBs can be absorbed through the digestive system, the respiratory tract, and the skin of mammals. Therefore, exposures resulting in ingestion, inhalation, or dermal contact of PCBs may lead to adverse health effects.
>
> The common toxic reactions to halogenated aromatic hydrocarbons, of which PCBs are one member, are numerous and include: loss of body weight, thymic atrophy, immunotoxicity, porphyria, dermal toxicity, endocrine effects, reproductive toxicity, and carcinogenicity.
>
> Occupational exposures have resulted in chloracne and brown chromodermatosis (Reggiani and Bruppacher, 1985). Other

physical complaints included burning sensation of the face and hands, nausea and body odor, anorexia, abdominal pain, and upper respiratory irritation.

PCBs have a high potential for bioaccumulation in fish with values ranging from 26,000 to 660,000 (U.S. EPA, 1991). In a study of a cohort of Michigan residents, it was found that those who regularly ate Lake Michigan fish had serum PCB levels up to 30 times greater than those who did not eat these fish (Humphrey, 1987).

PCB exposure, measured by both contaminated fish consumption and cord serum PCB levels, predicted lower birth weight and smaller head circumference of newborns (Fien et al., 1984). In addition, a significant relation between increased estimated serum PCB level and decreased birth weight and gestational age was documented (Taylor et al., 1989).

PCB-exposed and non-exposed infants were administered Fagan's test of visual recognition which measures preference for novel stimuli (Jacobson et al., 1985). This test has been found to have the ability to predict verbal IQ among children scoring in the normal to superior range. Visual recognition paradigms have been found to discriminate between normal and Down's syndrome infants, infants reared at home and in an institution, full term and preterm infants, and nonorganic and organic failure to thrive infants. This study found that preference for novel stimuli

decreased in a dose-dependent manner with increasing levels of prenatal PCB exposure. However, postnatal exposure from nursing was not related to visual recognition memory.

U.S. EPA's cleanup policy for PCBs is based on protection from the cancer-causing properties of this class of compounds. The following discussion is taken directly from the EPA's Integrated Risk Information System (IRIS)[1].

Human Carcinogenicity Data

> "Although there are many studies, the data are inadequate with respect to human carcinogenicity data, due to confounding exposures or lack of exposure quantification. The first documentation of carcinogenicity associated with PCB exposure was reported at a New Jersey petrochemical plant involving 31 research and development employees and 41 refinery workers (Bahn et al., 1976, 1977). Although a statistically significant increase in malignant melanomas was reported, the two studies failed to report a quantified exposure level and to account for the presence of other potential or known carcinogens. In an expanded report of these studies, NIOSH

[1]U.S. EPA (1992) Integrated Risk Information System (IRIS). Online. Office of Health and Environmental Assessment, Environmental Criteria and Assessment Office, Cincinnati, Ohio.

(1977) concurred with the Bahn et al. (1976) findings. Brown and Jones (1981) reported a retrospective cohort mortality study on 2,567 workers who had completed at least 3 months of employment at one or two capacitor manufacturing plants. Exposure levels were 24 to 393 mg/m^3 at plant A and 318 to 1260 mg/m^3 at plant B. No excess risk of cancer was observed. In a 7-year follow-up study, Brown (1987) reported a statistically significant excess risk of liver and biliary cancer, with four of the five liver cancers in female workers at plant B. A review of the pathology reports indicated that two of the liver tumors counted in the follow-up study were not primary liver tumors. When these tumors are excluded the elevation in incidence is not statistically significant. The results also may be confounded by population differences in alcohol consumption, dietary habits, and ethnic composition.

Bertazzi et al. (1987) conducted a mortality study of 544 male and 1,556 female employees of a capacitor-making facility in Northern Italy. Aroclor 1254 and Pyralene 1476 were used in this

plant until 1964. These were progressively replaced by Pyralenes 3010 and 3011 until 1970, after which lower chlorinated Pyralenes were used exclusively. In 1980 the use of PCBs was abandoned. Some employees also used trichlorethylene but, according to the authors, were presumed to be protected by efficient ventilation. Air samples were collected and analyzed for PCBs in 1954 and 1977 because of reports of chloracne in workers. Quantities of PCBs on workers' hands and workplace surfaces also were measured in 1977. In 18 samples, levels ranged from 0.2 to 159.0 ug/m^2 on workplace surfaces and 0.3 to 9.2 ug/m^2 on workers' hands.

The authors compared observed mortality with that expected between 1946 and 1982 based on national and local Italian mortality rates. With vital status ascertainment 99.5 percent complete, relatively few deaths were reported by 1982 [30 males (5.5 percent) and 34 females (2.2 percent)]. In cohort males, the number of deaths from malignant tumors was significantly higher than expected compared with local or national rates, as was the number of deaths from cancer of the

gastrointestinal (GI) tract (6 observed vs. 1.7 national expected and 2.2 local expected). Of the six GI cancer deaths, one was due to liver cancer and one to biliary tract cancer. Deaths from hematologic neoplasms in males were also higher than expected, but the excess was not statistically significant. Total cancer deaths in females were significantly elevated in comparison to local rates (12 observed vs. 5.3 expected). None of these were liver or biliary cancers. The number of deaths from hematologic neoplasms in females was higher than expected when compared with local rates (4 observed vs. 1.1 expected). This study is limited by several factors, particularly the small number of deaths that occurred by the cut-off period. The power of the study is insufficient to detect an elevated risk of site-specific cancer. In addition, the authors stated, after an examination of the individual cases, that interpretation of the increase in GI tract cancer in males was limited, as it appeared likely that some of these individuals had only limited PCB exposure. Confounding factors may have included possible contamination of the PCBs by dibenzofurans and exposure of

some of the workers to trichlorethylene, alkylbenzene, and epoxy resins.

Two occurrences of ingestion of PCB-contaminated rice oil have been reported: the Yusho incident of 1968 in Japan and the Yu-Cheng incident of 1979 in Taiwan. Amano et al. (1984) completed a 16-year retrospective cohort mortality study of 581 male and 505 female victims of the Yusho incident. A consistently high risk of liver cancer in females over the entire 16 years was observed; liver cancer in males was also significantly increased. Several serious limitations are evident in this study. There was a lack of information regarding job histories or the influence of alcoholism or smoking. The information concerning the diagnosis of liver cancer was obtained from the victims' families, and it is not clear whether this information was independently verified by health professionals. For some of the cancers described, the latency period is shorter than would be expected. Furthermore, the contaminated oils contained polychlorinated dibenzofurans and polychlorinated quinones as well as PCBs, and the study lacks data regarding

exposure to the first two classes of compounds. There is strong evidence indicating that the health effects seen in Yusho victims were due to ingestion of polychlorinated dibenzofurans, rather than to PCBs themselves (reviewed in EPA, 1988). The results of the Amano et al. study can, therefore, be considered as no more than suggestive of carcinogenicity of PCBs.[2]

Animal Carcinogenicity Data

PCB mixtures assayed in the following studies were commercial preparations and may not be the same as mixtures of isomers found in the environment. Although animal feeding studies demonstrate the carcinogenicity of commercial PCB preparations, it is not known which of the PCB congeners in such preparations are responsible for these effects, or if decomposition products, contaminants, or metabolites are involved in the

[2]More recently, the study Health Hazard Evaluation Report for Westinghouse Electric Corp. (1991) NIOSH HETA 89-116-2094, was released which supports a link between PCB exposures and cancer in humans. In this study, a retrospective cohort mortality analysis was conducted of 3,588 persons who ever worked at an electrical capacitor manufacturer having potential exposures to Aroclors 1016 and 1242. All causes of mortality and total cancer deaths were less than expected. However, more deaths were observed than expected for skin cancer and brain cancer, with the skin cancer deaths being statistically significant at four times greater than expected. Although the skin cancer deaths could not be related to cumulative PCB exposure, they were related (p=0.01) to plant location (i.e., production areas) as compared to working in office areas.

toxic response. Early bioassays with rats (Kimura and Baba, 1973; Ito et al., 1974) were inadequate to assess carcinogenicity due to the small number of animals and short duration of exposure to PCB. A long-term bioassay of Aroclor 1260 reported by Kimbrough et al. (1975) produced hepatocellular carcinomas in female Sherman rates when 100 ppm was administered for 630 days to 200 animals. Hepatocellular carcinomas and neoplastic nodules were observed in 14 and 78 percent, respectively, of the dosed animals, compared with 0.58 and 0 percent, respectively, of the controls.

The NCI (1978) reported results for 24 male and 24 female Fischer 344 rats treated with Aroclor 1254 at 25, 50, or 100 ppm for 104 to 105 weeks. Although carcinomas of the gastrointestinal tract were observed among the treated animals only, the incidence was not statistically significantly elevated. An apparent dose-related incidence of hepatic nodular hyperplasia in both sexes as well as hepatocellular carcinomas among mid-to high-dose treated males was reported (4-12 percent, compared to 0 percent in controls).

Norback and Weltman (1985) fed 70 male and 70 female Sprague-Dawley rats a diet containing Aroclor 1260 in corn oil at 100 ppm for 16 months, followed by a 50 ppm diet for an additional 8 months, then a basal diet for 5 months. Control animals (63 rats/sex) received a diet containing corn oil for 18 months, then a basal diet alone for 5 months. Among animals that survived for at least 18 months, females exhibited a 91 percent incidence (43/47) of hepatocellular carcinoma. An additional 4 percent (2/47) had neoplastic nodules. In males corresponding incidences were 4 percent (2/46) for carcinoma and 11 percent (5/46) for neoplastic nodules. Concurrent liver morphology studies were carried out on tissue samples obtained by partial hepatectomies of three animals/group at eight time points. These studies showed the sequential progression of liver lesions to hepatocellular carcinomas.

Orally administered PCB resulted in increased incidences of hepatocellular carcinomas in two mouse strains. Ito et al. (1973) treated male dd mice (12/group) with Kanechlors 500, 400, and 300

each at dietary levels of 100, 250, or 500 ppm for 32 weeks. The group fed 500 ppm of Kanechlor 500 had a 41.7 percent incidence of hepatocellular carcinomas and a 58.3 percent incidence of nodular hyperplasia. Hepatocellular carcinomas and nodular hyperplasia were not observed in mice fed 100 or 250 ppm of Kanechlor 500, nor among those fed Kanechlors 400 or 300 at any concentrations.

Schaeffer et al. (1984) fed male Wistar rats diets containing 100 ppm of the PCB mixtures Clophen A-30 (30 percent chlorine by weight) or Clophen A-60 (60 percent chlorine by weight) for 800 days. The PCB mixtures were reported to be free of furans. Clophen A-30 was administered to 152 rats, Clophen A-60 to 141 rats, and 139 rats received a standard diet. Mortality and histologic lesions were reported for animals necropsied during each 100-day interval for all three groups. Of the animals that survived the 800-day treatment period, 1/53 rats (2 percent) in the control group, 3/87 (3 percent) in the Clophen A-30 group, and 52/85 (61 percent) in the Clophen A-60 group had developed hepatocellular carcinoma. The incidence

in the Clophen A-60 group was significantly elevated in comparison to the control group. Neoplastic nodules were reported in 2/53 control, 35/87 Clophen A-30, and 34/85 Clophen A-60-treated animals. The incidence of nodules was significantly increased in both treatment groups in comparison to the control group. Neoplastic liver nodules and hepatocellular carcinomas appeared earlier and at higher incidence in the Clophen A-60 group relative to the Clophen A-30 group. The authors interpreted the results as indicative of a carcinogenic effect related to the degree of chlorination of the PCB mixture. The authors also suggested that these findings support those of others, including Ito et al. (1973) and Kimbrough et al. (1975), in which hepatocellular carcinomas were produced by more highly chlorinated mixtures.

Kimbrough and Linder (1974) dosed groups of 50 male BALB/cJ mice (a strain with a low spontaneous incidence of hepatoma) with Aroclor 1254 at 300 ppm in the diet for 11 months or six months, followed by a five-month recovery period. Two groups of 50 mice were fed a control diet for 11 months. The incidence of hepatomas in

survivors fed Aroclor 1254 for 11 months was 10/22. One hepatoma was observed in the 24 survivors fed Aroclor 1254 for 6 months.

Supporting Data for Carcinogenicity

Most genotoxicity assays of PCBs have been negative. The majority of microbial assays of PCB mixtures and various congeners showed no evidence of mutagenic effects (Schoeny et al., 1979; Schoeny, 1982; Wyndham et al, 1976). Of various tests on the clastogenic effect of PCBs (Heddle and Bruce, 1977; Green et al., 1975), only Peakall et al. (1972) reported results indicative of a possible clastogenic action by PCBs in dove embryos."

EPA places PCBs in category B2, probable human carcinogens, due to positive evidence in animals (for Aroclors 1254, 1260, Kaneclor 500, and Clophen A-30 and A-60) and inadequate evidence in humans. Because any PCB mixture that contains appreciable amounts of the components in Aroclors 1254, 1260, Kaneclor 500, and Clophen A-30 and A-60 are likely to present a carcinogenic risk and because the variety and variability of PCB mixtures, EPA recommended that all commercial PCB mixtures be classified as B2 carcinogens (U.S. EPA, 1988; IRIS). In addition, IARC (IARC, 1982) has classified PCBs in Group B2

compared with 0.8 mg/kg FW in the reference area, and Caspian tern (S. Caspia) eggs averaged 5.4 mg/kg FW.

Bald eagle eggs collected from 1969 to 1979 in 14 states in the U.S. contained PCB concentrations generally ranging between 0.53 and 98 mg/kg FW (there was one non-detect and one as high as 218 mg/kg). The geometric mean PCB levels were 13 mg/kg for unsuccessful nests vs. 7.2 mg/kg for successful ones; however, because PCB residues were correlated with DDE levels, it was not possible to separate the effects of PCBs from those of DDE or other contaminants (Wiemeyer et al., 1984).

Freshly laid brown pelican (Pelicanus occidentalis) eggs collected between 1971 and 1975 in the southeastern U.S. contained mean total PCB levels of 1.90 to 13.6 mg/kg FW in successful nests vs. 2.00 to 36.5 mg/kg in unsuccessful ones. Embryonated eggs from successful nests contained means ranging between 1.7 and 18.6 mg/kg FW PCBs, while unsuccessful nests contained 0.70 to 18.0 mg/kg. As in other studies, a strong positive intercorrelation between organochlorine contaminants was observed; however, the evidence indicated that DDE was the main pollutant influencing reproductive success in these birds (Blus, 1982).

In the study of Forster's Terns by Kubiak et al. (1989), the median concentration of total PCBs in eggs from the Green Bay

colony was 22.2 mg/kg FW, compared with 4.5 mg/kg from the reference area. PCBs were the most likely cause of the negative reproductive effects observed in the Green Bay colony. Eisler (1986) recommended less than 16 mg/kg FW as a target level for birds. This number, based on a study of ringed turtle doves, may not be appropriate for bald eagles, which may be as sensitive as chickens (Kubiak and Best, 1991). Other egg concentrations which were related to unsuccessful reproduction listed above ranged from 3 to 14 mg/kg for a lab study of chicks, to 22.2 for the Green Bay tern colony. Studies where PCBs were not likely affecting reproduction negatively measured egg concentrations between 1.2 and 18.6 mg/kg FW.

Wiemeyer (1990) states that PCB concentrations of less than or equal to 4 mg/kg FW in bald eagle eggs should be adequate to ensure normal reproduction, but that more information is needed on specific PCB congeners.

PCB Levels In Blood - Some data exist for PCB levels in bald eagle blood. Blood samples collected from bald eagles throughout the Great Lakes basin averaged 183.6 ug/L (blood plasma concentrations), while inland birds averaged 29.0 ug/L. For comparison, the blood levels measured in the 1979-81 study of western bald eagles (Wiemeyer et al., 1989) were converted to be equivalent to blood plasma levels and averaged 129 ug/L for

birds along the lower Columbia River (Oregon) and 22.0 ug/L in the outer Klamath basin (Oregon and N. California).

PCB Accumulation in Plants

Plant uptake and translocation of PCBs by crops is generally not significant (Bacci and Gaggi, 1985; Fries and Morrow, 1981; Iwata and Gunther, 1976; Weber and Mrozek, 1979; Webber et al., 1983). PCBs have been found in leaves and outer root peels of plants (e.g., corn, fescue, carrots) grown during laboratory studies of soils containing PCBs in excess of 100 milligrams per kilogram (mg/kg). However, PCB levels in the leaves of crops exposed during plant uptake studies are believed to be the result of dust settling and accumulation of volatilized PCBs rather than uptake and translocation of PCBs from soils.

1.3.4 Fate and Transport of PCBs in the Environment

The fate and transport of PCBs in the environment is greatly influenced by their low water solubility. This generally limits aqueous-phase concentrations to the low nanograms per liter range or less, unless significant amounts of solvents, oils, or colloids are present (Baker et al., 1986; Dragun, 1989). In general, the adsorption of PCBs to soils and sediments increases with increasing organic content, decreasing particle size, and increasing congener chlorination (Lyman et al., 1982; Pignatello, 1989). PCBs may volatilize from soil, but strong adsorption to soils tends to limit the extent of volatilization (ATSDR, 1989).

PCBs are very persistent in the environment, and degradation via chemical oxidation, hydrolysis, and photolysis in soil or aquatic systems is

generally insignificant. However, preliminary research indicates that PCBs may undergo a very slow transformation via biotransformation and biodegradation. Experimental evidence indicates that PCBs are susceptible to biodegradation under both aerobic and anaerobic conditions. In general, the degradability of PCB congeners under aerobic conditions increases as the degree of chlorination decreases. Laboratory research has shown that the lesser chlorinated PCB congeners (such as mono, di, and trichlorobiphenyls, which make up approximately 66 percent of Aroclor 1242), are subject to aerobic biodegradation by microorganisms indigenous to soils and sediments. Aerobic biodegradation of PCBs by bacteria generally proceeds towards mineralization through intermediates including chlorinated catechol and chlorobenzoic acid (Bedard et al., 1987a, 1987b; Hankin and Sawhney, 1984; Fries and Morrow, 1984).

Laboratory research has shown that PCBs undergo reductive dechlorination under anaerobic conditions by indigenous microorganisms. Study results indicate that the more highly chlorinated PCBs are transformed to lesser chlorinated congeners (Quensen et al., 1988) and that the lower chlorinated PCBs may be degraded to carbon dioxide, water, and chloride (Chen et al., 1988). Analysis of PCB degradation patterns in sediments from sites such as the Hudson River (New York), the Housatonic River (Massachusetts), Waukegan Harbor (Illinois), Sheboygan Harbor (Wisconsin), and New Bedford Harbor (Massachusetts) suggests that anaerobic biodegradation of PCBs occurs in the environment (Brown and Wagner, 1988). However, this transformation is very slow.

As previously stated, PCBs in aquatic systems tend to concentrate in the sediments. The affinity of PCBs for sediments is a function of chemical-specific factors (e.g., degree of chlorination) and site-specific factors (e.g., sediment grain size, organic content). PCBs generally adsorb more strongly to fine-grain, organic sediment than to coarse sediments with low organic content (Lyman et al., 1982; Pignatello, 1989).

Due to their lipophilic nature, PCBs bioaccumulate in aquatic organisms. Factors influencing the extent of bioaccumulation include the degree of PCB chlorination and bioavailability, in addition to ecological factors such as trophic relationships and community structure.

PCBs may also be removed from the water column via volatilization to the atmosphere; however, their volatilization rates are generally limited by their tendency to remain adsorbed to sediments and suspended solids. The lesser chlorinated congeners (tetrachlorobiphenyl and lower) have greater potential to volatilize than the more highly chlorinated congeners (ATSDR, 1989). PCBs in the atmosphere may be removed by vapor-phase photooxidation, dust fall, and precipitation. Estimated photooxidation half-lives range from approximately 13 days for monochlorobiphenyls to approximately 10 months for hexachlorobiphenyls (ATSDR, 1989).

SECTION 2 - SITE BACKGROUND

2.1 Overview

The Site is located in the mid-section of the Kalamazoo River watershed within Kalamazoo and Allegan Counties. The Kalamazoo River watershed is located in the southwest portion of Michigan's lower peninsula (Figure 1). The watershed contains approximately 400 miles of stream tributaries and encompasses a drainage area of over 2,000 square miles. The main stem of the Kalamazoo River forms in the city of Albion with the confluence of the North and South Branches. The river flows in a northwesterly direction for approximately 123 miles before draining into Lake Michigan near the town of Saugatuck.

The NPL Site, located within the larger area to be investigated (i.e., the Site), includes 35 miles of the Kalamazoo River from the river's confluence with Portage Creek downstream to the Allegan City Dam and approximately three miles of Portage Creek, from Cork Street in the city of Kalamazoo to its confluence with the Kalamazoo River.

Other reaches of the river to be investigated include the Kalamazoo River from Morrow Lake Dam to the Portage Creek confluence, and downstream of the Allegan City Dam to Lake Michigan. Within the Site, the river flows through the cities of Comstock (population 11,162), Kalamazoo (population 80,000), Parchment (population 1,960), Plainwell (population 4,000), Otsego (population 4,000),

Allegan (population 4,700), Saugatuck (population 1,100), and Douglas (population 950).

Between the Morrow Lake Dam and Saugatuck, the river is an alternating series of free-flowing sections and impoundments formed by low-level dams. Average river discharge at the upstream end of the Site is approximately 870 cubic feet per second (cfs) and increases to over 1,400 cfs at the Fennville gaging station downstream of the Lake Allegan Dam. The river has been impounded at six locations for the generation of hydroelectric power. The Plainwell, Otsego, and Trowbridge dams have been removed by MDNR to their sill levels; however, they still impound water. The Allegan City and Lake Allegan dams produce hydroelectric power. The river is also impounded by the Otsego City Dam, which does not generate hydroelectric power.

2.2 Topography and Geology

Using a combination of factors including land use (land use maps are located in Appendix B), land surface form, potential natural vegetation, and soil properties, Omernik (1986) defined the ecoregion which contains the Site as the South Michigan/Indiana Till Plains. This definition characterizes the area as consisting of irregular plains with oak, hickory, maple, and beech tree vegetation; land use of cropland, pasture, woodland, and forest; and soils of gray-brown podzol.

The soils within the Site have been categorized by the Soil Conservation Service. General soil associations and soil complexes in Kalamazoo and Allegan

Counties are described in the respective County Soil Surveys. In general, the soil in the area is described as ranging from nearly level to steep, and from poorly drained to well drained. The soils have loamy to sandy and loamy subsoils formed in glacial outwash and moraine deposits. More detailed descriptions are presented in later sections.

The regional topography was derived from the secession of several continental glaciers. The area was primarily influenced by the Wisconsin glacial period that occurred approximately 15,000 to 17,000 years ago. During this period, two large ice lobes, the Saginaw and Michigan, merged near the city of Otsego. The melting of the lobes and subsequent deposition of the entrained material gave rise to the present day landforms.

During the retreat of the ice lobes, the Saginaw lobe moved to the northeast and the Michigan lobe to the northwest, producing large quantities of outwash sand and gravel deposits which formed the Galesburg-Vicksburg outwash plain. Also, throughout this period, large blocks of ice broke away from the main ice body and were buried by outwash sediments. As the buried ice slowly melted, the overlaying sand and gravel collapsed forming many of the kettle lakes found throughout the area (Rheaume, 1990).

The retreat of the ice lobes halted in western Kalamazoo and Allegan counties. In this position, the ice lobe deposited sandy to very sandy till and massive to poorly bedded cobbly sand with isolated lenses and pockets of sandy clay. This depositional event formed the Kalamazoo Moraine, which is one of the largest continuous ridges in southern Michigan. The glacial deposits range

in thickness from approximately 50 feet to 200 feet and overlie the Coldwater Shale formed during the Mississippian Period of the Paleozoic Era. The shale is greater than 500-feet thick and dips to the northeast (Rheaume, 1990).

As the ice lobes continued to retreat, a drainageway was opened in front of the Michigan Lobe. Meltwaters that had been draining to the south ponded in the center of Kalamazoo County. The direction of flow changed from south to north, resulting in downcutting of the outwash plain and formation of the down-cut glacial drainage channels of the Kalamazoo River Valley. Eventually the lobes retreated out of Kalamazoo and Allegan counties, creating new drainage patterns and directing meltwater away from the Kalamazoo River Valley. As the new drainage pattern evolved, the flow through the Kalamazoo River decreased to its present pattern (Rheaume, 1990).

2.3 Climate

Table 1 summarizes meteorological data recorded for Kalamazoo County for the period of 1951 to 1980. In winter, the average temperature is 28.7°F, and the average daily minimum temperature is 20.9°F. The lowest temperature on record for the area is -16°F, which occurred in the city of Kalamazoo on February 10, 1885. In summer, the average temperature is 69.8°F, and the average daily maximum temperature is 81.3°F. The highest recorded temperature, occurring on July 13, 1936, was 100°F.

In Kalamazoo County, 58 percent of the average precipitation of 34.8 inches usually falls between April and September. Thunderstorms occur about 37 days

each year, generally in June and July. The heaviest 24-hour rainfall during the period of record was 5.6 inches, which occurred on May 11 and 12, 1914. The average seasonal snowfall is 73.1 inches. The average relative humidity at midday is 62 percent, with higher humidity at night and an average of 80 percent at dawn. The prevailing wind is from the southwest with the highest average wind speed occurring in January at 11.7 miles per hour (mph).

Allegan County's meteorological data are also summarized in Table 1 for the period 1951 to 1980. In winter, the average temperature is 27.9°F, and the average daily minimum temperature is 21°F. The lowest temperature on record is -20°F, which occurred in the city of Allegan on February 11, 1899. In summer, the average temperature is 67.8°F, and the average daily maximum temperature is 79.8°F. The highest recorded temperature, which occurred on July 13, 1936, was 104°F.

In Allegan County, 56 percent of the average precipitation of 35.6 inches usually falls between April and September. Thunderstorms occur about 38 days each year. The heaviest 24-hour rainfall event during the period of record was 6.23 inches, which occurred on June 26, 1978. The average seasonal snowfall is 78.4 inches, with the greatest recorded snow depth at any one time measured at 42 inches on January 14, 1910. The average relative humidity at midday is 62 percent, with higher humidity at night and an average of 82 percent at dawn. The prevailing wind is from the west, with the average wind speed being highest in January at 11.5 mph.

2.4 Hydrology

Of the 35 inches of annual average precipitation, 12 inches is discharged by streams. Of the 12 inches of stream discharge, 3 inches originate as overland flow and 9 inches are derived from ground-water flow. Regional ground-water recharge and evapotranspiration account for the remaining 23 inches.

The major waterways contained within the NPL Site include the Kalamazoo River and Portage Creek. Portage Creek, including its west fork, is approximately 18.5 miles long. Hydrologic data (Rheaume, 1990) for Portage Creek have been collected from a gaging station located approximately three miles south of the city of Kalamazoo. At this point, the creek drains an estimated area of 22 square miles. The 25-year average discharge is 40.6 cfs, with maximum and minimum flows of 407 and 8 cfs, respectively.

United States Geologic Survey (USGS) gaging stations on the Kalamazoo River are located in the upstream and downstream portions of the Site. The upstream gaging station is located near Comstock, and the other station is located in Fennville, four miles downstream from the Lake Allegan Dam. Data from the Comstock gaging station show the average flow on record as 868 cfs, with a maximum discharge of 6,910 cfs and a minimum average flow of 119 cfs.

The gaging station at Fennville is also a National Stream Quality Accounting Network station where water quality data is also collected. Discharge past the station averaged 1,451 cfs over the 59-year record. Extremes for the period of

record are 17,500 cfs and 50 cfs for high and low flows, respectively. Certain water quality parameters are also evaluated at the sampling station.

The USGS monitors the river stage on the Kalamazoo River and the ground-water elevation in the upstream end of the Site. The Comstock gauge station is located one mile downstream of Morrow Lake Dam (Figure 2), and the USGS ground-water monitoring well is located 1,000 feet away from the river in the upstream end of Morrow Lake, with a screened interval of 24 to 28 feet below ground surface. After one year of monitoring from August 1987 to August 1988, it was concluded that the river and the shallow aquifer are hydraulically connected (Rheaume, 1990). Changes in ground-water elevations reflect short-term and long-term changes in precipitation and local pumpage. In general, because of the permeable nature of the soils, there is a reported close interconnection between surface and ground-water flows.

River hydraulics have been influenced by a series of dams. Located downstream from the river's confluence with Portage Creek are the former impoundments at Plainwell, Otsego, and Trowbridge. Although these impoundments were drawn down, the natural river channel has not been completely reinstated. This can be observed at each of the former impoundments where hydraulic heads of approximately 5 to 10 feet still exist. However, after the drawdown of these impoundments, sediments that were once covered by the water column became exposed upon the floodplain. Current impoundments are formed by the Otsego City, Allegan City, and Lake Allegan dams. The Allegan City and Lake Allegan dams are used to generate electricity.

The primary ground-water sources in the area come from glacial deposits consisting mainly of sands and gravels. The most productive sources are the thick sand and gravel beds underlying the outwash plain or down-cut drainageway deposits. Water-well depths range from 25 to 328 feet, with the total depth of most domestic wells being less than 75 feet. The Coldwater Shale, which underlies the glacial deposits, yields small quantities of largely mineralized water. Except for rare instances, the Coldwater Shale aquifer is not used as a water source.

2.5 Site Characteristics

2.5.1 General

The Kalamazoo River drains over 2,000 square miles from 10 counties in southwest Michigan. The drainage basin is 162 miles long and varies in width from 11 to 29 miles. The main stem of the Kalamazoo begins in the city of Albion at the confluence of the North and South branches of the river. From Albion, the river flows northwesterly for approximately 123 miles before entering Lake Michigan near the towns of Douglas and Saugatuck (MDNR, 1989). The river has a relatively moderate stream gradient; however, the gradient increases to over two and one-half feet per mile between the cities of Plainwell and Allegan. This natural feature was instrumental in the siting of five dams on this stretch of river (MDNR, December 1987).

The entire basin is located in the South Michigan/Indiana Till Plains Ecoregion (Omernik, 1986). The region is topographically diverse and contains hills, valleys, irregular plains, ponds, and lakes. Low areas along the river form extensive flats, which are frequently intersected by streams. These flats, characterized by a high water table and muck soils, contain large areas of wetland habitat. Upland areas in the basin support diverse land uses including urban and suburban residential development, industrial and commercial use, and recreational development. Rural areas are dominated by cropland, pasture, woodland, and forest land uses (MDNR, December 1987).

In 1986, the MDNR Water Resources Commission filed with the Secretary of State, General Rule 323.1100. This rule stipulates that, at a minimum, all state waters are designated for the following uses:

- agriculture;
- navigation;
- industrial water supply;
- public water supply at point of water intake;
- warmwater fish;
- other indigenous aquatic life and wildlife; and
- partial body contact recreation.

The Site to be investigated includes approximately 75 miles of the river from the Morrow Lake Dam to the mouth of the river at Saugatuck and almost three miles of Portage Creek from Cork Street to the Kalamazoo

River. As described in previous reports (NUS, 1986; MDNR, December 1987), the river is typically divided into sections (or reaches) for descriptive purposes. The following ten sections of the Kalamazoo River and Portage Creek and pertinent adjacent areas will be discussed separately:

- Portage Creek, Cork Street to the Kalamazoo River (Figure 3), including the Allied Paper Property and the Performance Paper Mill;
- Kalamazoo River, Morrow Lake Dam to Portage Creek confluence, including Georgia-Pacific Corporation's Kalamazoo Mill, King Highway Landfill, Willow Boulevard Site, A-Site, the former King Mill Property, and the King Street storm sewer (Figure 3);
- Portage Creek confluence (Figure 3) to Main Street, Plainwell (Figures 4, 5, and 6);
- Main Street, Plainwell to the Plainwell Dam, including the Simpson Plainwell Paper Company Mill (Figure 6);
- Plainwell Dam to the Otsego City Dam, including the 12th Street Landfill (Figure 6);
- Otsego City Dam to the Otsego Dam (Figures 6 and 7);
- Otsego Dam to the Trowbridge Dam (Figures 7 and 8);
- Trowbridge Dam to the Allegan City Dam (Figure 8);
- Allegan City Dam to the Lake Allegan Dam (Figures 8 and 9); and,
- Lake Allegan Dam to Lake Michigan (Figures 9, 10, 11, and 12).

2.5.2 Portage Creek, Cork Street to the Kalamazoo River

Portage Creek, downstream of Cork Street, flows through the urban setting of the city of Kalamazoo (Figure 3). Significant portions of the creek are channelized to reduce flooding potential. Industrial, residential, commercial, and recreational land uses are interspersed along the creek's route to the Kalamazoo River.

The former residuals disposal area for Allied Paper, Inc., lies between Cork and Alcott Streets, adjacent to the semi-impounded Bryant Mill Pond (Figures 14 and 15). This area contains two clarifiers, a series of former decant lagoons, the former historic residuals dewatering lagoons (HRDLs), and a former licensed Type III landfill for residuals. This residuals disposal area and the former Bryant Mill Pond together constitute an operable unit.

Upstream of Alcott Street is a dam (Alcott Street Dam) with a partially closed orifice which, during high flow events, reimpounds portions of the former Bryant Mill Pond. This impoundment formerly covered an area of approximately 22 acres, and was drawn down with the approval of MDNR, exposing historical sediment deposits. Portions of these sediment deposits have been revegetated, as have portions of the HRDLs. Miller et al. (1985) estimated that the mass of PCBs contained in the exposed sediments of this reach ranged from 22,000 to 36,000 pounds, while the creek channel in this reach contains 260 pounds of PCBs.

Downstream of the Alcott Street Dam, the creek flows through the Performance Paper Mill (Figure 13) and continues through the city of Kalamazoo. The majority of this route is through residential neighborhoods, and at least one large park (Upjohn Park) is situated adjacent to the creek. Commercial and industrial development exists along the creek in the vicinity of the Allied complex to the south and in the general vicinity of the creek's confluence with the Kalamazoo River.

2.5.3 Kalamazoo River, Morrow Lake Dam to Portage Creek Confluence

The segment of the Kalamazoo River between the Morrow Lake Dam and Portage Creek (Figures 2 and 3) is approximately 4.8 miles long, with an average width of 40 feet, depth of 2.5 feet, and flow of 868 cfs (Rheaume, 1990). The river bottom can be described as being predominantly gravel, sand, and detritus (MDNR, November 1982).

This reach has land uses varying from forested wetlands to industrial. (Land use maps are located in Appendix B). The river in the upstream section of the reach initially flows through forested wetlands and then into residential and secondary business areas as it enters the city of Comstock. Once out of Comstock, the river again flows through a forested area. As the river approaches and enters the city of Kalamazoo, the land use changes to industrial and recreational. Industrial land use continues to the end of the reach (USGS 1961, 1967a).

Georgia-Pacific Corporation's Kalamazoo Mill lies along the northeastern bank of the river within this reach (Figure 18). Across the river from the

mill is the 23.3-acre King Highway Landfill (Figure 19), which is a licensed Type III landfill. The 11-acre Willow Boulevard Site (Figure 21) and 22.7-acre A-Site (Figure 23) are located to the south of the Kalamazoo River.

Also within the vicinity of this river segment lies the site of the former King Mill (Figure 17) and the King Street storm sewer (Figure 19).

Natural landmarks along the segment include two oxbows located on the north bank of the Kalamazoo River, and Davis Creek, which flows into the Kalamazoo River 1.8 miles upstream of the Portage Creek Confluence. There are six motor vehicle bridges which cross the river in this section. Michigan Avenue and South Mills Street Bridges are located at the downstream end of the segment and King Highway Bridge is located just outside of the Kalamazoo City line. Sprinkle Road and River Street Bridges are located 2.5 miles and 1.5 miles downstream of the Morrow Lake Dam, respectively.

Pedestrian access and recreational craft-access from unmaintained launch areas is available at Comstock Township's Merrill Park, North Park, and South Park. Merrill Park has playground equipment, a softball field, basketball hoops, rest room facilities, picnic tables with a shelter, grills, and river access. North and South Parks have only picnic tables and grills. There is also an unmarked, unmaintained MDNR-owned boat launch area on the river in the vicinity of Sprinkle Road. Recreational craft access is available from this unmaintained launch area (Katanski and Gervasi, 1990).

Access to the river is also possible at Red Arrow Park and Riverview Park (formerly Sutherland Park). Red Arrow Park is a golf course located adjacent to the Kalamazoo River. Riverview Park is a recreational area, including a ball park, which is open to the public. There are no boat ramps, launching facilities, or other improvements for boating purposes at any of these areas.

2.5.4 Portage Creek Confluence to Main Street, Plainwell

The stretch of the Kalamazoo River between Portage Creek and Plainwell (Figures 3 through 6) is approximately 15 miles in length and is described as an erosional zone (NUS, 1986), typically 1 to 3 feet deep, with a predominantly sand and gravel bottom (MDNR, October 1984).

The upstream portions of this reach are in the city of Kalamazoo and support extensive industrial development. Downstream of Kalamazoo, development near the river declines such that the surrounding land use in the vicinity of the Kalamazoo/Allegan County line is rural. As the river approaches Plainwell, it flows through areas of suburban and urban land use.

In addition to Portage Creek, streams tributary to this section of river include Silver Creek and Spring Brook. Wastewater flow into this reach includes the discharge from the city of Kalamazoo's wastewater treatment plant.

Kalamazoo River access in this area is either unmaintained or via developed boat launching facilities. Small boats such as rowboats and

canoes can be loaded into the river from private landholdings at a variety of points. In terms of public access, Verburg Park, a 10-acre parcel on the western bank from Gull Road to Paterson Street in Kalamazoo, is open to the public, and has a formal boat launching facility (boat ramp). The park also has baseball facilities and picnic grounds used by local residents (Kalamazoo City Parks Department, 1991).

Almost all of the eastern riverbank in Parchment is industrialized. The Kalamazoo Nature Center is located north of the city of Kalamazoo and has areas where small boats may be carried a short distance to the river.

2.5.5 Main Street, Plainwell to the Plainwell Dam

The stretch of the Kalamazoo River between Main Street, Plainwell, and the Plainwell Dam is a short stretch (approximately 2 miles) that consists mainly of the former Plainwell Impoundment (Figure 6). The Plainwell Dam is a former hydroelectric facility which has been dismantled down to the sill level (NUS, 1986). When in operation, the dam had a head of 13 feet and impounded water covering an area of approximately 123 acres (Miller, 1966). Presently, the Plainwell Dam has a head of approximately 5 feet (MDNR, 1989). A portion of the former impounded area lies exposed above the existing water line. This area is covered with historically deposited sediments and has since revegetated. Miller et al. (1985) estimated the mass of PCBs in the river channel and in the exposed sediments of this reach to be 8,000 pounds and 7,000 to 12,000 pounds, respectively.

The upper areas of this reach located in the city of Plainwell are urbanized and contain residential, commercial, and industrial land uses. The Plainwell wastewater treatment plant outfall is located within the town limits. The Simpson Plainwell Paper Company Mill is located adjacent to the river just downstream of Main Street (Figure 25). The area further downstream and outside the incorporated limits of the city of Plainwell is dominated by rural land uses. There are no significant tributaries to this reach of the river.

Access to the Kalamazoo River in the reach between Main Street in Plainwell and the Plainwell Dam is informal. Several riverside parks are located in this section, but do not have boat ramps or other provisions for boat launching. Sherwood Park, Pell Park, Darrow Park, and Hick's Park in Plainwell have fairly flat grades to the river's edge and small boats and canoes could be launched from these locations. Pedestrians may also gain access to the river from these parks (City of Plainwell, 1991). Additional informal access to the river is possible at a variety of places in this reach, including the Plainwell Dam, Douglas Avenue Bridge, and I-131 Bridge.

2.5.6 Plainwell Dam to the Otsego City Dam

The 1.7-mile stretch of river downstream of the Plainwell Dam contains the Otsego City Dam Impoundment (Figure 6). The impoundment contains large amounts of silt, and the adjacent shoreline is characterized by swampy, marshy conditions (NUS, 1986). The Otsego City Dam, which is also known as the Menasha Dam, has a head of 8.5 feet and impounds

approximately 500 acre-feet of water. Also adjacent to this stretch of river is the 6.5-acre 12th Street Landfill (Figure 22), immediately downstream of the Plainwell Dam.

Land use along the upper portions of this reach is predominantly rural-residential, with limited crop and pasture lands, woodlands, and forests. Land use in this lower stretch of river is characterized by limited residential development.

Access to the river in this area would be impeded by the wet marshy areas which predominate in most riverbank areas of this reach. Boats may be launched at the Otsego City Dam. Access is fairly limited however, and only small boats might be launched in this area. No boat ramps are located in this stretch.

2.5.7 Otsego City Dam to the Otsego Dam

Between the Otsego City Dam and the Otsego Dam, the river flows a distance of 3.3 miles (Figures 6 and 7). This stretch begins in the city of Otsego and has considerable industrial development in the vicinity of the Highway 89 Bridge. The lower portion, which is rural in character, contains the former Otsego Dam and Impoundment. Miller et al. (1985) estimated the mass of PCBs in this reach of river channel to be 1,050 pounds, while the exposed sediments are estimated to contain between 3,000 and 5,000 pounds of PCBs. The Otsego Dam is now owned by the MDNR and has been dismantled down to the sill level. While in use, the dam had a head of 14.5 feet and impounded water with a surface area of approximately 330

acres (Miller, 1966). The remaining structure has a head of approximately 6 feet. The impoundment has been drawn down, resulting in the exposure of historically deposited sediments which have since revegetated.

The Otsego wastewater treatment plant outfall is located within the city limits just downstream of the North Street Bridge.

Pine Creek discharges to the river upstream of the Otsego Dam. The creek is impounded at Jefferson Road prior to its confluence with the river, thus forming Pine Creek Pond which is approximately 70 acres in size (MDNR, 1989).

The lower part of this reach is less industrial than the upper part. Formal boat launching facilities in this section of the river are limited to the canoe launch located at Brookside Park in Otsego. This park is located on the south shore of the river near the beginning of the Otsego City Dam Impoundment. Boats may also be launched in Pine Creek Pond or along Pine Creek. The dam at Jefferson Road prevents direct movement by boat from Pine Creek to the river. The water treatment plant in Otsego is identified as a river access point by the Kalamazoo River Partners Program. Pedestrian access to the river may be provided at each of the three bridge crossings (Farmer Street, Route 89, and North Street) in this section. The Otsego Dam is also a potential pedestrian access point.

2.5.8 Otsego Dam to the Trowbridge Dam

The 4-mile stretch of the Kalamazoo River between the Otsego Dam and the Trowbridge Dam is rural with limited development (Figure 7). The

Miller et al. (1985) estimated the mass of PCB in the Lake Allegan sediments to range from 50,000 to 90,000 pounds.

Development along the 2-mile stretch of river in Allegan is extensive and includes residential, commercial, industrial, and recreational land uses. The Allegan County Fairgrounds are also located adjacent to the river. The Allegan wastewater treatment plant outfall is located on this stretch of river.

Although it is likely that most recreational activities on this stretch of river would involve Lake Allegan waters, access to the upper reaches is available at Riverfront Park (a canoe launch) and at the Allegan County Fairground.

Lake Allegan has considerable recreational development along its southern shoreline. Public facilities include boat launches and picnic/recreation areas. Limited residential development also exists along the southern shore. Access to the river is also possible at the Lake Allegan Dam via a boat launch.

There are two tributary streams in this section of the river. Rossman Creek enters the river just downstream of the Allegan City Dam, and Dumont Creek flows into Lake Allegan from the north (USGS, 1981a).

2.5.11 Lake Allegan Dam to Lake Michigan

The final segment of the Kalamazoo River spans 26 miles from the Lake Allegan Dam to Lake Michigan and has a subbasin drainage area of 460 square miles (Figures 9 through 12). The average mainstream width (excluding Kalamazoo Lake) is 100 feet with a range of 50 feet to 150 feet.

The river has an average water depth of 4 to 6 feet, with some areas as deep as 18 feet, and a bottom consisting mainly of sand. There are 12 tributaries flowing into the river segment with the largest being the Rabbit River. The banks along the river are relatively low (2 to 6 feet in height) and have extensive floodplains along the main channel, especially in the middle section of the reach (MDNR, December 1987).

Public access points in the upper reach of this stretch of river include two boat launch facilities; one located immediately downstream of the Lake Allegan Dam and another three miles further downstream at Swan Creek Marsh. Downstream of Lake Allegan Dam, the river flows through the extensive Allegan State Game Area. Informal access to the river is possible throughout the State Game Area. However, the marshy conditions of floodplain soils impede both vehicle and pedestrian access. Within the State Game Area, the river travels through three large marshes, the Koopman, Swan Creek, and Ottawa marshes, as well as the Palmer and Big Daily Bayous (Figures 10 and 11). Another boat launch facility is located at the main Ottawa Landing in Ottawa Marsh.

As the river leaves the Allegan State Game Area, it passes by the Rabbit River Confluence and the small town of New Richmond. A boat ramp is located on the river near the town of New Richmond. The river then flows by Morrison Bayou and into a large wetlands area. Another public access point (Hacklander) is located below the Morrison Bayou just upstream of the confluence of the river with Peach Orchard Creek above

Douglas. River Bluff Park is on the Kalamazoo River upstream of the Douglas Bayou. It is open to the public for recreational purposes and offers informal access to the river. Several boat launching ramps are located in Douglas Bayou at Howard Shultz Park and in the City of Douglas (MDNR, 1990e). As the river approaches Saugatuck, it broadens to form Kalamazoo Lake. This point is within 2.5 miles of the river mouth at Lake Michigan. Located on the northern bank of Kalamazoo Lake is Saugatuck and on the southern bank is Douglas (Figure 12). Both towns support residential and secondary and commercial businesses.

2.6 Fisheries Issues

2.6.1 Fisheries Management

Until the 1960s, the Kalamazoo River had never been the subject of a fisheries management plan. Poor water-quality conditions prevailed throughout most of the river for many years, particularly during the 1940s, 1950s, and 1960s. In response to improving water quality in the 1970s, the MDNR began augmenting sport fish populations through stocking programs in select portions of the river (i.e., those which had demonstrated the potential to sustain local fisheries). In recent years, the circumstances described in this section led to the development of a basin-wide fisheries management plan, of which the Kalamazoo River is a major part.

The main stem of the Kalamazoo River has been dammed at 10 locations yielding seven impoundments with a combined current surface area

of approximately 3,100 acres (MDNR, 1989). The Kalamazoo River Basin Fisheries Management Plan identifies management objectives for the entire main stem of the river and some tributaries.

The poor water quality conditions which historically occurred in the Kalamazoo River are well known. In the 1970's, concerns about the environment drew attention to the poor condition of the Kalamazoo River and other surface waters nationwide. Historical records indicate that significant water-quality impacts occurred in the Kalamazoo River immediately downstream of the larger population centers and in areas of intense industrial activity. The 33-mile stretch of the Kalamazoo River between the city of Kalamazoo and Lake Allegan was subject to the most severe impairment. The discharge of chemical and other wastes from domestic and industrial sources into the river resulted in degraded water-quality conditions. Depletion of oxygen in water, thermal warming, and chemical contamination of the surface water, sediments, and biota have been the direct result of these discharges. With improved treatment facilities and the administration of wastewater discharge permits within the last 20 years, water quality conditions in the Kalamazoo River have continually improved.

PCBs remaining in the aquatic sediments were cited by MDNR (1989) as limiting usage of the resource. A fish consumption advisory is currently in effect, as described in Section 2.6.2, due to the presence of PCBs (MDNR, 1991).

Additional indications of improving water quality in the river are provided by two fish surveys conducted in 1971 and 1982 (MDNR, 1972; MDNR, October 1984). These surveys documented large species diversity, significant fish populations, and naturally sustaining populations of game fish in both the upper reach (Albion to Kalamazoo) and lower reach (Lake Allegan Dam to Saugatuck) of the river. Despite the general improvements, both surveys cite obvious deterioration of water quality and competitive pressures by large populations of rough fish as the cause of observed declines in species diversity and overall population levels in the reach between Kalamazoo and the Lake Allegan Dam.

The stream classification for the Kalamazoo River also reflects the decline in water quality of the middle reach. The upper and lower reaches of the river are classified as top-quality warm water (i.e., contains a self-sustaining population of warm-water game fish) (MDNR, 1989). The middle reach is classified as second-quality warm water (i.e., containing significant populations of warm-water fish species, but game fish populations are appreciably limited by pollution, competition, or inadequate natural reproduction) (MDNR, 1989).

Anadromous fish species are those species which ascend freshwater streams from the sea or other large bodies of freshwater or saltwater to spawn. Anadromous species stocked by the state of Michigan in Lake Michigan tributaries include chinook salmon, coho salmon, steelhead, and brown trout. The lower Kalamazoo River is stocked annually with chinook

salmon, steelhead, and brown trout. Spawning runs of these three species have occurred on the river since the early 1970s and currently extend up the river to the Lake Allegan Dam (a distance of 26 miles).

The MDNR Division of Fisheries has expressed interest in the possibility of extending the anadromous fishery for a significant distance up the river (MDNR, 1987a). Yearly stocking of chinook salmon, steelhead, and brown trout in the river near Saugatuck are scheduled to continue for the foreseeable future.

From a historical perspective, no significant fisheries management initiatives on the Kalamazoo River existed prior to the 1960s. Limited stocking of both resident and anadromous species began in the late 1960s (MDNR, 1987a).

Only two sections of the main stem river have been targeted for fish stocking in the past: Morrow Lake and the river immediately upstream of Morrow Lake. In the late 1960s, channel catfish were introduced into the river upstream of Morrow Lake. In 1971 and in 1980, walleye pike were introduced into Morrow Lake. These stocking efforts have been successful in re-establishing a self-sustaining channel catfish population and in developing a walleye fishery (MDNR, 1989). The second section of river targeted for stocking is the area immediately downstream from Lake Allegan Dam. Interest in stocking this area is related to the discovery that a number of walleye fry planted in Morrow Lake in 1971 had migrated downstream and were inhabiting this area. Their success prompted more

stocking of both walleye fry and fingerlings. The present walleye fishery in this stretch of river is a result of these stockings (MDNR, 1989).

Coho salmon were first stocked in the river below Lake Allegan Dam in 1969, and the first significant stocking of chinook salmon occurred in 1972. In 1973, the stocking of coho salmon was discontinued in southern Lake Michigan streams due to poor returns of the fish to the eastern shore of the lake during the summer months. However, chinook salmon have provided a good fishery below Lake Allegan Dam, and annual stocking of 100,000 salmon smolts is continuing. Brown trout were first stocked in the Kalamazoo River in 1972, and steelhead smolts were released in 1974. Anadromous runs of both these species provided very good fishing. Currently, annual stocking of 10,000 yearling steelhead and 10,000 yearling brown trout maintain the fisheries for these two species (MDNR, 1989). Domestic rainbow trout stocking was initiated in 1972. This fishery was managed on an intermittent basis throughout the 1970s; however, by 1980 all rainbow trout stocking in the Kalamazoo River was discontinued (Johnson, 1991).

Most of the main stem of the river downstream from the Ceresco Dam (approximately 55 miles upstream from Morrow Lake) is navigable by canoe. Between the Lake Allegan Dam and the river's mouth, the river is wide and deep enough to be navigable by small boats with motors. The development and maintenance of access facilities (i.e., boat launches) has paralleled the development of anadromous and resident fisheries. Developed access is

considered adequate only in the lower basin from Lake Allegan Dam downstream to Lake Michigan and in a section in the middle basin from the Fort Custer Recreation Area downstream to Comstock (MDNR, 1989).

Specific goals of the Fisheries Management Plan (MDNR, 1989) which apply to the main stem reach of the Kalamazoo River include: 1) extension of the anadromous fishery approximately 41 miles upstream to the Battle Creek Dam; and 2) creation of a high quality warm-water sport fishery throughout the entire main stem reach of the river.

Key issues which have been considered regarding attainment of these goals include: 1) possible conflicts with hydroelectric development of the river (since resolved); 2) current dam barriers to anadromous fish passage; and 3) resolution of PCB issues (MDNR, 1989).

A significant issue is the passage of fish over seven in-place dams. Some of these dams are owned by the state of Michigan (Plainwell, Otsego, and Trowbridge) and are currently removed to the sill level. They are reportedly slated to be completely removed from the river sometime in the future (MDNR, 1989). The remaining four dams (Morrow Lake, Otsego City, Allegan City, Lake Allegan) will require the construction of fish ladders if anadromous fish species are to access upstream areas.

The presence of PCBs in sediments of the Kalamazoo River is considered by the MDNR to be a major issue. The Fisheries Management Plan (MDNR, 1989) notes that some of the management recommendations

are conditional upon the removal of PCB-containing sediments from the Kalamazoo River.

The following management recommendations were put forth by the Division of Fisheries in the Fisheries Management Plan (MDNR, 1989) to meet the goals for expanding the anadromous fishery and creating a high quality warm-water fishery in the mainstream of the Kalamazoo River:

1. Complete removal of the state-owned dams;
2. Construction of fish ladders at the Lake Allegan Dam, the Allegan City Dam, the Otsego City Dam, and the Morrow Lake Dam;
3. Chemical reclamation (via rotenone to eradicate the rough fish) of the middle reach of the Kalamazoo River (city of Kalamazoo to Lake Allegan Dam);
4. Restocking of warm-water sport fish species; and,
5. Increased anadromous fish stocking totals.

According to MDNR (1989), complete removal of the state-owned dams (Trowbridge, Otsego, and Plainwell) is more desirable than laddering the remaining sills for a number of reasons, including: 1) enhanced movement of anadromous species; 2) free passage of the warm-water fish that would be stocked throughout this area of the river; 3) elimination of habitat attractive to carp upstream of these dams; and 4) control of the repopulation of rough fish species.

A fish survey conducted on the Kalamazoo River in 1982 found that the fishery in the middle reach of the river between the city of Kalamazoo

and Lake Allegan Dam was almost non-existent (MDNR, October 1984). Although fisheries habitat was good, fish populations were dominated by carp and white suckers. In Lake Allegan, where the habitat was better, the fishery was dominated by relatively small carp (MDNR, October 1984). In a fish population survey conducted in 1986 from above the Kalamazoo wastewater treatment plant to 0.9 miles downstream, 44 individuals representing 10 species were caught, with 52.3 percent being gamefish. Most of the fish caught were healthy looking (Gaule, 1987). The MDNR has proposed that the entire main stem of the Kalamazoo River from the city of Kalamazoo to Lake Allegan Dam (including Lake Allegan) be chemically reclaimed with rotenone to eradicate rough fish and restocked with warm-water sport fish including walleye, smallmouth bass, largemouth bass, and channel catfish (MDNR, 1989).

To accomplish the proposed increase in the anadromous fishery, the Fisheries Management Plan (MDNR, 1989) suggests that annual stocking of chinook salmon be increased from 100,000 to 400,000, and steelhead be increased from 15,000 to 70,000. It also calls for the reintroduction of coho salmon with stockings of 300,000 annually. If these plans were implemented, such numbers would make the Kalamazoo River one of the most intensely managed steelhead fisheries in the state of Michigan and perhaps in the entire Lake Michigan basin. The projected stockings of chinook and coho salmon would rank them third and fourth, respectively,

in terms of size for these respective stocking programs in the state (MDNR, 1990c; WDNR, 1989).

2.6.2 Fish Consumption Advisories

The MDPH first issued an advisory concerning consumption of fish from the Kalamazoo River and Portage Creek in 1977 due to the presence of PCBs (MDNR, March 1990).

This advisory, in place from 1977 to 1982, recommended that "consumption of fish of all species should be avoided if caught from the Kalamazoo River downstream from Kalamazoo to the river mouth at Saugatuck or from Portage Creek downstream from Milham Park" (MDPH, 1983).

The fish consumption advisory contained in the 1991 Michigan Fishing Guide, "...as applied to the surface waters in the vicinity of the Kalamazoo site is that carp, catfish, suckers, and largemouth and smallmouth bass taken from Portage Creek below Monarch Mill Pond (upstream of the Allied Paper, Inc., site) and the Kalamazoo River from Morrow Lake Dam (upstream of Kalamazoo) to Lake Allegan Dam (the outlet of Lake Allegan) should not be eaten. Consumption of all other species taken from these waters should be restricted to no more than one meal per week, and nursing, expectant, and intending mothers and children age 15 and younger should not eat any of these fish. Downstream from Lake Allegan Dam on the Kalamazoo River, the advisory is that carp, catfish, and northern pike longer than 25 inches should not be eaten, and smaller pike, largemouth

bass longer than 15 inches, and smallmouth bass should be eaten no more than one meal a week, with the sensitive populations mentioned above advised not to eat fish of these species and sizes from the river at all" (MDNR, March 1990).

The 1991 Michigan Fishing Guide also stated that migratory salmon and trout from Lake Michigan - coho salmon over 26 inches, chinook salmon from 21 to 32 inches, lake trout from 20 to 23 inches, and brown trout up to 23 inches - that enter the Kalamazoo River and its tributaries downstream from the Lake Allegan Dam should be consumed in no more than one meal per week and should not be eaten by children under age 15 or by women who are pregnant, nursing, or expect to have children. Also, lake trout over 23 inches, chinook salmon over 32 inches, brown trout over 23 inches, carp, and catfish should not be eaten at all.

Fish consumption advisories are developed by the MDPH and are based on sampling data and professional judgement (MDPH, 1983); however, they are not legally binding (MDNR, March 1990). No other advisories pertaining to wildlife and waterfowl exist.

2.7 Floodplain Wildlife

2.7.1 Floodplain Habitat

The Kalamazoo River watershed contains a variety of wildlife habitat. Major land cover types within the drainage basin include: 1) urban and suburban development, 2) wetland, 3) open water, 4) forest land/brush land,

and 5) crop land/grass land (USDA, 1975). Cropland and pasture account for the greatest share of land in the watershed (57 percent). Forest land (21 percent) is the second most common land use. The remaining 22 percent consists of wetlands (3 percent), water (2 percent), urban areas (8 percent), and other land uses (9 percent) (MDNR, December 1987). Most of the lands classified as "other" are used as recreational lands. Land use maps are located in Appendix B.

In 1975, the United States Department of Agriculture (USDA) completed an analysis of wildlife habitat in the Kalamazoo, Black, Macatawa, and Paw Paw River basins (USDA, 1975). The habitat inventory was based on existing land uses (as recorded by high altitude photography) and their suitability for supporting certain wildlife species (white-tailed deer, ring-necked pheasant, bobwhite quail, cottontail rabbit, muskrat, and waterfowl). Land parcels measuring a square mile in area were selected as an appropriate management unit based on the overall ranges of the representative species listed above. Each management unit's habitat type was distinguished by the existence of one or a combination of six land cover types (forest land, cropland, grassland, marsh, open water, and urban development).

Recognizing that each management unit contains a variety of land cover types, the USDA ranked each unit to distinguish its associated habitat value. Wetlands were considered the most important land cover because of their high wildlife productivity, relative scarcity, and valuable water

resources. Forest land and brushland provide habitat for the greatest number of wildlife and were considered the next most valuable cover type. Sections with 50 percent or more of urban development were classified as urban use, as extensive development in the remaining area could be expected in the future.

The habitat value of each management unit in the basin was then determined according to land cover composition and wildlife habitat management priorities. Table 2 presents the ten land cover compositions identified by the USDA for evaluating habitat value in the Kalamazoo, Black, Macatawa, and Paw Paw River basins.

Results of the USDA evaluation (USDA, 1975) indicate the primary wildlife habitat of each management unit in the Kalamazoo River basin. These results show slight differences in the habitat value of the Kalamazoo River Floodplain in Kalamazoo and Allegan counties. Within Kalamazoo County, wetland/woodland (type WD), woodland (type D), and urban (type U) habitats predominate. Within Allegan County, wetland/woodland and woodland habitats predominate. A third habitat type common to the Kalamazoo River floodplain in Allegan County is the R type, which includes considerable percentages of cropland/grassland habitat. These habitat characterizations reflect the contrasting land use patterns within these two counties, as Kalamazoo County supports a broad urban/industrial development, while Allegan County supports a more extensive agricultural base.

Wetland habitats provide optimal environs for waterfowl. Both Allegan and Kalamazoo County lie in several waterfowl fall migration corridors. Other wetland species include a variety of amphibians, reptiles, birds, and mammals. Woodland habitats provide excellent food and forage for big game (e.g., white-tailed deer). Forest land habitats also support a variety of small mammals and woodland species of game and song birds. The upland habitat (more common to Allegan County) contains significant portions of grassland/cropland areas and provides good habitat for many grassland species in addition to forest land species. These habitats are the most diversified and provide habitat that will produce the greatest number of bird, mammal, amphibian, and reptile species (USDA, 1975).

As part of the Kalamazoo, Black, Macatawa, and Paw Paw River basins study, wetlands have been inventoried, classified, and mapped for the Kalamazoo River basin (USDA, 1976). A complete listing and delineation of wetlands areas within the area under investigation will be completed during preparation of the ecological assessment. In addition, investigations have determined that no listed or proposed critical habitat exists in the project area at this time (US FWS, 1991).

2.7.2 Threatened or Endangered Species

2.7.2.1 General

Information is available on population estimates of threatened or endangered species within the Kalamazoo River basin. An endangered species is one in danger of extinction through all or a significant part

of its range. A threatened species is one likely to become endangered within the foreseeable future. Both the Federal Endangered Species Act and the Michigan Endangered Species Act of 1974 require the conservation of threatened and endangered species and the ecosystems upon which such species depend. In accordance with these statutes, lists of threatened, endangered, or rare species have been compiled for the Kalamazoo River basin. Rare species are not necessarily endangered or threatened but are uncommon. As such, unless they have been designated as a species deserving special consideration (i.e., have been proposed or are under consideration to be proposed for reclassification as an endangered or threatened species) rare species of the Kalamazoo River basin will not be included in subsequent listings of endangered or threatened species presented in this report.

2.7.2.2 Federally Listed Species

The following species of fish, wildlife, and plants native to the Kalamazoo River basin have been listed or are proposed to be listed as endangered or threatened species in accordance with the Federal Endangered Species Act (US FWS, 1991).

Listed Fish and Wildlife

Common Name	Scientific Name	Classification
Indiana bat	Myotis sodalis	Endangered
Bald eagle*	Haliaeetus lecocephalus	Threatened

Listed Plants

Common Name	Scientific Name	Classification
White fringed prairie orchid	Platanthera leucophaea	Threatened
Pitcher's thistle	Cirsium pitcheri	Threatened

*Designates those species also included on the Michigan State List.

Fish and Wildlife Proposed for Listing

Common Name	Scientific Name
Lake Sturgeon	Acipenser fulvescens
Eastern Massasauga	Sistrurus catenatus
Kirtland's snake*	Clonophis kirtlandii

*Designates those species also included on the Michigan State List.

2.7.2.3 State-Listed Species

The following species of fish, wildlife and plants native to the Kalamazoo River basin have been listed or are proposed to be listed as endangered or threatened species in accordance with the Michigan Endangered Species Act of 1974 (MDNR, 1990d).

Listed Fish and Wildlife

Common Name	Scientific Name	Classification
Kirtland's snake	Clonophis kirtlandii	Endangered
Bald eagle	Haliaeetus leucocephalus	Threatened
Ottoe skipper	Hesperia ottoe	Threatened

Listed Plants

Common Name	Scientific Name	Classification
Log fern	Dryopteris celsa	Threatened
Nodding or three-birds Pagonia Orchid	Triphora trianthophora	Threatened

Fish and Wildlife Proposed for Listing

Common Name	Scientific Name	Classification
Weed shiner	Notropis texanus	Proposed Threatened

Proposed Plants

Common Name	Scientific Name	Classification
Tinted spurge	Euphorbia commutata	Proposed Threatened

2.7.3 Floodplain Species

Technical Papers number 5 and 6 of the Kalamazoo, Black, Macatawa, and Paw Paw River basins study (Pippen, 1976; Brewer, 1976) present the

results of efforts to compile species lists describing the dominant flora and fauna of this region. Noting that several animals characteristic of the region in the past have disappeared from the area and others have been added, these reports characterize the flora and fauna of the region as of the early 1970's. These lists are presented in Tables 3 and 4.

SECTION 3 - SITE HISTORY

3.1 Development of the Paper Industry

The combined area of Kalamazoo and Allegan counties was home to Native American cultures prior to the exploration of the area by French missionaries. From the missionaries' diaries, the area was described as dense hardwood forests with a few scattered grass meadows. Settlement of the area began in 1825, and by 1835 both Kalamazoo and Allegan counties were organized. After the Civil War, lumbering increased, and the dense forests were harvested and replaced by farms.

This period also coincides with the expansion of the paper industry in the area. The paper industry was historically located in the Great Lakes area because of the presence of a large pulp resource and the availability of process water. These two factors led to the placement of paper mills adjacent to the Kalamazoo River and the river's major tributaries.

The first reported efforts to establish the paper industry in Kalamazoo occurred in 1847 when the editor of the Kalamazoo Gazette wrote in the July 9th edition, "Capitalists who would embark in a profitable enterprise would do well to establish a paper mill in this village. We have the best facilities..." (Kalamazoo Gazette, November 16, 1947). The invitation was accepted in 1866 when Benjamin F. Lyon initiated plans to establish the Kalamazoo Paper Company.

By 1911, the paper-making industry was marked by great expansion, growth, and financial activity. From 1872 to 1911, 17 additional district mills were

opened. By World War I, Kalamazoo had become the largest paper-producing area in the United States, employing one-half of the city's work force (Massie and Schmitt, 1981). By 1947, the paper-making industry employed 6,900 people in Kalamazoo and had a reported annual payroll of $22 million. In 1950, Michigan Employment Security Commission records reported that 9,200 jobs in Kalamazoo were provided by the paper industry, comprising 20.2 percent of the non-farm employment (Lewis, 1963). By the 1950's, eight companies owned 10 sites in the area, with as many as three mills per site producing 2 percent of the United States daily output of paper and paperboard (Emerson, 1974).

By 1960, the number of jobs had declined to 9,000, 15.8 percent of the non-farm employment (Lewis, 1963). It was stated that the decline was as a result of a diversification of the area's industrial base. Today the paper industry employs 4,400 people and is constantly updating operations and streamlining processes to keep the industry competitive (Jones, 1990).

During the period of industrialization from the mid-19th century to the early 20th century, natural pulp resources became scarce and the industry turned to recycling waste paper from nearby cities. The recycling process produced a waste stream, the quality of which was a function of the type of waste paper stock recycled and the required quality of the paper stock to be manufactured. Specifically, the manufacturing of high-quality paper stock from waste paper requires removal of printing ink from the waste paper. This process is called deinking. During the period when carbonless copy paper, commonly found in office paper, contained Aroclor 1242 (1957 to 1971), the deinking of office paper produced a waste stream that contained PCBs. This occurred at a time when

PCBs were not recognized as toxic, and the only parameters regulated were suspended solids (SS) and biochemical oxygen demand (BOD). Treatment systems were designed and constructed to remove SS and BOD. According to MDNR, this treatment was not totally effective in stopping the discharge of PCBs to Portage Creek and the Kalamazoo River (MDNR, May 1991). Emerson (1974) reported that a large part of the industrial point-source pollution load discharged into the Kalamazoo River and its tributaries was generated from the wastewater produced in the deinking of waste paper stock required for recycling the waste. In 1950, 62 percent of the BOD discharged into the river was attributed to deinking mills in the Kalamazoo area. According to MDNR, the discharges from the KRSG-member mills contributed to the presence of PCBs in the Kalamazoo River and Portage Creek.

3.2 Water Quality

As the mills utilized river and creek water as a source of process water, they also discharged wastewaters bearing solids and oxygen demanding substances. Wastewater from a variety of industries, in addition to municipal sewage, was also discharged with little, if any, treatment.

Related water-quality problems that were commonly found in the Kalamazoo River included excessive daily variations of dissolved oxygen (DO) and pH; reduced DO levels; excessive plant nutrient levels; and elevated levels of total mercury, phenols, bacterial levels, and un-ionized ammonia (Beck and Buda, 1978).

A water quality survey conducted by the Michigan Stream Control Commission (MSCC) in the 1930's found that parts of the river were essentially without dissolved oxygen. The most critical conditions occurred in a 17-mile reach downstream of the city of Kalamazoo (Figures 4, 5, and 6). Extensive investigations conducted in 1946 by the National Council for Stream Improvement and the Michigan Water Resources Commission (MWRC), formerly the MSCC, identified beds of deposited organic solids in the river as a major pollution problem (Velz, 1946). The load of oxygen-demanding substances and solids was found to be two and one-half times greater than that found in a 1930 survey.

By 1950, DO levels had depleted to a point where anaerobic conditions were found in the river from the city of Kalamazoo to Plainwell. Odorous hydrogen sulfide emanated from the river's surface. The conditions also appeared responsible for a significant fish kill at Lake Allegan in 1953 (Emerson, 1974). Deposits of organic solids appeared to contribute to this sharp decline in DO levels. Consequently, on October 24, 1951, the MWRC adopted an order restricting the paper mills of the Kalamazoo River Valley to specified permissible discharge waste loads. By 1956, higher DO concentrations were observed as a result of the waste treatment and pollution control provided by all mills to remove or reduce settleable solids, and the treatment of sewage by the city of Kalamazoo. Organic solids deposits appeared to be smaller in 1956 than they were in 1946, but anoxic conditions persisted in certain parts of the Kalamazoo River.

The waste surveys conducted in 1955 and 1956 (MWRC, 1958) indicated that 18 industries, including paper companies, municipal wastewater treatment

plants, and a meat packing house, discharged wastewater to the Kalamazoo River between the city of Comstock and the Trowbridge Dam. Excellent reaeration conditions were observed over extensive reaches between the cities of Kalamazoo and Plainwell, and immediately below the city of Otsego where high velocities and a rough, rocky river bottom created zones of high turbulence. However, much of the critical reach immediately below the city of Kalamazoo contained areas of lower velocity due to fallen trees and snags, thus creating eddy or cross-current areas. It appears that critical DO conditions in this reach were not only a consequence of the pollution load into the river, but poor reaeration conditions as well.

The average 1955 total organic load for both municipal and industrial discharges was about 98,500 pounds of BOD_5 (five-day biochemical oxygen demand) into the river downstream of Kalamazoo. In 1968, the total organic load was about 28,000 pounds of BOD_5, representing an approximate 70 percent reduction from the 1955 level (GLBC, 1975).

In 1975, the Great Lakes Basin Commission (GLBC) reported that since 1955, pollution loads entering the river have declined and water quality has substantially improved. The improved water quality observed in the Kalamazoo River was thought to be primarily a result of the water pollution control measures implemented by the local industries.

Allied Paper, Inc., Simpson Plainwell Paper Company, and Georgia-Pacific Corporation have all utilized in-plant pollution control measures to reduce the pollution load into Portage Creek and the Kalamazoo River. Ironically, the greatest contribution of point-source pollution to these water bodies emanated

from paper recycling operations, an important conservation measure. Recycled wastepaper had to be deinked before it could be manufactured into high-quality paper. The process which removed ink and other contaminants, including PCBs, from paper stock produced a wastewater with very high total BOD which required extensive pre-treatment in order to avoid high demands on the stream for waste assimilation.

Between 1957 and 1971, operations related to the deinking of office paper containing carbonless copy paper resulted in the release of PCBs to the Kalamazoo River and Portage Creek. The Plainwell Mill operated such a deinking process between 1957 and 1962 (Thacker, 1991). Based upon current knowledge, deinking was practiced at Allied's Bryant Mill between 1957 and 1971 (Peterson, 1991). Deinking also occurred at the King Mill until 1965 (Oeming, 1965). A mill currently owned by Georgia-Pacific also deinked waste paper from the 1950s until the present. The discharge to the river was eliminated in 1964 when wastewater was diverted to the Kalamazoo wastewater treatment plant (Schmidt, 1991).

During the period that carbonless copy paper was deinked at these mills, the PCB-containing residuals from treated effluent were disposed at sites adjacent to the creek and river, including Allied's residuals disposal area, the 12th Street Landfill, the King Highway Landfill, the A-Site, and the Willow Boulevard Site.

By the mid-1970s, the river was no longer a source of odors, the water became more aesthetically pleasing, DO increased, and game fish were being caught in the reach just downstream of the city of Kalamazoo (Emerson, 1974).

According to MDNR, the major remaining problem for this stretch of river is contamination of the water column, sediments, and biota with PCBs (MDNR, December 1987).

3.3 Allied Paper, Inc.

As noted previously, at the time of this report's preparation, a great deal more is known about the Allied Paper portion of the Site than the rest of the Site. This is largely due to the information generated in connection with litigation pending between the State and Allied Paper, Inc. (Frank J. Kelly et al., versus Allied Paper, Inc., et al., United States District Court, Western District of Michigan, Case #L87-89CAS).

3.3.1 Paper-Making Operations

The former Allied Paper facility is located along Portage Creek in the city of Kalamazoo, approximately 3 miles upstream from Portage Creek's confluence with the Kalamazoo River (Figure 13). The Allied Paper Company was formed in 1922 by the merger of the King, Bardeen, and Monarch Paper Companies (Kalamazoo Gazette, 1934). The Bardeen Mill in Otsego closed in 1956 (Kalamazoo Gazette, 1956). The King Mill was operated until 1971; information on this mill is provided in Section 3.4.

The Monarch Mill was originally the Kalamazoo Paper Company Mill, built in 1867 on Cork Street. In 1872 it was rebuilt out of brick after the original building was destroyed by fire. It was sold to Gibson Paper Company in 1899, and then to the Monarch Paper Company in 1906 (Troyer, 1957). It became Allied's Monarch Mill with the merger in 1922.

In December 1980, the Monarch Mill was closed and subsequently razed (MDNR, 1984c). The Monarch Mill produced carbon tissue and book printing paper, using both bleached and unbleached kraft, and deinked stock (MWRC, 1967). As of 1965, the Mill was using 100 percent virgin fiber (Oeming, 1965).

The Bryant Paper Company was formed in 1895, and was sold in 1946 to the St. Regis Paper Company (Kalamazoo Gazette, 1955). It was purchased by Allied Paper in 1956 and became Allied's Bryant Mill. In 1988, the mill was sold to Performance Paper, Inc., and operations ceased in 1989.

During its 94 years of operation, the Bryant Mill produced a variety of high-quality papers including bible, bond, uncoated book, end leaf, gift wrapping, label, map, offset, opaque, sensitizing, text, vellum, xerographic, litho, chart, music, and watermark paper. Production averaged 275 tons of product daily (Lockwood-Post, 1991). Raw materials used included both recycled paper products that underwent the deinking process and virgin pulp.

Allied Paper, Inc. deinked and recycled large amounts of wastepaper at the Bryant Mill A. From the late 1950's until 1971, carbonless copy paper that was not removed by Allied's inspectors in the sorting room began to enter the wastepaper stream and was subsequently deinked at the Allied facility. Deinking operations were discontinued in 1971. The Mill A building was sold to American Pulp Corporation in 1972, then to Upgrade Company in the mid 1970's, and was demolished around 1978.

3.3.2 Water Pollution Control and Waste Management

Until the early 1950's, process waste was discharged directly into Portage Creek. In the 1950's, Allied constructed a primary treatment facility for the Monarch Mill to meet acceptable discharge limits of BOD and SS. Allied was the first paper mill in the area to have such a proposal accepted by the Water Resources Commission. Allied installed clarifying tanks, and residuals dewatering and storage lagoons. The St. Regis Paper Company also installed a treatment facility for its mill in 1954 similar to that constructed by Allied at the Monarch Mill. This facility was used by Allied when it acquired the Bryant Mill.

As part of the early residual disposal process, lagoons were used to dewater waste residuals. These historic residual dewatering lagoons (HRDLs) occupy approximately 40 acres just north of Cork Street, as illustrated on Figure 15.

The HRDLs were constructed in the mid-1950's simultaneously with the installation of clarifiers. The largest HRDL area is located north of Portage Creek adjacent to the Bryant Clarifier and is referred to as the Bryant HRDL (Figure 15). A separate HRDL is located on the south side of Portage Creek adjacent to the Monarch Clarifier and is referred to as the Monarch HRDL. The Monarch HRDL area has not been an active residuals disposal area since the 1960's (Wilkins & Wheaton, 1986). The Bryant HRDL area has been filled and inactive for at least the past 10 years. The only recent activity in the HRDLs has been occasional filling activities, maintenance of the perimeter dikes, and construction of new surface berms

in the middle of the Bryant HRDL to facilitate the solidification of the residuals (Limno-Tech, Inc., January 1990a).

In 1966, Allied began operation of a 7.8-acre Type II landfill for solid paper-waste licensed under Act 87, Public Acts of 1965. In 1984, the landfill was classified as Type III. Under this classification, the landfill received paper-waste residuals.

Allied was issued a Type III landfill license on February 8, 1985, which was, by law, a two-year license. Allied applied for license renewal on January 29, 1987. On May 1, 1987, MDNR issued a "Notice of Denial of Renewal" based on the presence of PCBs in ground water at two monitoring wells downgradient from the landfill, and based on a determination that there had been some disposal of waste material outside the area covered by the license. The denial did not prevent Allied from submitting a second application for renewal.

On July 29, 1987, Allied reported to MDNR that the alleged landfilling activities outside the licensed area, in fact, related to disposal of inert materials as part of the closeout of the old dewatering lagoons.

Also on July 29, Allied submitted its second application for renewal; on August 18, 1987, that application was rejected as "administratively incomplete." In December, the State sued Allied Paper and others, and included claims concerning the landfill. After discussions with the State, Allied filed a Work Plan for further investigation of the landfill. MDNR approved the Work Plan, and Allied filed the report of results of the Work Plan with MDNR on November 1, 1988. In December 1988, the State and

Allied entered into an Order by Consent, which allowed Allied to continue to operate the landfill as long as Allied was in compliance with the Order by Consent.

In 1969, Allied tied into Kalamazoo's wastewater treatment facility (Strickler, 1969). Thereafter, wastewater treatment at Allied Paper's plant involved the collection of wastewater into a common tank (Gray Tank), which was then pumped to the Bryant Clarifier for primary clarification (Figure 13). A portion of the effluent from the Bryant Clarifier was directed to the Monarch Clarifier, while the remainder went to the municipal sanitary waste treatment system. Effluent from the Monarch Clarifier went into either Portage Creek or was recycled to a filter plant (Figure 13). Residuals from the Bryant Clarifier were pumped into the decant lagoons for dewatering and subsequent landfilling. The previously identified Type III Landfill and HRDLs between Cork and Alcott Streets are believed to have received all of the residuals generated by both the Bryant Mill and the Monarch Mill. According to MDNR, the clarification process was not totally effective in stopping the discharge of PCBs to Portage Creek, and thus, these releases would have contributed to PCB contamination in Portage Creek and the Kalamazoo River (MDNR, May 1991).

3.3.3 History from Aerial Photographs

In a 1938 photograph (Figure 27), the Allied Paper, Inc., Monarch Mill and Bryant Paper Company Mills are both present, including Mill A, the deinking mill. No disposal of residuals is apparent in the present disposal area. The area consists of mostly grass and some trees with a small trail

1986 (Figure 35), the Monarch Mill is absent. The licensed Type III Landfill appears to be in use. In the 1991 photograph (Figure 36), the area where the Monarch HRDL was located is covered with vegetation. The area to the west of the Bryant clarifier has become slightly revegetated. A building (a bakery) occupies part of the area where the Monarch Mill stood.

3.4 King Mill

3.4.1 Paper-Making Operations

The King Paper Company was founded by John King in 1901, as a one-machine mill at 1608 Lake Street in Kalamazoo (Figure 17). In 1922, during the formation of the Allied Paper Company, the King Paper Company became Allied's King Division (Kalamazoo Gazette, June 24, 1934). Deinking was performed at the mill until June 1965 (it is unknown when deinking commenced), after which 100 percent virgin fiber from a pulp mill in Alabama was used (Oeming, 1965). The mill's main product was book printing material, which was generated at approximately 200 tons per day on four paper machines in the late 1960s. The water supply for processing came from a well field located near the river to the northeast of the mill, while the water used for cooling came both from the well field and the Kalamazoo River (MWRC, 1968).

The mill was abandoned by Allied in 1971 and sold to Arthur Dore of the Dore Wrecking Company, presently Dore Enterprises. After fires had damaged the mill in 1975 and 1976, Mr. Dore completed demolition of the mill in December 1978 (Hager, 1979). According to current property

records, Arthur Dore is the present owner of the majority of the property. Some parcels are also owned by Michigan Barricading - West, Inc., Consumers Power Company, and the Kalamazoo Fraternal Order of Police.

3.4.2 Water Pollution Control and Waste Management

Until 1955, prior to the appearance of PCBs in waste paper, untreated effluent was conveyed to the Kalamazoo River through a 48-inch concrete culvert (Oeming, 1954). After 1955, the waste treatment for the mill consisted of save-alls for each of four paper machines and a 110-foot diameter clarifier. A large percent of the clarified effluent was reused in the paper-making process (MWRC, 1968). The remainder was conveyed to the Kalamazoo River via a 48-inch concrete culvert which discharged to the Kalamazoo River adjacent to the King Street storm sewer outfall, according to city sewer maps.

Residuals resulting from mill operations were primarily dewatered and disposed of at the A-Site, which was later purchased by the Georgia-Pacific Corporation. Also, some residuals were evidently disposed in on-site lagoons (Figure 17). In 1970, an application for a 2.89-acre solid waste disposal area was filed with MDPH. Aerial photographs, however, do not indicate that the area, located southwest of the intersection of Vine Street and Schuster Avenue, ever received wastes from the King Mill.

3.4.3 History from Aerial Photographs

The King Mill is present in the 1938 aerial photogragh (Figure 37). There is also an apparent wastewater discharge within the inward edge of a meander of the Kalamazoo River in the area referred to as the "King

Street Storm Sewer". In the 1950 photograph, shown on Figure 38, no significant changes are apparent. In the 1955 aerial photograph (Figure 39), no changes to the physical plant or the area of wastewater discharge are apparent. However, to the northeast of the mill just south of Vine Street the 110-foot diameter clarifier is under construction. There also appears to be an elongated lagoon running north-south just east of the mill proper. The area does not appear to have defined berms, but appears to be more of a shallow excavation.

Figure 40 shows the 1960 aerial photograph with no changes to the physical plant of the mill from the photographs taken in the 1950s. The clarifier appears to be operating and there is evidence that the north-south running lagoon has piles of material within its boundary. There is also evidence of a disturbed area to the northeast of the lagoon. The apparent wastewater discharge in the area of the King Street storm sewer is not as pronounced as in the previous photographs and deposition appears to be occurring in the inward section of the meander. The 1967 aerial photograph (Figure 41) again shows no changes to the physical plant of the mill. The elongated north-south running lagoon appears to be filled and vegetation is encroaching into the lagoon. The lagoon to the northeast has defined berms which appear vegetated. The lagoon contains fill material and possibly ponded water. The 110-foot diameter clarifier appears full with a dark colored wastewater. To the southeast of the clarifier a new, smaller-diameter clarifier is under construction. The wastewater

discharge in the King Street storm sewer is not apparent and the inward section of the meander appears filled with vegetation occurring.

The physical plant is unchanged in the 1974 aerial photograph (Figure 42). The elongated north-south running lagoon is filled and vegetated. The lagoon to the northeast is still visible, however it appears that vegetation is encroaching into the lagoon. The 110-foot diameter clarifier has been removed and the smaller clarifier appears to be operating. There is no evidence of wastewater discharge in the sewer and the inward section of the meander is filled and vegetated.

In the 1981 aerial photograph (Figure 43), significant changes are visible. The mill and small clarifier have been razed and material has been removed. The lagoons are filled and vegetation is apparent on the property. The inward section of the meander is filled and vegetated. The 1986 aerial photograph (Figure 44) shows no apparent change from the 1981 photograph. The aerial photograph taken in 1991, and shown on Figure 45, again shows no change in the property occupied by the Mill except the Michigan Baricade West, Inc. building. To the northeast of Michigan Barricade West, Inc. is an automobile scrap yard.

3.5 Georgia-Pacific Corporation Kalamazoo Mill

3.5.1 Paper-Making Operations

The Georgia-Pacific Corporation Kalamazoo Mill, located on King Highway (Figure 18), was originally owned by the Wolverine Paper Company

until it was sold to the Kalamazoo Paper Company in 1899. Georgia-Pacific Corporation purchased the Mill in 1967.

The original facility consisted of five mills: three paper mills and two coating mills. Mills 1, 2, and 3 were the paper mills, and mills 4 and 5 were used for finishing and converting operations (Figure 18). Mill 2 was razed in the early 1970s and Mill 5 was razed in the 1980s. Mills 1 and 3 are the current paper mills, while Mill 4 is used as a storage area.

The Kalamazoo Paper Company started deinking waste paper in the 1950s at Mills 1 and 3. However, PCBs did not appear in waste paper until 1957. Mill 1 stopped deinking in the late 1970s. The deinking process used before the late 1960's at Mill 3 started with a conveyor and a pulper. Chemicals that were added included caustic soda, solvents, soda ash, and tetrasodium tripolyphosphate. Pulp was sent to a screw press, then to a washer. All wastewater went to a sewer. Mill 3 stopped deinking in the late 1960s and resumed in 1975. The eleven chests used in the deinking process and the old floor drains were torn down and replaced with a new system in 1975. The conveyor and pulper are still present.

Currently, the company produces 400 tons per day of bond, offset, label, coated, and recycled grades of paper (Lockwood-Post, 1991). The raw material used comprises 50 percent waste paper and 50 percent virgin pulp (Wilkins & Wheaton, 1981).

Included in the Georgia-Pacific property is the location of the former Hawthorne Paper Mill, located at the eastern edge of the site (Figure 18).

Hawthorne Paper began manufacturing high grade bond, ledger, and printing paper in 1912, mainly from rag stock. Hawthorne's specialty was watermark paper (Kalamazoo Gazette, June 24, 1934). Although the mill recycled paper, the recycle stock was pre-consumer waste paper and did not require deinking. The company shut down in 1976 and the mill was purchased by Georgia-Pacific in 1978. Shortly after its purchase, the mill was torn down.

The former National Gypsum Company plant is located just south of Mill 4 and is surrounded by Georgia-Pacific property. The company produced gypsum board liner until its closing in 1988. Presently, the building is owned by Kalamazoo Township.

3.5.2 Water Pollution Control and Waste Management

In 1954, the Kalamazoo Paper Company constructed a 110-foot diameter clarifier for primary treatment of its process waste. Previously, all industrial wastewater from the mills was discharged to the Kalamazoo River. During operation, wastewater flowed from the mills to a centrally located intercept station, which pumped the mill effluent to the clarifier. Overflow from the clarifier went to the Kalamazoo River, while underflow was pumped to the adjacent lagoons. Several lagoons and a clarifier located to the northwest of the plant were also used at this time to treat wastewater from Mill 2. The King Highway dewatering lagoons were constructed on the opposite side of the river in the late 1950s for dewatering the underflow from the clarifier. The lagoons adjacent to the clarifier were subsequently used as emergency lagoons until 1980, when they were excavated and the

material was taken to the King Highway Landfill. Currently, they are partially backfilled with soil.

Mill 2, which housed two paper-making machines, did not conduct deinking. The mill and its wastewater treatment facilities ceased operations in 1970.

Beginning in 1964, the clarifier's effluent was sent to the Kalamazoo wastewater treatment plant for secondary treatment and the underflow, which contained two to four percent solids, was pumped to the King Highway dewatering lagoons. The supernatant from the lagoons was returned to the clarifier. Periodically, the lagoons were excavated and the waste material was sent to the Willow Boulevard Site (Figure 21) until 1975 when the Willow Boulevard Site reached capacity. After 1975, dewatered residuals from the King Highway dewatering lagoons were excavated and disposed of at the A-Site (Figure 23).

In 1977, Georgia-Pacific updated their entire waste treatment system by installing a new 135-foot diameter primary clarifier, a 50-foot diameter sludge thickener, and two dewatering presses. These presses increased the solids content of the waste to 40-50 percent. The waste could then be trucked directly to the A-Site from the dewatering presses.

The former King Highway dewatering lagoons started to receive residuals from the filter press when the A-Site reached capacity and closed in 1987. The King Highway Landfill is currently the Georgia-Pacific Kalamazoo Mill's licensed Type III landfill.

3.5.3 History from Aerial Photographs

Georgia-Pacific Corporation

The five mills which constitute the Kalamazoo Paper Company Mill are shown in the 1938 aerial photograph (Figure 37). The Hawthorne Paper Company Mill and National Gypsum Company are also shown on property adjacent to the Kalamazoo Paper Company. No entrances to the property from King Highway are evident; traffic enters from Michigan Avenue between Mills 1 and 2. There is an apparent discharge into the river south of Mill 1.

The mill structures are essentially unchanged in the 1950 aerial photograph (Figure 38). An entrance now exists off of King Highway in addition to the Michigan Avenue entrance. The apparent outfall to the river and mill vegetation appear the same as they did in the 1938 photograph.

The filter plant is under construction in the 1955 aerial photograph (Figure 39), while the remainder of the mill structures are unchanged. The primary clarifier constructed in 1954 appears to be operating. Two lagoons appear to the west of the clarifier. Three lagoons and a clarifier also appear on the property of the Kalamazoo Paper Company to the northwest of the mill. A clarifier is also under construction at the Hawthorne Mill and a discharge to the river is evident. An entrance parallel to Hawthorne's drive is present, leading to Mill 3. The outfall south of Mill 1 is no longer visible; however, there is a discharge apparent near the new clarifier.

In the 1960 photograph (Figure 40) construction of the filter plant, along with a warehouse near Mill 5, is complete. There are no visible

outfalls of wastewater to the river. Hawthorne's clarifier is in operation; however, no outfall discharging to the river is apparent.

The administration building and corresponding entrance first appear in the 1967 photograph (Figure 41). No outfall is apparent in the photograph. A clarifier is also in operation at the eastern edge of the National Gypsum plant. Also, another clarifier is evident near the three lagoons to the northwest of the mill.

In the 1974 photograph, Mill 2 is razed and an oil tank is present at the location (Figure 42). The lagoons to the northwest of the mill appear filled. Hawthorne's clarifier is absent and National Gypsum's clarifier appears to be out of service.

Georgia-Pacific's new primary clarifier is in operation in the 1981 photograph (Figure 43). The sludge thickener and dewatering facility are also present. The Hawthorne Mill was razed in 1978 and does not appear in the 1981 photograph.

In the 1986 photograph, Mill 5 is absent (Figure 44). One of the emergency lagoons by the clarifier is no longer visible, and the other has been filled with soil. The lagoons and clarifiers to the northwest of the mill are no longer visible. In the 1991 photograph, no major changes subsequent to the 1986 photograph are evident (Figure 45).

King Highway Landfill

The location of the present King Highway Landfill as it appeared in 1938 is shown in Figure 37. In this photograph, the most notable feature

is a former oxbow which appears inactive but contains water. In 1950 (Figure 38), the eastern half of the oxbow appears filled and vegetated; the western half appears to be cut off from the river and substantial filling has occurred. By 1955 (Figure 39), the western end of the oxbow has been filled. In all three photographs, the remaining area was covered with grass and trees.

By 1960, a series of decant lagoons had been constructed, as shown on Figure 40. Berms separate three distinct dewatering lagoons. The system drainage pattern appears to be from the west to east as is evident from the diminishing levels of turbidity towards the east. The berm between the western and middle lagoon is vegetated with grass, while the berm between the middle and eastern lagoons has grass and a few trees. The area southwest of the lagoons has a soil pile without vegetation; the remainder of the site is covered with vegetation including a dense grouping of trees north of the eastern lagoon.

In the 1967 photograph, residuals appear in the eastern lagoon and the southern half of the middle lagoon (Figure 41). Ponded water is present in the remainder of the middle lagoon and the entire western lagoon. Roads appear to be leading into the eastern lagoon from King Highway. The vegetation on the berms has increased since the 1960 photograph. There is a roadway constructed where the soil pile used to be in the southwest corner of the site.

In the 1974 photograph (Figure 42), the eastern-most lagoon evident in the 1960 photograph has been divided diagonally into two lagoons. The

area surrounding the lagoons appears vegetated and the access roads have been completed. The two western lagoons appear to contain solidified residuals, while the other two contain water with slightly different degrees of clarity.

The eastern-most lagoon appears to hold ponded water in the 1981 photograph (Figure 43). The other three lagoons appear inactive. Figure 44 shows that in 1986, the eastern lagoon is still holding ponded water, while the other three lagoons have vegetative cover. In 1991 (Figure 45), the licensed landfill is receiving solidified residuals in the two western areas, and the other areas appear unchanged.

Willow Boulevard Site

In the 1938 aerial photograph (Figure 37), the Willow Boulevard Site is not apparent. The area now occupied by the Willow Boulevard Site appears as an embayment of the river which contains vegetated sand bars. The Lakewood community was already established to the south of the river. By 1950 (Figure 38), deposition had occurred in the area of the Willow Boulevard Site and a land mass is now apparent. The river bisected this land mass along its east-west axis.

In 1955, it appears that further deposition had occurred allowing vegetation of the area (Figure 39). In 1960 (Figure 40), the river level was higher and the land mass was inundated; however, vegetation is still present.

In 1967, residuals are present and the boundaries of the Willow Boulevard Site are approximately the same as they are today (Figure 41).

There is shrubby vegetation in the northeast corner of the area. There is a road present leading from Willow Boulevard to the center of the property. An island has fully formed in the river to the northwest of the area.

By the 1974 aerial photograph, vegetation has grown on the northwestern half of the property, while the remainder appears unchanged (Figure 42).

Grassy vegetation is covering the area in the 1981 aerial photograph (Figure 43). In 1986, there are many shrubs and residuals are not visible except for a small part of the southeast corner (Figure 44). This vegetative growth, in addition to trees, completely covers the area in the 1991 aerial photograph (Figure 45).

A-Site

In the 1938 aerial photograph, the A-Site (Figure 37) appears as an open field with a few scattered trees. It appears that Olmstead Creek has been rechannelized to the south and Davis Creek is a straight channel along the eastern side of the property to the Kalamazoo River.

Flow in Davis Creek is not evident in the 1950 photograph (Figure 38), and the property appears unchanged. The flow in the river is also very low. In the 1955 photograph, the water level in the river and creek are still low. The A-Site is yet an undeveloped field. The area east of Davis Creek appears to be disturbed with a path leading from Lake Street to the riverbank (Figure 39).

In the 1960 photograph, three distinct dewatering lagoons are present (Figure 40). An area to the south of the lagoons appears to contain

residuals in its western half. A small and narrow area of ponded water is evident east of Davis Creek. Residuals are not evident in this area.

The two western-most lagoons evident in the 1960 photograph have merged, as evident in the 1967 photograph (Figure 41). The area to the south now contains residuals in its entire length. The northeast corner of the A-Site contains ponded water. Exposed soils, which may include residuals, appear in the area east of Davis Creek.

In the 1974 photograph (Figure 42), sparse vegetation appears on the inactive dewatering lagoons. The area east of Davis Creek appears well vegetated and no exposed soils are evident.

In the 1981 photograph (Figure 43), the berms in the interior of the disposal area are absent. Vegetation is growing on the western edge of the property, while a small area of ponded water is present at the eastern end. Ponded water appears in the area east of Davis Creek.

The A-Site is partially vegetated in the 1986 aerial photograph (Figure 44). The areas of ponded water have disappeared from the A-Site, and in the area east of Davis Creek.

By 1991 (Figure 45), the A-Site has revegetated with grassy plants except in the western half. Ponded water still exists in the northeast corner and along the southern end. In the area east of Davis Creek, the water appears the same as it did in 1981.

3.6 Simpson Plainwell Paper Company

3.6.1 Paper-Making Operations

The Simpson Plainwell Paper Company (Figure 25) was originally founded by the Michigan Paper Company in 1886. Hamilton Paper purchased the mill in 1956 and named it the Michigan Division. Weyerhaeuser acquired the company in 1961 and operated the mill through the 1960s. Lockwood-Post's Directory of the Pulp, Paper and Allied Trades shows Nicolet Paper Company as the owner during 1971-1975; it appears that the mill first became known as the Plainwell Paper Company during this time. According to Lockwood Post's Directory, the mill retained the name Plainwell Paper Company under ownership by Philip Morris Inc. and Philip Morris Industrial Inc. (mid-1970s through 1984), and after the mill was purchased by Chesapeake Corporation in 1985. In late 1987, Simpson Paper Company purchased the mill and it became the Simpson Plainwell Paper Company.

Deinking of waste paper prior to reuse of the wood pulp was practiced at the mill between 1910 and 1962 (Creal, September 1987); however, PCBs did not appear in waste paper until 1957. Deinking of PCB-containing office paper at the mill ended in 1962.

The deinking process, which occurred in the northwest corner of the facility, consisted of a single 16-foot diameter hydropulper where steam, a petroleum product (to break up the inks), and hydrosulfite were added to a slurry of wastepaper. The pulp was then sent to inclined screen washers. In the late 1950s, the hydrosulfite ceased to be used as the

bleaching agent. It was replaced with hypochlorite, which was added in a bleach tower (tank reactor) that followed the first set of inclined washers. Another set of inclined washers followed the bleach tower.

The areas of the mill in which the deinking operation and its piping were located have been either refurbished or are no longer in use. The hydropulper, bleach tower, and stock chests used in the deinking process have been used at the mill since deinking was terminated.

The Simpson Plainwell Mill produces coated and uncoated book and cover, release base, and technical specialty paper products. Currently, production capacity is approximately 260 tons per day (Lockwood-Post, 1991).

3.6.2 Water Pollution Control and Waste Management

Between 1910 and 1962, the Plainwell Mill obtained pulp through the recycling of used paper which required deinking (RMT, 1990). The area of the mill where deinking took place drained via a system of internal and external drains. This drainage system has since been reconfigured, and drains that were not taken out of service or removed now discharge through an open drain to the mill's wet well.

As was the standard practice at the time, wastewater was discharged directly into the Kalamazoo River until 1954, when a clarifier was installed adjacent to the mill and wastewater was treated by primary clarification. The clarified effluent was discharged into the Kalamazoo River. The underflow from the clarifier was dewatered in a series of on-site lagoons.

Typically twice each year, each lagoon was excavated and the material was taken to the 12th Street Landfill, located near the Plainwell Dam.

In 1967, secondary treatment was initiated with the installation of a 1.85 million gallon plastic-lined aeration basin to the east of the lagoons and a secondary clarifier measuring 55 feet in diameter and 13 feet in depth located 500 feet east of the aeration basin (Thinnes, 1967). Effluent from the aeration basin was conveyed to the secondary clarifier. The effluent from the secondary clarifier went to the Kalamazoo River, and the underflow went to the lagoons. Some biosludges produced in the aeration basin were excavated and taken to the 12th Street Landfill. In 1981 a new primary clarifier was constructed and the old primary clarifier was subsequently torn down. A mechanical dewatering system (belt press), which produces a cake of 30 to 40 percent solids, also began operating in 1981. Consequently, the lagoons ceased receiving residuals. Residuals produced from the mechanical dewatering system were disposed of at commercial landfills. Residuals remaining in some of the lagoons were removed in 1981 and taken to the 12th Street Landfill. In 1983, the residuals from the rest of the lagoons were consolidated into four of the lagoons. These four lagoons are presently covered with soil and are well vegetated. The other lagoons were filled with soil after being cleaned out and are almost entirely located under the mill's present wastewater treatment facilities. The secondary treatment system was updated in 1983 with the installation of a new secondary clarifier, and the old secondary clarifier was taken out of service. At this time, the aeration lagoon was

also taken out of service and was replaced by an activated sludge treatment system (Lawton, 1987). The aeration basin was partially backfilled with construction and demolition waste. The activated sludge treatment system is in use today along with the primary and secondary clarifiers.

It is believed that PCBs were introduced into the residuals as a result of the recycling of carbonless copy paper during operations at the plant between 1957 and 1962. This period corresponds to the use of a primary clarifier and lagoon system for treatment of wastes. The treated waste was disposed at the 12th Street Landfill.

The 12th Street Landfill (Figure 26) is approximately one and one-half miles northwest of the city of Plainwell. The 6.5-acre property is located along the west bank of the Kalamazoo River adjacent to and downstream of the Plainwell Dam. Residuals consisting predominantly of wood fiber, water, and mineral matter generated at the Plainwell Mill were deposited at the 12th Street Landfill.

Based on historical aerial photographs, it was determined that between 1955 and 1967 a retaining berm was constructed along the southeast portion of the north half of the disposal area. The purpose of the berm was to prevent sludge from entering the river (RMT, 1990).

RMT, Inc., also concluded that between 1974 and 1980 the berm was increased in thickness and was extended around the entire perimeter of the site. According to Simpson-Plainwell personnel, the berms were constructed of gravel, ash, and residuals. In 1984, the 12th Street Landfill was covered with soil and seeded (RMT, 1990).

3.6.3 History from Aerial Photographs

Simpson Plainwell Mill

Aerial photographs of the Simpson Plainwell Mill were reviewed from 1938, 1950, 1955, 1960, 1967, 1974, and 1991. The condition of the mill and surrounding areas is detailed in the following paragraphs.

In the 1938 aerial photograph (Figure 46), the mill structure is bordered by the Kalamazoo River to the north, a mill race to the east, and a residential area to the south and west. The mill appears smaller than the current structure. The mill property is covered with grass and trees.

In the 1950 aerial photograph (Figure 47), the mill's physical plant has been slightly expanded. There is an apparent discharge just downstream of the plant. It appears that earthwork has begun at the western-most portions of the mill's property.

A primary clarifier and lagoons are apparent on the 1955 aerial photograph (Figure 48). A series of lagoons is located along the riverbank at the western end of the mill's property; nine lagoons are in a row with one lagoon to the south of the row. There is an apparent overflow discharge from the primary clarifier. An addition to the south of the plant is evident. The beginnings of the Plainwell wastewater treatment plant are visible to the west.

Two additional lagoons (one in the main row and one northwest of the row) are present in the 1960 aerial photograph (Figure 49) and the primary clarifier appears to still be in operation.

The aeration basin and secondary clarifier are under construction in the 1967 photograph (Figure 50). The lagoon to the northwest of the row, visible in 1960, is not evident; however, two lagoons were added to the row, making a total of 14 lagoons on-site, with one no longer visible. The mill structure has been enlarged as compared to the previous photograph and there is an apparent discharge from the primary clarifier. The mill race that is evident is not in use.

The 1974 aerial photograph has the aeration basin, secondary clarifier, and primary clarifier in operation (Figure 51) and 13 lagoons are present; however, their location has changed. The lagoon previously visible to the south of the main row is no longer visible, and the lagoon to the northwest is now visible again. There is an apparent discharge from the secondary clarifier.

The lagoons are no longer present in the 1991 photograph (Figure 54). The original primary clarifier has been torn down and its location is currently a parking lot. The activated sludge tanks and current clarifiers are built where lagoons had once been located. The new primary clarifier is in operation, while the original secondary clarifier is not operating. A faint outline of three former lagoons is visible at the west end of the site, along with the former lagoon south of the row. The sludge dewatering facility, built in 1981, is also present.

12th Street Landfill

Aerial photographs of the 12th Street Landfill were reviewed from 1938, 1950, 1955, 1960, 1967, 1974, 1981, 1986, and 1991. The condition of the

12th Street Landfill and surrounding areas is detailed in the following paragraphs.

In the 1938 photograph, the only apparent development in the area consists of the Plainwell Dam and associated structures (Figure 55). Flow through the dam is occurring through the western-most portion of the dam. A small keyhole shaped disturbed area, most likely the beginnings of a gravel pit now present in the area, is evident immediately west of the area. From the photograph it is not possible to determine whether this area was disturbed through filling or excavation. The actual property consists of agricultural land and an apparent wetland area. The remaining surrounding area consists of wooded and agricultural lands to the south and west of the property and apparent wetland areas vegetated with a scrub-shrub sequence to the north. A surface drainageway was observed beginning at the disturbed area and flowing in a northwesterly direction to the Kalamazoo River.

The 1950 photograph (Figure 56) shows the area to be similar to that observed in the 1938 photograph. The disturbed area to the immediate west is now approximately 50 percent vegetated. A new disturbed area further to the west is now evident and appears to consist of an excavated area. A small sand and gravel mine is now present approximately one-quarter to one-half miles west-southwest of the area. Flow through the dam is now occurring through the eastern section. The land use in the area and south and west of the area continues to be agricultural. The

area to the north is still apparently wetlands with a scrub-shrub vegetative sequence.

Filling on the property is apparent in the 1955 photograph (Figure 57). Two areas of fill are visible. The primary area consists of a generally east to west band of fill placed on the northern edge of the agricultural field which constituted a portion of the area. The fill extends from the corner of the dam access road to a point nearly on the edge of the river. The secondary area is located along the eastern portion of the disturbed area to the west of the property that was identified in the 1938 photograph. Both areas appear to have been accessed using haul roads which are visible in the photograph. The disturbed area and the sand and gravel mine observed in the 1950 photograph are essentially unchanged in size and appearance. The drainageway observed in the 1938 photograph is present as well as a second drainageway which appears to originate at the western end of the primary area and flows in a north-to-northwest direction from the landfill.

The primary fill area has approximately quadrupled in the 1960 photograph (Figure 58). The secondary area has revegetated and does not appear to be receiving new fill. Drainage from the northern boundary of the primary fill area flows in a north-to-northwesterly direction. The sand and gravel operation has drastically increased in size and extends nearly to the western boundary of the property. This dramatic increase in size is apparently in response to the construction of the interstate interchange to the east of the area. A haul road used to move sand and gravel materials

from the operation to the interchange location is visible. An equipment yard is visible to the south of the wooded area, which is south of the property. The water level in the Plainwell Dam Impoundment has also decreased.

Approximately one-half of the filled area observed in the 1960 photograph has revegetated in the 1967 photograph (Figure 59). A berm-like structure is evident on the eastern edge of the primary fill area. The secondary fill area is now completely vegetated and is not distinguishable from the surrounding areas. Drainage patterns are the same as those observed in the 1960 photograph, although less pronounced. The area involved in sand and gravel removal is the same as in 1960. The equipment yard previously located to the south is absent. The dam and impoundment are the same as they were in the 1960 photograph.

The primary fill area is approximately 75 percent vegetated in the 1974 photograph (Figure 51). Roads are still visible in the unvegetated areas. The drainage patterns from the landfill are no longer visible. The sand and gravel operation has been extended to the north, to include the secondary fill area, and to the east. The eastern extension includes the former equipment yard and extends east for approximately one-quarter mile along the riverbank. The area of the dam impoundment which is no longer submerged appears to have been cleared of vegetation and graded.

The landfill has been covered with soil and graded in the 1981 photograph (Figure 52). A pond is present in the gravel operation's eastern extension directly to the south of the landfill. Drainage patterns

are not visible in this photograph. The building that was located on the western-most portion of the Plainwell Dam is gone. Otherwise, the dam and impoundment are the same as they were in 1974.

In the photograph from 1986 (Figure 53), the cap on the landfill is vegetated. The sand and gravel operation and the dam and impoundment are the same as was observed in the 1981 photograph.

The sand and gravel operation has abandoned the excavation on the western portion of their property in the photograph from 1991 (Figure 60). The area of the secondary fill now contains some type of facility which may be either a sand sizing plant or an asphalt or concrete batching facility. The area is unchanged from the 1986 photograph, and is being vegetated with what appears to be grasses. Trees border the soil cover which was placed prior to 1981. Two surface water bodies are present in the wetlands to the north of the former secondary fill area. Some type of waterway is present between these water bodies and the Kalamazoo River.

3.7 History of MDNR-Owned Impoundments

The relevant history of the NPL Site includes the partial removal of the Plainwell, Otsego, and Trowbridge MDNR-owned dams on the Kalamazoo River.

The Otsego Dam was originally constructed in 1902 for the generation of hydroelectric power. The stone masonry dam had five 20-foot by 12-foot tainter gates with an original tailrace which was 100-feet wide. The dam was renovated in 1925 by installing two vertical shaft turbines and generators housed in steel enclosures outside the original powerhouse. In addition, the tailrace width was

reduced to 60 feet (Wood, 1983). The dam was approximately 750-feet wide, operated with a head of 14.5 feet, and impounded an area of approximately 330 acres.

Power generation at the Otsego Dam was suspended on December 27, 1965, and the dam was deeded by Consumers Power Company to MDNR on September 29, 1967. Water levels were maintained in order to enhance hunting and fishing opportunities with periodic regulation of water levels to reduce flood hazards (Wood, 1983).

In 1968, a barricade was erected across an access trail to restrict public access to the dam. In 1970, MDNR's Region III Manager, Bill Laycock, proposed a plan to eliminate "immediate" hazards to public safety by leveling the structures as rapidly as possible. The plan was approved on November 20, 1970, and over the next several months the water levels were gradually reduced to the sill level. The five steel lift gates were then raised and held open. The dam structure was closed in an attempt to prohibit public access, although vandalism continued (Wood, 1983).

Faced with high costs for maintaining and securing the dams and related structures, MDNR altered the management objectives for the impoundments from waterfowl production and recreation to eventual restoration of a riverine environment.

In 1974, the Otsego Township contacted United States Representative Guy VanderJagt and informed him that the Plainwell and Otsego Dams had been extensively vandalized, were structurally unsafe, and posed a dangerous situation for the citizens of nearby communities (Planning Commission, 1974). Between

July 1974 and June 1975, permits were issued for the removal of salvageable metal from the Otsego Dam structures (Wood, 1983).

In the early 1980s, federal incentives to develop hydroelectric power resulted in a 1981 proposal to renovate the Otsego Dam for power generation and the sale of power to the Consumers Power Company (Figure 7). However, attempts to develop power generating facilities at the river were not permitted because of PCB-related problems that may have occurred with the development of such a facility (Harrington, 1984). By 1986, a permit was issued allowing the dismantling of the dam superstructure to be completed.

The Trowbridge Dam, located approximately 5 miles upstream of the city of Allegan, is the smallest of the three former impoundment dams (Figure 7). It was completed in 1898 and, like the others, was constructed of stone masonry. The entire surface area of the dam was encased in cement in 1941. This dam had the shortest overall length of the three dams (approximately 400 feet). The structure consisted of a 150-foot southern embankment, an 80-foot spillway section, a 104-foot powerhouse structure, and an 80-foot northern embankment. The spillway section had three 24-foot tainter gates that allowed an estimated average annual flow of 3,900 cfs to pass. During its operation, this dam operated with a head of 21.4 feet, the highest of the three former impoundment dams (Roman, 1982).

The Plainwell Dam is located on the Kalamazoo River approximately one mile downstream of the city of Plainwell (Figure 6). The dam was constructed for the generation of hydroelectric power, began operations in 1903, and has since undergone some renovation (National Dam Safety Program Inspection

Report, I.D.# 491, August 1979). The plant configuration consisted of eight 20-foot lift-gate sections and a 40-foot needle stoplog bay. Between the turbine tailrace, located near the left bank, and the spillway, located on the right bank, was an embankment consisting of a 100-foot earthen section and a 75-foot concrete section. Three vertical shaft turbines and generators were housed in the powerhouse. The tailrace was approximately 66 feet long, thus making the total length of the dam 465 feet. There was also a 750-foot-long earthen dike extending from the right end of the spillway to the high ground, making the total length of the structure 1215 feet. The estimated mean annual flow through the dam was approximately 3,500 cfs with a head of 13 feet.

As with the Otsego Dam, the Trowbridge and Plainwell dams ceased operations in 1965, and the facilities were deeded to MDNR in 1967. Vandalism, public safety, and enhanced recreation were also the issues that led to the partial dismantling of these dams in 1986. While these dams impounded water, PCB-contaminated sediments were deposited in the impoundments. When the superstructures of these dams were removed in 1986 and the water level was lowered, some of these contaminated sediments were exposed in the floodplain.

SECTION 4 - CURRENT CONDITIONS

4.1 Area to be Investigated

The Allied Paper, Inc./Portage Creek/Kalamazoo River NPL Site consists of Portage Creek from Cork Street to its confluence with the Kalamazoo River, and the Kalamazoo River for 35 miles downstream of the Portage Creek confluence to the Allegan City Dam (Figure 1). Other areas to be investigated include the Kalamazoo River from the Morrow Lake Dam to the Portage Creek confluence, and from the Allegan City Dam to Lake Michigan. In addition, other facilities currently or previously owned, operated or leased by respondents will be investigated.

Specific areas to be included in the RI are listed below.

1. Portage Creek, from Alcott Street to the Kalamazoo River, and the Kalamazoo River from the Morrow Lake Dam to Lake Michigan, broken into the following reaches:
   - o From Morrow Lake Dam to the Portage Creek confluence;
   - o From the Portage Creek confluence to Main Street, Plainwell;
   - o From Main Street, Plainwell to the Plainwell Dam (including the former Plainwell Impoundment and floodplain);
   - o From the Plainwell Dam to the Otsego City Dam;
   - o From the Otsego City Dam to the Otsego Dam (including the former Otsego Impoundment and floodplain);
   - o From the Otsego Dam to the Trowbridge Dam (including the former Trowbridge Impoundment and floodplain);

- From the Trowbridge Dam to the Allegan City Dam;
- From the Allegan City Dam to Lake Allegan Dam; and
- From Lake Allegan Dam to Lake Michigan.

2. Performance Paper Mill and property.
3. Former King Mill Property.
4. Georgia-Pacific Corporation Kalamazoo Mill and property.
5. King Street storm sewer outfall in Kalamazoo.
6. Simpson Plainwell Paper Co. Mill.

Several of the areas under investigation have been segmented into operable units. These include:

1. Allied Paper, Inc. Operable Unit between Cork and Alcott Street, including:
   - Historic residuals dewatering lagoons (HRDLs);
   - Former residual dewatering lagoons (FRDLs);
   - Type III solid-waste landfill;
   - Portage Creek from Cork Street to Alcott Street, including the former Bryant Mill Pond; and,
   - Other Allied Paper, Inc. property between Cork Street and Alcott Street as necessary.
2. King Highway Landfill Operable Unit.
3. Willow Boulevard and A-Site Operable Unit.
4. Simpson Plainwell Paper Co. 12th Street Landfill Operable Unit.

4.2 Allied Paper, Inc. Operable Unit

4.2.1 Characteristics

4.2.1.1 HRDLs and Type III Landfill

A significant consequence of the paper-making process is the generation of large quantities of wastewater. From the mid-1950s, until the cessation of operations, the Bryant Mill and Monarch Mill provided primary treatment of this wastewater in treatment facilities encompassing a total of 51 acres. Solids were settled out in primary clarifiers and subsequently dewatered in lagoons before being landfilled.

Until 1969, when Allied connected to the Kalamazoo wastewater treatment plant, wastewater resulting from the dewatering of residuals was discharged directly to Portage Creek.

The HRDLs are located together with the clarifiers and the Type III landfill at the southern end of the operable unit (Figure 15). Also in this area are the former dewatering lagoons (FRDLs) which were most recently used for dewatering underflow from the Bryant Clarifier. These lagoons became inactive in November 1989, and have not been used since.

The soils underlying these facilities have been characterized by the Soil Conservation Service (SCS) as Urban/Glendora and Urban/Oshtemo complexes. The Glendora complex consists of nearly level areas of urban land with poorly-drained, highly-permeable soils. They are generally distributed along the north-eastern border of the

facility. The Oshtemo complex is characterized by the SCS as having moderately rapid permeability and is well-drained. These soils are located at the southwestern end of the facility.

Outwash deposits are prevalent over much of Kalamazoo County and are composed of medium to very coarse sand and gravel (Rheaume, 1990). Interfingered with the sand and gravel are layers of silt and clay. The Coldwater Shale, of Mississippian age, underlies the glacial deposits at the facility, and is estimated to be greater than 150 feet below the surface.

Six cross-sections have been developed for the Allied Paper HRDLs and landfill and former Bryant Mill Pond areas based on subsurface logs of borings and ground-water monitoring wells installed in these areas. Figure 16A indicates the locations of the cross-sections, and Figures 16B through 16G present cross-sections A-A' through F-F', respectively. Cross-sections A-A' and B-B' are oriented north-south and the other four sections (C-C' through F-F') are oriented west-east.

Section A-A' presents the subsurface conditions from Cork Street on the south boundary of the area, north to Alcott Street. A thin layer of peat (generally less than 2 feet, with a maximum observed thickness of 5 feet) lies below fill material along this section. Below the fill and peat is sand with varying amounts of silt, clay, and gravel. The cross-sections indicate the complexity of the subsurface.

There are apparently several clay layers present beneath the area; this is best shown on cross-section C-C' (Figure 16D). The upper clay unit generally occurs between elevations 780 and 795 feet above mean sea level (MSL), although the base of this layer extends down to 765 feet MSL in the area underlying the Bryant HRDL (cross-section E-E', Figure 16F). A second clay unit was identified between 750 and 760 feet MSL to the northeast of the landfill area; this clay layer appears to extend up to 780 feet MSL south of the landfill at well cluster MW19 as indicated on cross-section C-C'. A third, deeper clay unit was also evident at well cluster MW19, located in the central portion of the area. As shown on cross-section C-C', the clay layers appear to increase in depth to the northeast toward Portage Creek and possibly to the north toward Portage Creek, as shown on cross-section A-A' (Figure 16B).

Based upon observations of ground-water elevation, ground water beneath the Allied Paper Operable Unit flows generally toward Portage Creek. In addition, ground-water observations in several monitoring well clusters screened both above and below the clay units indicate an upward ground-water flow gradient at most locations (Tables 15 and 35). Available data suggest that the ground-water bearing units underlying the area are under artesian conditions and recharge Portage Creek.

Stiff diagrams (Appendix E) were constructed for ground-water quality data collected at the Allied Paper, Inc. Operable Unit. Water

quality concentrations (in units of milliequivalents per liter, meq/L) for eight parameters are indicated on each of the diagrams. The eight parameters are: sodium (Na); calcium (Ca); magnesium (Mg); iron (Fe); chloride (Cl); sulfate (SO_4); bicarbonate (HCO_3); and nitrate (NO_3). There were thirteen sampling events for which sufficient data were available for the construction of Stiff diagrams. These sampling events are: May 22, 1982 (drawing 1); February 21, 1984 (drawing 2); April 26, 1985 (drawing 3); October 1, 1985 (drawing 4); November 25, 1985 (drawing 5); March 25, 1986 (drawing 6); December 10, 1987 (drawing 7); June 13, 1988 (drawing 8); July 14, 1988 (drawing 9); June 19, 1989 (drawing 10); October 4, 1989 (drawing 11); December 5, 1989 (drawing 12); and June 24, 1991 (drawing 13). During the RI additional geophysical data will be collected and used in conjunction with this information to better define aquifer characteristics.

Within the Allied Paper Operable Unit, there are two HRDLs: the Bryant HRDL to the north and west of Portage Creek and the smaller Monarch HRDL to the south and east of Portage Creek. The dikes that contain the residuals were constructed on an as-needed basis in order to accommodate residual dewatering and disposal. Limno-Tech (January 1990a) reports that the 1950 average surface elevation of the Bryant HRDL was approximately 795 feet MSL, while the current elevation is 810 feet MSL. The residuals in the Bryant HRDL are approximately 12-feet thick and overlie native topsoil and peat. Residuals deposited within the HRDL are primarily clay and wood fiber

material. When deposited, the water content of these materials ranged from 60 to 80 percent. Due to the high water content and the size of particles being deposited, the residuals have a very low compressive strength which, therefore, create unstable conditions. Underlying the topsoil/peat interval is an interval of interbeded of sandy clay and silty sand (Limno-Tech, January 1990a).

Residuals disposal within the Bryant HRDL has not occurred for the past decade (Limno-Tech, Inc., January 1990a). Instead, solids that had settled in the Bryant Clarifier were pumped to dewatering lagoons. The resulting decant water from the lagoons was allowed to flow by gravity to a collection lagoon from where it was recycled back to the Bryant Clarifier. The solids remaining in the lagoons after dewatering were stabilized and transported by dump truck to the Type III landfill for disposal (Limno-Tech, Inc., January 1990a). A description of the landfill is contained in Section 3.3.2.

The Allied Paper HRDLs and landfill area have been investigated with respect to PCBs in sediment, residuals, soil, and ground water. Historic residuals that were sampled have PCB concentrations that range from non-detectable to 1,200 mg/kg, with a mean PCB concentration of 120 mg/kg (Limno-Tech, Inc., January 1990a). Soil samples were also collected during the installation of monitoring wells and analyzed for PCBs. Limno-Tech (January 1990a) reported soil PCB concentrations that ranged from non-detectable concentrations to 13 mg/kg. Samples from ground-water "seeps" and monitoring wells in the

floodplain (MW13 and MW14) adjacent to the HRDL berm had PCB concentrations ranging from non-detectable (at a detection limit of 0.01 ug/L) to 26 ug/L. A subsequent ground-water investigation of the HRDLs conducted by Limno-Tech, however, did not detect PCBs in any ground-water samples in wells at the HRDL perimeter except one (MW12), which had a total PCB concentration of 0.10 ug/L (Limno-Tech, Inc., January 1990a). MW12 may have been impacted by residuals during installation and therefore is being replaced.

These results are discussed in more detail in Section 5.

4.2.1.2 Portage Creek from Cork Street to Alcott Street Including the Former Bryant Mill Pond

The former Bryant Mill Pond area is located adjacent to the Allied Paper property in the southern portion of the city of Kalamazoo, immediately north (downstream) of the Allied Landfill and HRDLs. It is bordered by Alcott Street to the immediate north. Residential development exists adjacent to the upper end of the former impoundment. There is some residential development west of the Conrail tracks. The Allied residuals disposal facilities are situated generally to the south of Bryant Mill Pond. The area includes a stretch of Portage Creek measuring approximately 4,000 feet between Cork and Alcott Streets, as illustrated on Figure 14 (O'Brien & Gere, 1990).

A dam exists to the south of Alcott Street, and prior to 1976, this dam was regulated to form the approximately 22-acre Bryant Mill Pond.

In 1976, the dam was opened, which resulted in the drawdown of the impoundment.

The present characteristics of this area are described as consisting of a stream channel varying in width from 20 feet to approximately 75 feet and a floodplain varying from 30 feet to approximately 400 feet (O'Brien & Gere, 1990). The soil/sediments of this area have been found to contain elevated concentrations of PCBs.

The floodplain soils are reported as fine-grained to clay soils, overgrown with cattails and other vegetation indigenous to wetlands (O'Brien & Gere, 1990). Almost 50 percent of the floodplain soils exist in a saturated state under normal conditions (Limno-Tech, Inc., 1989).

Floodplain limits are defined on both sides of Portage Creek by embankments measuring approximately 10 feet high. Overgrown with deciduous trees and undergrowth, these slopes vary in vertical to horizontal ratio from 1:3 to 5:1. A limited number of industrial, residential, and commercial properties are located at the top of the embankments adjacent to Portage Creek (O'Brien & Gere, 1990).

Historic releases of wastewater to the impounded Bryant Mill Pond area have resulted in considerable residuals/sediment deposition in this area. It was later determined that these sediments contained PCBs.

The lowering of the pond exposed much of the sediment from the former Bryant Mill Pond. Studies performed in the area have identified PCBs at a maximum depth of 8 feet below the surface sediments

(Limno-Tech, Inc., 1988). Samples collected from the area of exposed sediment include both surface grab and core samples. Surface sediments exhibited an average PCB concentration of approximately 175 mg/kg (MDNR, December 1987). Most of the core samples taken throughout this area exhibited PCB concentrations consistent with those of the surface sediment samples. In a review of the available data (Limno-Tech Inc., 1988), PCB concentrations ranged from non-detectable to 1,000 mg/kg at 1 to 2 feet below the surface sediments, and PCB levels declined with increasing depth. A volume-weighted estimate of average PCB concentration was calculated by Limno-Tech, Inc. to be approximately 110 mg/kg (neglecting data presented as below detection).

Surficial and core soil samples were collected in 1991 from five residential properties along the east bank of the former Bryant Mill Pond (Blasland & Bouck Engineers, 1992).

The locations were selected for sampling based upon site reconnaissance and the interpretation of historic air photos which together indicate that the sampled areas had formerly been low areas which were adjacent to or part of Bryant Mill Pond but had received fill in their development as residential properties. Observations made during sample collection confirmed the presence of fill upon underlying soils (i.e., former sediment or native soil). Samples were collected at the current surface and just below the interface of the fill and underlying soil. The results of PCB analyses of the surface soils

(0.025 to 0.34 mg/kg) are all below levels considered to be significant.

PCBs were reported for two of the five subsurface samples at concentrations greater than 1 mg/kg. The sample collected at a depth of 4.5-5.0 feet below the surface of a vacant lot had a reported PCB concentration of 16 mg/kg. The sample collected on another lot at a depth of 4.0-4.5 feet had a reported PCB concentration of 1.4 mg/kg. Considering the relatively low concentrations and the isolated nature of the associated subsurface soil layer, the results do not suggest a significant risk to residents.

The water column of Portage Creek at Cork Street has exhibited non-detectable PCB concentrations (less than 0.01 ug/L). These concentrations were assumed to be at background levels (MDNR, December 1987). However, on one occasion a concentration of 0.017 ug/L was detected. The results of the 27 water-column samples collected between 1985 and 1987 at Alcott Street had PCB concentrations ranging from 0.032 to 0.34 ug/L (MDNR, December 1987). Based on these data, an average PCB concentration was calculated to be 0.13 ug/L. Water samples collected in 1989 at Alcott Street indicate significantly lower concentrations ranging from non-detectable (at a detection limit of 0.01) to 0.06 ug/L (Peterson, 1990). Four samples collected at Alcott Street in the Fall of 1990 had non-detectable PCB concentrations (at a detection limit of 0.01 ug/L) and eight water-column samples collected in 1991 had PCB concentrations

The entire Allied Paper/Former Bryant Mill Pond area is an inactive industrial area. Access to the area is restricted by a fence along the perimeter of the property. The perimeter is posted against trespassing, and "NO ENTRY, HAZARDOUS SUBSTANCES" warning signs have also been posted at short intervals along the perimeter by the MDNR.

Even though the potential for human expcsure is limited, exposure of on-site receptors to PCB-contaminated media could occur during site-maintenance related or trespassing activities. These activities might involve contact with on-site soils, historic residuals, and/or Portage Creek water and sediments. There are no potable uses of on-site ground water.

Off-site receptors include those individuals who may inhale fugitive dust originating from on-site soils which contain PCBs.

Incidential inhalation of PCBs by trespassers, employees, or off-site receptors from fugitive dust is anticipated to be limited in the former Bryant Mill Pond area due to the current vegetative cover.

4.3 Performance Paper Mill

4.3.1 Characteristics

The Performance Paper, Inc., Mill is located along Portage Creek in Kalamazoo, Michigan (Figure 13) and has been a paper manufacturing facility since the mid-1800s. The majority of the surviving structures at the mill were constructed between 1896 and 1911. The Mill A building, used for deinking, was demolished between 1978 and 1986. The Mill C and D buildings are still standing. Mill C is bordered to the south by Alcott

Street, to the north by Bryant Street, to the east by Portage Road, and to the west by Portage Creek. Mill D is bordered to the south by Bryant Street, to the north by Reed Street, to the east by Belford Street, and to the west by the Conrail Railroad.

The Performance Paper, Inc. property is approximately 40 acres in area. Roughly 5.5 acres of this area are paved and 10.1 acres are covered by buildings. The rest of the area is unpaved.

The building drainage system collects and conveys process wastewater and storm-water runoff from the flat-roofed buildings. The water from the building area drainage system is collected in a sump near Mill D and is pumped to the Gray Tank near former Mill A, which serves as a collection point for all of the building drains at the mill. When in operation, water from the Gray Tank was then pumped to the 100-foot diameter Bryant Clarifier, which settled collected water before it was discharged to the Kalamazoo wastewater treatment facility (Outfall 001) or to Outfall 002 which is located at the 90-foot diameter Monarch Clarifier. Outfall 001 was constructed in 1969 and leads to the city sanitary sewer system (MDNR, October 20-21, 1987). Water conveyed to the Monarch Clarifier was recycled or discharged to Portage Creek through Outfall 002. Settled solids were discharged to the Bryant Clarifier, which discharges to the decant lagoons. Decant water from the farthest northeast decant lagoon was recycled to the Bryant Clarifier. Presently, any water which collects at the lagoons is being pumped to the city sewer after activated carbon treatment.

Because the mill is presently not in service, the flow collected by the building drainage system is primarily rainfall collected by the roof drains.

4.3.2 Potential Exposure to PCB-Contaminated Media

The Performance Paper, Inc. Mill is located in an industrial area surrounded by a mixture of secondary business, commercial, and residential land uses. Access to the property is not restricted to the public; however, the buildings that remain on the property are secured against trespass. The former deinking facility has been removed. Portage Creek flows through the plant area.

The mill is currently inactive and as noted above, the buildings are secured against trespass, thus minimizing the potential for trespassers to be exposed to site media. Current on-site receptors will mainly consist of maintenance and security personnel who visit the mill on a regular basis.

Exposure risks at this facility will be determined in the Remedial Investigation.

4.4 Portage Creek, Alcott Street to the Confluence with the Kalamazoo River

4.4.1 Characteristics

This segment of Portage Creek (approximately 1.7 miles) lies entirely within the city of Kalamazoo (Figure 3), beginning at the Alcott Street Dam and continuing to the creek's confluence with the Kalamazoo River (NUS, 1986).

Portage Creek flows from south to north with an average flow rate of approximately 60 cfs (O'Brien & Gere, 1990). The creek along this section is described as being quite channelized and possessing erosional characteristics (NUS, 1986). The environmental setting of Portage Creek in this area is urban, and a large percentage of the surrounding land consists of impervious surfaces.

Sediment samples were collected in this reach between 1972 and 1983. PCB concentrations in six samples collected in 1972 ranged from 12 to 26 mg/kg (wet weight); one sample also collected in 1972 had a dry weight PCB concentration of 120 mg/kg (Lauer, 1973; MDNR, December 1987). Sediment samples collected in 1976 ranged in PCB concentration from 0.50 to 56 mg/kg. Samples collected in 1982 and 1983 showed PCB concentrations ranging from 10 to 85 mg/kg.

Water-column sampling performed in 1972 along this stretch of Portage Creek produced data that show PCB concentrations ranging from 0.22 to 3.6 ug/L (Lauer, 1973), while sampling performed during the drawdown of Bryant Mill Pond in 1976 shows PCB concentrations ranging from 0.17 to 290 ug/L (Harvey, 1976; Przybysz, 1976). Two water-column samples collected in 1985 had PCB concentrations of 0.08 and 0.16 ug/L (Limno-Tech, Inc., unpublished data).

Fish samples were collected by MDNR in 1981 at a location approximately one-quarter mile upstream of the mouth of Portage Creek. Analysis was performed on skin-off fillets for carp and skin-on fillets from five individual white suckers and three, five-fish white sucker composites.

Average total PCB concentrations were found to be 0.7 mg/kg for carp and 4.1 mg/kg for white suckers (MDNR, October 1982b). The fish in this section of Portage Creek appear stressed by relatively poor water quality as evidenced by the statistically lower lipid content of these fish as compared to fish from the Kalamazoo River, according to MDNR (December 1987). Lipid content tends to be an important factor affecting intraspecies variability of PCB concentrations. For equivalent exposures, individuals with higher lipid content will generally exhibit higher flesh PCB concentrations. Thus, variations in lipid content of fish from different locations can obscure differences in environmental exposure when such exposure is measured solely by fish flesh PCB concentrations. Another fish survey of Portage Creek was performed in 1985. A composite sample of three smallmouth bass and one carp were collected and showed total PCB concentrations of 1.6 and 3.1 mg/kg, respectively (Limno-Tech, Inc. unpublished data).

These data are described in more detail in Section 5.

4.4.2 Potential Exposure to PCB-Contaminated Media

Portage Creek from Alcott Street to the Kalamazoo River is accessible to the general population. PCBs have been detected in surface sediments and in the water column of Portage Creek (NUS, 1986). Accordingly, the potential exists for the occurrence of human exposure to PCBs in the creek. Portage Creek passes through Upjohn Park and a playground which is located in proximity to several schools.

The Conrail railroad tracks are in proximity to Portage Creek, and a major railroad yard is located in Kalamazoo. It is unlikely, however, that

railroad workers would come into contact with creek sediments during routine work activities.

The primary potential routes of exposure are likely to be via dermal contact, incidental ingestion of creek water, sediments or adjacent floodplain soils containing PCBs, ingestion of fish, and possible inhalation of dusts generated from floodplain soils.

A fish consumption advisory is currently in effect for all of Portage Creek downstream of the Monarch Mill Pond. Anglers are advised not to eat any carp, suckers, catfish, smallmouth bass, or largemouth bass taken from the creek. MDNR has indicated that the possibility exists that some anglers may not heed the advice and consume fish taken from the creek. For this reason, the ingestion of Portage Creek fish is a potential exposure pathway. Of the potential exposure pathways considered for this section of the Site, incidental ingestion of sediments and ingestion of fish appear to be the most significant potential exposure pathways (ATSDR, 1991).

Residents visiting areas adjacent to Portage Creek are the most likely human receptors to be exposed to PCBs via contact with stream sediments. Older individuals who visit the Portage Creek area (i.e., Upjohn Park or other creek-bank areas) on a routine basis are likely to experience less total exposure because of their anticipated activities when in proximity to the creek.

4.5 Kalamazoo River and Floodplain

4.5.1 General Characteristics

The Kalamazoo River extends approximately 75 miles from the Morrow Lake Dam to Lake Michigan (Figures 3 through 12) and is described by MDNR (December 1987) as free-flowing. The river bottom is mainly sand and gravel with some areas, particularly the impoundments, containing silt and clay. Some sections of the river are erosional zones, while others are depositional zones. Extensive areas along the river are characterized by wetlands (NUS, 1986).

There are two lakes in this section of the Kalamazoo River. Lake Allegan, the largest lake on the river, is located downstream of the city of Allegan. Kalamazoo Lake is located near the towns of Douglas and Saugatuck.

The floodplains along the Kalamazoo River are described by MDNR (December 1987) as being generally broad and covered with lowland forest or located within marshy wetlands. Wooded vegetation is described as consisting of varying mixtures of willow, cottonwood, silver maple, and ash with sycamores scattered singly or in clumps throughout the lowland areas. The marsh areas are described as containing various amounts of sedges, rushes, cattail, and aquatic species such as pond weeds and water lilies.

The main stem of the Kalamazoo River between the Morrow Lake Dam and Lake Michigan is dammed at six locations. These dams were constructed primarily for generating electric power. The MDNR acquired three of these dams (Plainwell, Otsego, and Trowbridge) in the 1960s with

plans to utilize them for fisheries and waterfowl development (Figures 6 and 7). Vandalism and high maintenance costs forced the MDNR to demolish the dam superstructures and draw the impoundments down to a low-sill head (MDNR, December 1987). While these dams impounded water, PCB-contaminated sediments were deposited in the impoundments. When the water level was lowered and the superstructures removed in 1986, some of these contaminated sediments were exposed in the floodplain. Two of the other dams (Allegan City and Lake Allegan Dams) still generate hydroelectric power. The river is also impounded by the Otsego City Dam, which no longer generates hydroelectric power.

4.5.2 Detailed Characteristics

As with Portage Creek and the Portage Creek/Bryant Mill Pond areas, PCBs have been found in the fish, water, sediment, and floodplain of the Kalamazoo River. In general, sediment PCB concentrations in the Kalamazoo River are lower than those in Portage Creek while fish PCB concentrations are comparable between the two areas. The following nine segments of the river will be discussed separately:

- Morrow Lake Dam to Portage Creek confluence;
- Portage Creek confluence to Main Street, Plainwell;
- Main Street, Plainwell to the Plainwell Dam;
- Plainwell Dam to the Otsego City Dam;
- Otsego City Dam to the Otsego Dam;
- Otsego Dam to the Trowbridge Dam;
- Trowbridge Dam to the Allegan City Dam;

- Allegan City Dam to the Lake Allegan Dam; and
- Lake Allegan Dam to Lake Michigan.

Included in these descriptions are short discussions of the PCB concentrations found in various media. The data are described in more detail in Section 5. However, because of the similarities among the nine river segments (e.g., similar physical characteristics, PCB distribution among environment media, receptor populations, and on-site activities), a discussion identifying human receptor populations and an evaluation of potential exposure pathways is not included in Sections 4.5.2.1 through 4.5.2.9. Rather, a discussion addressing these issues for the entire stretch of river from the Morrow Lake Dam to Lake Michigan is presented in Section 4.5.3.

4.5.2.1 Kalamazoo River, Morrow Lake Dam to Portage Creek Confluence

This section of the river extends a distance of approximately 4.8 miles from the Morrow Lake Dam to the river's confluence with Portage Creek (Figures 2 and 3).

Surface sediment samples from this segment of the Kalamazoo River were collected and analyzed for PCBs in 1976 and 1982. The 1976 surficial sediment samples taken at the River Street and the Michigan Avenue Bridges were found to contain total PCB concentrations of non-detect (at a detection limit of 0.5 mg/kg) and 7.7 mg/kg, respectively (Wuycheck, 1976). In the 1982 survey, PCB concentrations were not detected at a detection limit of 0.05 mg/kg at

the King Highway and Michigan Avenue Bridges (MDNR, November 1982).

In 1972, settleable solids were collected over an eight-day period at the River Street and Michigan Avenue Bridges and analyzed for PCBs (Lauer, 1973). The settleable solids samples collected had total PCB concentrations of 0.23 mg/kg and 0.56 mg/kg, respectively. Settleable solids were also collected in 1976 for 4 weeks from the River Street, King Highway, and Michigan Avenue Bridges and analyzed for PCBs (Wuycheck, 1970). The results showed total PCB concentrations ranging from 0.82 mg/kg to 1.9 mg/kg with an average concentration of 1.2 mg/kg. The results of these surveys are presented in Table 5.

The MDNR, during a three-year survey conducted from 1985 to 1987, collected 19 water samples from the River Street Bridge, 11 water samples from the Michigan Avenue Bridge, and five samples from the King Highway Bridge. In ten of the water samples collected at the River Street Bridge, PCBs were not detected (at a detection limit of 0.01 ug/L). The other nine samples ranged in PCB concentrations from 0.011 to 0.14 ug/L with an average total PCB concentration of 0.032 ug/L. The five water samples collected at the King Highway Bridge were all found to have non-detectable PCB concentrations (at a detection limit of 0.01 ug/L). Four out of eleven samples collected at the Michigan Avenue Bridge had PCB concentrations above the detection limit. These four samples ranged

in total PCB concentration from 0.014 to 0.041 ug/L with an average of 0.032 ug/L (MDNR, December 1987). A sample collected from the Michigan Avenue Bridge in 1972 (Lauer, 1973) had non-detectable levels of PCBs (at a detection limit of 0.10 ug/L), and two samples collected from the River Street Bridge in 1988 had non-detectable PCB concentrations (at a detection limit of 0.020 ug/L) (GZA-Donahue, 1988).

PCB concentrations in fish captured from this section of the river were determined in 1971 and 1976. In 1971, four fish were collected from between the Morrow Lake Dam and the King Highway Bridge. This included one each of carp, white sucker, rock bass, and bullhead. PCB concentrations in samples of fish flesh were 8.9, 18, 2.3, and 3.3 mg/kg respectively. In 1976, two fish were collected from below the Morrow Lake Dam at River Street. One smallmouth bass and one largemouth bass were captured and skin-off fillets were analyzed for PCB content. Total PCB concentrations in these two fish were 1.2 and 0.40 mg/kg, respectively.

4.5.2.2 Portage Creek to Main Street, Plainwell

This stretch of river is approximately 15 miles in length, and extends from the confluence with Portage Creek to Main Street, Plainwell (Figures 3 through 6).

Surface sediment samples were collected from various locations within this reach in 1976, 1982, 1984, and 1986 and exhibited PCB concentrations ranging from non-detectable (at a detection limit of 0.05

mg/kg) to 57 mg/kg (MDNR, December 1987; Creal, April 1984; Gaule, 1987). Average total PCB concentrations were calculated, based on these data, to be 9.0, 36, 13, and 3.6 mg/kg in 1976, 1982, 1984, and 1986, respectively. As stated by MDNR (December 1987), no general temporal trends can be detected from the annual averages due to the limited data available.

Based on the sample locations, some spatial gradients seem to be apparent. Results from samples collected in 1976 showed concentrations of under 15 mg/kg with the PCBs being distributed throughout the entire reach. The 1982 and 1984 data suggest higher concentrations with the highest concentration (57 mg/kg) found upstream at Paterson Street (Figure 4). PCB concentrations at D Avenue (Figure 5) and Commerce Street were as low as 1.6 and 1.0 mg/kg (MDNR, December 1987). Results from the six samples taken in 1986 ranged from non-detectable (at a detection limit of 0.5 mg/kg) to 8.1 mg/kg total PCBs, with the two highest total PCB concentrations (8.1 and 7.6 mg/kg, wet weight) located at Paterson Street and 66 feet below the Kalamazoo wastewater treatment plant outfall, respectively (Gaule, 1987) (Figure 4).

Water-column samples collected from various locations within this reach in 1985, 1986, and 1987 indicated PCB concentrations ranging from non-detectable (at a detection limit of 0.010 mg/kg) to 0.044 ug/L (MDNR, December 1987). Estimated average PCB concentrations

were 0.032, 0.016, and 0.025 ug/L, in 1985, 1986, and 1987, respectively.

PCB concentrations in various fish species were monitored sporadically from the Mosel Avenue area from 1971 to 1986. The most commonly sampled species was carp, which contained average total PCB concentrations of 170 mg/kg (1971) in flesh samples, and 8.0 mg/kg (1976), 2.3 mg/kg (1981), 3.5 mg/kg (1983), 5.0 mg/kg (1985), and 4.7 mg/kg (1986) in skin-off fillets. Bass analyzed in 1981 and 1985 had average PCB concentrations in skin-on fillets of 1.2 and 1.7 mg/kg, respectively. One smallmouth bass collected in the vicinity of the Kalamazoo wastewater treatment plant in 1986 had a PCB concentration of 1.1 mg/kg. Other species which were monitored less frequently include the white sucker in 1971, and bluegill, black crappie and rock bass in 1981. An average PCB concentration of 57 mg/kg was found in 20 gram flesh samples of white sucker. PCB concentrations of 0.92, 3.0, and 1.5 mg/kg were found in skin-on fillets of bluegill, crappie, and rock bass, respectively. Bluegill, black crappie, yellow bullhead, rock bass, and redhorse sampled in 1986 from the vicinity of the Kalamazoo wastewater treatment plant had PCB concentrations of 1.1, 0.88, 0.41, 1.9, and 0.97 mg/kg, respectively. Average PCB concentrations in fish generally decreased from 1971 to 1986 (MDNR, December 1987).

4.5.2.3 Main Street, Plainwell to the Plainwell Dam

This section of the Kalamazoo River extends approximately two miles from Main Street, Plainwell, to the Plainwell Dam and includes the former Plainwell Impoundment (Figure 6). This reach of the Kalamazoo River accumulated a large quantity of sediments during the nearly 70 years of impoundment. During the early 1970s, the impoundment was drawn down by MDNR after they acquired the Plainwell Dam in 1966. This consequently exposed historical sediment deposits. Following the drawdown, the river eroded a channel through the sediments to such an extent that most of the former sediments are now above the existing water line (MDNR, December 1987).

The now vegetated floodplain sediment is periodically submerged by flooding and according to MDNR (December 1987), certain areas are still being eroded despite the vegetation, possibly releasing PCBs to the river.

Sediment data collected in this reach indicate PCB concentrations to be lower than those found in the former Bryant Mill Pond in Portage Creek. Surface grab and core sediment samples were collected from various locations throughout this reach from 1976 to 1985. Samples were collected from within the river channel as well as from above the existing water line. Surface sediment samples collected in the river or at the edge of water showed PCB concentrations ranging from non-detectable (at a detection limit of 0.08 mg/kg) to 56 mg/kg just upstream of the Plainwell Dam. Sediment

samples collected above the water line exhibited PCB concentrations ranging from non-detectable (at a detection limit of 0.5 mg/kg) to 37 mg/kg (Creal, 1983; Harrison and Yerkes, 1983; Creal, June 1984; MDNR, December 1987).

Water-column samples collected in 1985, 1986, and 1987 from the 10th Street Bridge, Plainwell, had PCB concentrations ranging from 0.012 to 0.15 ug/L (MDNR, December 1987). Annual maximum concentrations for samples collected in 1985, 1986, and 1987 were 0.11, 0.15, and 0.097 ug/L, respectively, with average concentrations of 0.067, 0.083, and 0.063 ug/L, respectively.

Fish were collected from the Plainwell Impoundment in 1976 and 1986 (NUS, 1986; MDNR, 1986b). In 1976, skin-off fillets of carp and white sucker had average PCB concentrations of 13 and 4.3 mg/kg, respectively. In 1986 skin-off fillets of 21 carp had an average PCB concentration of 4.1 mg/kg.

4.5.2.4 Plainwell Dam to the Otsego City Dam

This reach of the Kalamazoo River extends a distance of approximately 1.7 miles downstream of the Plainwell Dam to the Otsego City Dam (Figure 6). This section of the river is characteristic of an impoundment possessing swampy, marshy, and depositional conditions. However, during relatively high river-flow events, it may also possess erosional characteristics (MDNR, December 1987). During these instances, according to MDNR, certain areas may be eroded, thus resulting in releases of PCB-contaminated sediments to the river.

The overall data base for this reach is limited. Four surface sediment samples and one core sample were collected from within the river channel in 1982, and two surface sediment samples and one core were collected from the riverbank in 1985. In-stream PCB sediment concentrations ranged from non-detectable (at a detection limit cf 0.15 mg/kg) to 6.6 mg/kg (Bhaskar et al., 1983). PCB concentrations found in surface sediment samples from the riverbank in 1985 ranged from 7.9 to 57 mg/kg. At depths greater than 2 feet, concentrations ranged from 0.91 to 5.9 mg/kg (Anon., January 1985). A surface sediment sample taken in June 1991 at a near-shore point adjacent to the Otsego City Dam was found to have a PCB concentration of 180 mg/kg. A sample collected at a depth of 1 foot had a PCB concentration of 1.0 mg/kg (MDNR, October 1991).

A total of four water-column samples collected during April, May, June, and July 1985 exhibited PCB concentrations ranging from 0.031 to 0.070 ug/L, with an average concentration of 0.055 ug/L. One additional sample collected in May 1986 exhibited a PCB concentration of 0.091 ug/L (MDNR, December 1987).

Fish sampling below the Plainwell Dam was conducted from 1971 to 1987. Sample preparation in 1971 consisted of the removal of 20 grams of flesh from the side of the fish. Sample preparation for fish collected after 1981 consisted of edible portions (skin-on or skin-off fillets) as required by the MDNR. Carp were the most commonly sampled species and exhibited average total PCB concentrations of 21

mg/kg in flesh samples (1971), and 3.2 mg/kg (1981), 5.5 mg/kg (1983), 5.3 mg/kg (1985), and 5.2 mg/kg (1987) in skin-off fillets. Average total PCB concentrations for white suckers were 21 mg/kg in 1971. Total PCB concentrations in bullhead collected in 1971 were 6.7 mg/kg. Fish analyzed for PCBs in 1981 were collected from Douglas Avenue and in the vicinity of the Plainwell Dam (MDNR, October 1982b). Mean total PCB concentrations in skin-off fillets of brown bullhead, yellow bullhead, channel catfish, and northern pike were 0.45 mg/kg, 0.36 mg/kg, 1.6 mg/kg, and 0.50 mg/kg, respectively. Mean total PCB concentrations in skin-on fillets of largemouth bass, bluegill, black crappie, and pumpkinseed were 0.47 mg/kg, 0.98 mg/kg, 0.95 mg/kg, and 2.2 mg/kg, respectively. One smallmouth bass collected in 1985 contained a total PCB concentration of 3.3 mg/kg (skin-off fillet).

4.5.2.5 Otsego City Dam to the Otsego Dam

The lower half of the 3.25-mile reach between the Otsego City Dam and the Otsego Dam includes the former Otsego Dam Impoundment (Figure 7). The Otsego Dam was acquired by the MDNR in 1967, and as with the former Plainwell Dam Impoundment, drawdown caused much of the historically deposited sediments to be exposed above the river's current water line (MDNR, December 1987). These sediments are now covered by vegetation and are periodically submerged by flooding. According to MDNR (December 1987), as of 1987 certain areas were still being eroded, despite the vegetation.

In-stream sediment samples collected in 1982 exhibited PCB concentrations ranging from non-detectable (at a detection limit of 0.15 mg/kg) to 0.52 mg/kg. Two surface sediment samples collected above the water line near Highway M-89 in Otsego exhibited PCB concentrations of 67 mg/kg and 27 mg/kg in 1976 and 1982, respectively.

A total of 10 core samples were collected from various locations above the water line in March 1983. These samples were collected from the lower section of the reach in the exposed-sediment areas. These samples exhibited PCB concentrations ranging from 0.79 to 28 mg/kg (Miller, 1983). In addition, a 7-foot core was taken from within the river channel less than one-tenth of a mile upstream from the dam. The analysis of samples collected at one-foot intervals showed PCBs to be under 0.30 mg/kg at all depths (Anon., 1984).

A total of four water column samples were collected near Farmer Street in Otsego during April, May, June, and July of 1985. Water column PCB concentrations were found to range from 0.046 to 0.09 ug/L (MDNR, December 1987). The average of these measurements is 0.06 ug/L.

Fish samples were collected by the MDNR from this section in 1971 (20 gram samples of fish flesh) and 1976 (skin-off fillets) and analyzed for PCBs. Average total PCB concentrations for carp were 59 mg/kg and 12 mg/kg, respectively, while the white sucker averaged

13 mg/kg and 4.0 mg/kg. Also collected in 1976 was one bass with a total PCB concentration of 1.5 mg/kg (MDNR, 1972; NUS, 1986).

4.5.2.6 Otsego Dam to the Trowbridge Dam

The Kalamazoo River flows approximately 4 miles between the Otsego Dam and the Trowbridge Dam, with the lower portion of this reach including the former Trowbridge Impoundment (Figure 7). This area is described as possessing characteristics similar to those of the former Plainwell and Otsego impoundments (i.e., having swampy, marshy, and depositional characteristics) (NUS, 1986). The drawdown of this impoundment has also exposed historic sediment deposits. The former sediments are now vegetated and release PCBs to the river when submerged by flooding, according to MDNR (1987), despite the vegetation.

Sediment samples were collected in this reach in 1982, 1983, and 1984. Three surface sediment samples and one core sample were collected from within the river channel in 1982. These samples exhibited PCB concentrations ranging from 1.7 to 38 mg/kg. One sample core was also collected within the river channel in 1983. This core was collected approximately 150 feet upstream from the Trowbridge Dam in an active depositional zone (Bhaskar et al., 1983). The results of this core showed PCB concentrations of 8.4 and 13 mg/kg at depths of 0 to 2 inches and 0 to 18 inches, respectively (Creal, 1983).

Surface sediment grab samples collected in 1983 above the water line exhibited PCB concentrations ranging from 23 to 81 mg/kg (Creal, 1983). Analysis of the 1983 and 1984 sediment samples collected at the edge of the water and above the water line indicated PCB concentrations ranging from 1.1 mg/kg to 64 mg/kg in the upper 3 feet of sediment, while concentrations at depths greater than 3 feet were found to be less than 5 mg/kg (Harrison and Yerkes, 1983; Creal, 1983; Creal and Wuycheck, 1984; MDNR, December 1987).

A total of four water-column samples were collected from near the Otsego Dam in April, May, June, and July of 1985. PCB concentrations ranged from 0.049 to 0.12 ug/L and averaged 0.076 ug/L (MDNR, December 1987).

Fish samples were collected by MDNR from the Otsego Dam area in 1971 and 1976. Because of the broad descriptions of the reaches in these surveys, it is not apparent whether these fish were collected above or below the Otsego Dam. Therefore, these results have been discussed in Section 4.5.2.5.

4.5.2.7 Trowbridge Dam to the Allegan City Dam

The Kalamazoo River flows approximately nine miles between the Trowbridge Dam and the Allegan City Dam (Figure 8). The Allegan City Dam Impoundment, approximately 1.7 miles long, has been described as a depositional zone characterized by large sediment deposits (NUS, 1986). The 7.3-mile portion of this reach located

upstream of the Allegan City Dam Impoundment is described as an erosional zone (NUS, 1986).

One sediment sample collected upstream of the Allegan City Impoundment near Bridge Street contained no detectable PCBs (MDNR, December 1987). The analysis of surface sediment grab and core samples collected from the bed of the Allegan City Impoundment in 1985 indicated PCB concentrations ranging from 0.96 to 57 mg/kg from the surface to a depth of 8 feet (Anon., May 1985). In addition, a total of six surface sediment and core samples were collected from within the river channel in 1982. These samples exhibited PCB concentrations ranging from 9.5 to 57 mg/kg (Bhaskar et al., 1983).

Water-column samples were collected from two locations within this reach in 1985. Samples were collected from near 26th Street just downstream of the Trowbridge Dam and Williams Road and just upstream of the Allegan City line during April, May, June, and July of 1985. Water-column PCB concentrations near 26th Street ranged from 0.043 to 0.13 ug/L, while concentrations ranged from 0.071 to 0.12 ug/L near Williams Road (MDNR, December 1987). Average PCB concentrations were 0.086 and 0.10 ug/L for 26th Street and Williams Road, respectively.

Fish were collected from the section of river between the Trowbridge Dam and the Allegan City Dam in 1971 and included specimens of carp, white sucker, and northern pike. Respective mean

PCB concentrations in 20-gram samples of fillet were 4.1 mg/kg, 12 mg/kg, and 8.2 mg/kg (MDNR, 1972).

4.5.2.8 Allegan City Dam to the Lake Allegan Dam

Lake Allegan is the largest of the impoundments downstream of Kalamazoo (Figures 8 and 9). The lake is approximately 8.5 miles long, and its surface area is about 1,650 acres, which is more than 70 percent of the total river surface between the city of Kalamazoo and the Lake Allegan Dam (Harrison, 1982). It has a relatively large carp population which is thought to contribute to mixing and suspension of the lake sediment (MDNR, December 1987).

Sediment samples were collected from Lake Allegan on five occasions between 1976 and 1987. Reported PCB concentrations ranged from 2.3 to 42 mg/kg. In July 1983, five to six cores were taken along each of three transects in addition to three cores at other locations. Cores range in length from 8 to 16 inches. The top 4 inches and the bottom 4 inches of all cores within each transect were composited (Creal, 1983). The top 4 inches of the cores had an average PCB concentration of 17 mg/kg while those of the bottom 4 inches averaged 26 mg/kg.

Water-column samples were collected at the M-118 bridge on 11 occasions in 1985 and on one occasion in 1986. Total PCB concentrations ranged from 0.057 to 0.19 ug/L. About 75 percent of the PCBs were reported as Aroclor 1242, with the balance being reported as Aroclor 1254.

Lake Allegan has been the site of frequent sampling to measure PCB concentrations in resident fish. Fish were first collected in 1971 and since that time sampling has occurred in 1976, 1978, 1981, 1983, 1985, 1986, 1987, and 1990. Throughout this period, sampling has focused on five species of fish. These include carp, northern pike, white sucker, smallmouth bass, and largemouth bass. In addition, the 1971 sample included a single bullhead and the 1983 sample included a single bluegill.

Carp were sampled each year. Mean PCB concentrations in Lake Allegan carp ranged from a high of 51 mg/kg in 1978 (skin-off fillets) to a low of 2.8 mg/kg in July 1983 (skin-off fillets). Mean concentrations in northern pike ranged from a high of 13 mg/kg in 1971 (20-gram flesh sample) to a low of 2.1 mg/kg in 1976 (skin-off fillets). Pike were also sampled in 1978 and 1987. White suckers were sampled in 1971, 1976, and 1978. Mean PCB concentrations ranged from a high of 14 mg/kg in 1971 (20-gram flesh sample) to a low of 6.3 mg/kg in 1978 (skin-off fillets). Largemouth bass were sampled in 1981, 1983, and 1985. Mean PCB concentrations in skin-on fillets ranged from 0.44 mg/kg in 1983 to 3.1 mg/kg in 1985. Smallmouth bass were collected in 1981, 1985, and 1987. Mean PCB concentrations in skin-on fillets ranged from 1.3 mg/kg in 1981 to 3.1 mg/kg in 1987. Twenty carp were collected in 1990. Ten samples were prepared as skin-off fillets and ten as whole fish. Mean PCB concentrations in these samples were 3.7 and 12 mg/kg, respectively.

4.5.2.9 Lake Allegan Dam to Lake Michigan

This section of the river extends approximately 26 miles from the Lake Allegan Dam to Lake Michigan (Figures 9 through 12). It was initially surveyed to identify sediment PCB distributions in 1982 by Horvath (1984) and again by the MDNR in 1985 (MDNR, December 1987). The average PCB concentrations found in the 1982 and 1985 surveys for this reach were 0.23 and 0.35 mg/kg, respectively. The PCB concentrations for the two surveys ranged from non-detectable (at a detection limit of 0.03 mg/kg) to 1.7 mg/kg. The highest concentrations were found in the deepest part of Kalamazoo Lake (1.7 mg/kg) and 10.9 miles downstream of the Lake Allegan Dam (1.4 mg/kg). The only other PCB concentration found above 1.0 mg/kg was at a point 1.3 miles downstream of the Lake Allegan Dam, with a concentration of 1.1 mg/kg.

Water-column monitoring was conducted at the mouth of the river from 1971 to 1972 by the MDNR. The average PCB concentration found in this survey was 0.065 ug/L (MDNR, December 1987). Water column monitoring was also conducted from 1980 to 1981 by Marti (1984), in 1982 by Horvath (1984), and in 1985 by the MDNR (December 1987). The average water-column PCB concentration for these three surveys combined was 0.07 ug/L, with a range of concentrations of non-detectable (at a detection limit of 0.030 ug/L) to 0.17 ug/L. Average PCB concentrations were 0.12 ug/L at Lake Allegan Dam, 0.061 ug/L at New Richmond, 0.075 ug/L at the US31

Bridge, 0.054 ug/L in the channel to Lake Michigan, and 0.044 ug/L at the mouth of the river.

Fish were sampled from this reach in 1971, 1976, 1978, 1981, 1983, 1985, 1986, and 1987. Over 230 fish representing 18 species were taken from the river during these eight sampling events and analyzed for PCBs. Fish were collected at three locations on the river: New Richmond, Douglas, and Saugatuck. Of the 18 species included in the combined sampling efforts, only four species: carp, northern pike, white sucker, and largemouth bass, were consistently collected.

Fish were collected at New Richmond in 1978 and 1981. Mean PCB concentrations in skin-off fillets of carp and northern pike collected in 1978 were 63 and 7.2 mg/kg, respectively. The 1981 sampling effort captured carp, largemouth bass, and bowfin. Mean PCB concentrations were 4.8 mg/kg for the carp (skin-off fillet), 1.7 mg/kg for the bass (skin-on fillet), and 2.3 mg/kg in the bowfin (skin-off fillet).

Fish were collected at Douglas in 1981 only. Carp skin-off fillets and largemouth bass skin-on fillets each had mean PCB concentrations of 8.3 mg/kg.

Fish were collected near Saugatuck in 1971, 1976, 1978, 1981, 1983, 1985, 1986, and 1987. Carp were successfully captured and analyzed for PCBs in each of these years. Mean PCB concentrations in carp ranged from a high of 45 mg/kg in a 20 gram flesh sample

of a single carp taken in 1971, to a low of 3.6 mg/kg for 20 carp (skin-off fillets) taken in 1985. The average PCB concentration in carp collected in 1987 (skin-off fillets) was 4.5 mg/kg. Northern pike were taken at Saugatuck in 1971, 1976, 1978 and 1987 and had mean PCB concentrations of 8.7 in a 20-gram flesh sample and 4.7, 4.9, and 1.3 mg/kg in skin-off fillets, respectively. White suckers were collected in 1971, 1978, and 1987 with mean PCB concentrations of 46 mg/kg in a 20-gram flesh sample and 6.4 and 1.1 mg/kg in skin-on fillets, respectively. Largemouth bass were collected in 1981, 1985, 1986, and 1987. Mean PCB concentrations in skin-on fillets were 3.0, 1.3, 0.58, and 1.1 mg/kg, respectively.

4.5.3 Summary of Potential Human Exposure Pathways

The 75-mile stretch of river between the Morrow Lake Dam and Lake Michigan flows through a variety of settings including eight municipalities (Comstock, Kalamazoo, Parchment, Plainwell, Otsego, Allegan, Douglas, and Saugatuck) and extensive tracts of rural land. Land use along the river includes urban commercial and industrial; agricultural; urban, suburban, and rural residential; and recreational development. PCBs have been detected in river sediment, water, and biota samples, as well as in exposed sediments at the former impoundments.

Kalamazoo River water is not used for potable water supplies. All residential and municipal water supplies in the Kalamazoo River basin are obtained from ground-water sources (ATSDR, 1991). The cities of Kalamazoo, Parchment, Plainwell, Otsego, Allegan, and Saugatuck currently

operate municipal water supply wells within one-half mile of the river. The pumping rates of these cities range from 0.4 million gallons per day (MGD) in Plainwell to 45 MGD in Kalamazoo. A number of private residential wells are also located within one-half mile of the river, according to the MDNR Geological Survey Division.

Recreational uses of the river include swimming, boating, and fishing (MDNR, December 1987). Public recreation facilities include boat launches, fishing piers, parks, and tracts of undeveloped land (e.g., Allegan State Game Area). Undeveloped areas may provide river access suitable for launching small boats, fishing, hiking, birding, or picnicking. Fishing and boating are reportedly fairly common on this stretch of river, but are concentrated in the lower reaches (Johnson, 1991). Recreational use of Lake Allegan may also include water skiing and jet skiing activity.

There are currently no publicly maintained swimming areas on the river between the Morrow Lake Dam and Lake Michigan. Reports of individuals swimming in the river are limited to locations upstream of the Site and include Morrow Lake and a stretch of river in the vicinity of Augusta (Johnson, 1991).

Numerous wildlife populations also exist in the area, making it probable that some level of hunting (i.e., waterfowl, small game, large game) and trapping activity occurs in the floodplains adjacent to the river.

Agricultural uses of the floodplain include crop production and limited areas of pasturage. MDNR staff have observed beef cattle on one occasion grazing upon the floodplain on the east side of the river upstream of the

Plainwell Dam. On a second occasion evidence of grazing animals (feces) was found in the same area. According to MDNR both instances apparently involve the same farm. It is also reported (ATSDR, 1991) that a number of agricultural supply (i.e., irrigation) intakes are maintained on the river.

Direct ingestion and dermal contact are identified as potential routes of exposure to ground water due to the current level of potable ground-water use within the immediate floodplain (one-quarter to one-half mile from the river) from municipal supply wells. However, given the environmental chemistry of PCBs it is not likely that PCBs have migrated from river sediment into adjacent aquifers. The RI will identify residential well use in the area.

Recreationists pursuing activities on or adjacent to the river have the potential to become exposed to PCBs in the water column and underlying sediments. Dermal contact and incidental ingestion exposures may occur to swimmers, waders, boaters, anglers, hunters, or trappers as they access the river and adjacent areas and pursue these activities. If activities are conducted in proximity to the former Trowbridge, Otsego, or Plainwell impoundments, a limited potential exists for inhalation of dusts generated from exposed sediment deposits. Anglers and hunters who consume fish and game may also be exposed to PCBs in these food items.

Recreational use of the river is concentrated in the lower reaches (Lake Allegan to Lake Michigan). These areas show the lowest concentrations of PCBs in river media. This fact, along with the seasonal character of most recreational activities (i.e., most exposures will be

low/absent during the late fall, winter, and early spring) and their infrequent nature and relatively short durations, combine to decrease the significance of most recreation-based dermal contact and incidental ingestion exposures.

Agricultural-based exposure to river media may occur through the maintenance and use of irrigation systems which draw water from the river. Dermal contact and incidental ingestion exposure to sediments and river water may occur during routine maintenance of intake equipment. Dermal contact with river water may also occur during maintenance of irrigation distribution systems and during actual irrigation activities. Each of these issues will be addressed in the Risk Assessment. However, incidental ingestion and dermal exposures to river media from agricultural-based activities will be infrequent in nature and of short duration, due to seasonal limitations including a limited growing season, low irrigation requirements, and low PCB levels in water.

Industrial and municipal employees (i.e., maintenance personnel who maintain intake/outfall structures within the river) may experience dermal contact or incidental ingestion of river water and sediment during these activities. Additionally, production employees may have occasional dermal contact with production/process waters withdrawn from the river.

Residents, owners, and employees of riverbank properties may experience dermal contact and incidental ingestion exposure to river water, sediments, and floodplain soils during routine property maintenance. Additional concerns include the possible inhalation of dusts generated while working with floodplain soils.

4.6 Former King Mill Property

4.6.1 Characteristics

The former King Mill, in the Edison neighborhood of the city of Kalamazoo, is bordered to the north by East Vine Street, to the west by Clarence Street, and to the south by Lake Street (Figure 17). The mill was operated by Allied until 1971 after which it was sold to Arthur P. Dore and Shirley Dore of the Dore Wrecking Company, presently Dore Enterprises, located in Bay City, Michigan. According to current property records, they are the owners of the majority of the property, which consists of 14 parcels. Parcels of land are also owned by Michigan Barricading-West, Inc., Consumers Power Company, and the Kalamazoo Fraternal Order of Police.

Fire damaged the King Mill in June 1975 and again in March 1976. Demolition of the remaining structure was completed by the Dore Wrecking Company in December 1978 (Hager, 1979). Since that time, the lot has developed an extensive cover of grass and shrub-type vegetation. To the east of the former mill property are two former lagoons. A clarifier was once located to the northeast of the mill. These areas have all been covered with vegetation. The property lies to the east of a residential neighborhood and is in a light industrial area. Petrolane Gas Service is located to the north of the area, and Kalamazoo City Yards lies to the west.

The soils underlying the area are urban in nature (SCS, 1979). The urbanized nature of the area makes it difficult to specify the soil type.

Two former lagoons exist to the east of the former mill, and three soil samples were collected in this area in 1987 by the MDNR and analyzed for PCBs. PCB concentrations ranged from non-detectable (at a detection limit of 0.65 mg/kg) to 9.1 mg/kg.

4.6.2 Potential Exposure to PCB-Contaminated Media

The area where the King Mill formerly stood is accessible to the public. Although the area surrounding most of the mill is industrial, the Edison residential neighborhood lies to the west of the property. Preliminary investigations conducted by MDNR have identified the presence of low levels of PCBs in surface soils which appear to be in the area of the mill's former lagoons.

Possible on-site receptor populations include trespassers who may access the property as recreationists or pedestrians. Local residents may utilize the open area of the former mill for a variety of purposes. Use of this property will result in varying degrees of exposure to surface soils. Dermal contact and incidental ingestion exposures are possible. Inhalation exposures are likely to be mitigated by the extensive on-site vegetative cover. However, if on-site activities created sufficient disturbances to surface soil, inhalation exposure to dusts could occur.

Off-site receptor populations include nearby residents and employees of adjacent facilities. Possible exposures will be limited to inhalation of fugitive dusts originating from the area. As noted before, it is unlikely that dust inhalation will be a significant pathway due to the vegetated condition of the property and the limited areas of the former lagoons.

covers currently present on these lagoons. Trespassers on the property may also experience dermal or incidental ingestion exposures to lagoon contents.

Off-site exposures to PCB-containing material originating from the mill area are unlikely. At this time, off-site migration of mill area media has not been observed.

4.8 King Highway Landfill

4.8.1 Characteristics

The King Highway Landfill (Figure 19) is bordered to the south by M-96 (King Highway), to the east and north by the Kalamazoo River, and to the west by the Grand Trunk Railroad right-of-way and the King Street storm sewer. The landfill lies within the city of Kalamazoo and Kalamazoo Township.

The 23.3-acre landfill is located east of Riverview Park, formerly named Sutherland Park, and Red Arrow Golf Course, which are built on top of a former Kalamazoo city dump. The dump closed in the early 1950s and contains all types of domestic and commercial waste (Wilkins & Wheaton, February 1982c). South of the landfill is a maintenance yard for the city of Kalamazoo which formerly contained an asphalt plant, and now has a salt storage facility, and equipment for road work and snow removal. Superior Metal Shredder, Inc./Superior Salvage Co./Superior Industrial Waste Disposal Service lies to the west (Wilkins & Wheaton, February 1982b).

The landfill was originally a series of lagoons used by the Kalamazoo Paper Company from the late 1950s until 1967, and by the Georgia-Pacific Corporation from 1967 to 1977 for dewatering underflow residual solids from the mill's primary clarifier. Residuals from the lagoons were disposed at the Willow Boulevard Site until 1975, and then at the A-Site until 1977. The installation of belt-filter presses in 1977 made the use of lagoons for dewatering obsolete. Consequently, residuals were sent directly to the A-Site until it closed in 1987.

The King Highway Landfill, a licensed Type III facility since 1983, has been used since 1987 by Georgia-Pacific for disposal of its dewatered paper-waste residuals. The landfill's license was last renewed in January 1991.

The Environmental Impact Assessment (Wilkins & Wheaton, 1982b) for the landfill, prepared in 1982, reported that the depth of the existing residuals ranged from 5.5 to 23.3 feet in Area 1, from 9 to 23 feet in Area 2, and from 9.5 to 16.3 feet in Area 3. Area 4 contained primarily water with some residuals. Since 1987, dewatered residuals from the Kalamazoo plant have been placed in Area 1 and Area 2. The residuals were found to have a very low permeability, thus the existing material would act as a seal preventing leachate migration (Wilkins & Wheaton, February 1982b). A maximum thickness of paper residuals of approximately eleven feet has been placed in Area 1. The placement of residuals at the landfill has been conducted under the existing Type III landfill permit. Underlying the residuals, the soil is composed of mostly glacial sand and gravel deposits

with traces of clay and silt (Wilkins & Wheaton, 1981). These glacial deposits have been extensively reworked by the Kalamazoo River.

An aerial photograph from 1938 identified the remnants of a river oxbow beneath the present location of Areas 3 and 4. Later photographs indicate that this oxbow was filled in naturally prior to the development of the lagoons.

Bedrock, consisting of Coldwater Shale deposited in the Mississippian period of the Paleozoic Era, lies approximately 50 to 75 feet below the land surface, based on soil borings drilled between 1945 and 1947, prior to development of the landfill.

Three cross-sections (Figure 20) were developed based on the boring logs' descriptions of subsurface materials encountered in the five borings drilled at the King Highway Landfill between 1945 and 1947 and the seven ground-water monitoring wells installed between 1981 and 1989. The unconsolidated materials underlying the landfill area consist primarily of sand with varying amounts of gravel and clay. There is a layer of clay or clay and sand approximately 15 feet below ground surface which was observed during the drilling of ground-water monitoring wells.

Under the landfill, the direction of ground-water flow is to the north-to-northwest towards the Kalamazoo River. Ground-water gradients are slight and range between 0.0014 and 0.0006 ft/ft (Wilkins & Wheaton, February 1982b and Hester, November 3, 1989). The ground-water gradients and flow directions are likely influenced by the Kalamazoo River. The depth to the static potentiometric surface ranges from about 11.7 feet to 25 feet

to 29 feet in depth. As expected by the history of residual disposal and usage of PCBs in carbonless paper, the concentrations of PCBs found near the surface of Areas 1 and 2 are much lower than levels found in the deeper residuals. PCB levels near the surface in Area 3 appear comparable to those at the surface of Areas 1 and 2.

Quarterly ground-water monitoring has been conducted at the landfill since March 1987. The original ground-water monitoring network included MW-1, MW-2, MW-3, MW-4, MW-5, and the piezometer cluster MW-6A, MW-6B, and MW-6C (this cluster was decommissioned in 1987). Quarterly analyses consisted of general inorganic parameters and limited metals analyses. Analysis of MDNR Scans 1 and 2 has been conducted on an annual basis since June 1988. In 1989 an additional upgradient well, MW-7, was installed and was included in the annual sampling of June 1989. The analyses of ground-water samples indicated the presence of vinyl chloride at MW-1 (an upgradient well), MW-4, MW-5, and MW-7. Cis-1,2-dichloroethene was also detected at the upgradient well MW-1, MW-5, and MW-7. Based on an evaluation of the ground-water flow direction, the apparent source of these compounds is upgradient of the landfill (Hester, November 3, 1989). These data are described in more detail in Section 5.

4.8.2 Potential Exposure to PCB-Contaminated Media

The majority of the land surrounding the landfill is used for industrial or secondary commercial purposes, and the remainder is non-forested shrub or central hardwood deciduous forested land (Blasland & Bouck, October 1991). The nearest residential neighborhoods are located approximately

1,100 feet to the west in the city of Kalamazoo (Edison) and 1,200 feet to the southeast in Kalamazoo Township (Lakewood). Across the Kalamazoo River to the north lies the Georgia-Pacific Corporation Kalamazoo Mill.

Preliminary investigations have identified PCBs in residuals at the landfill. It is not presently known if ponded water in Area 4 contains PCBs. PCBs have also been measured in soil samples collected at the foot of the dikes near the river.

The area is relatively isolated from human traffic. There is fencing and lockable gates at the three entrances (Wilkins & Wheaton, February 1982a). Direct contact exposure to landfill residuals could occur to trespassers, employees, and environmental receptors (flora and fauna) since King Highway is an active landfill.

There is a relatively small potential for inhalation exposure of trespassers, employees, and off-site receptors to PCB-containing fugitive dust. The potential for leaching of PCBs from paper residuals is generally low due to the hydrophobic nature of PCBs, and the adsorptive characteristics and low permeability of paper residuals. At the King Highway Landfill, PCBs have not been detected in ground water; therefore, the probability of exposure to PCBs in ground water is minimal.

4.9 Willow Boulevard Site

4.9.1 Characteristics

The Willow Boulevard Site, approximately 11 acres in size, is located southeast of the intersection of Business I-94 and Highway M-96 (King

Highway) in Kalamazoo Township. The Willow Boulevard site is bordered by the Kalamazoo River to the north and northwest, the A-Site to the east, and Willow Boulevard to the south and southwest (Figure 21). Across the Kalamazoo River to the north lies a deciduous forested area and further north is the Georgia-Pacific Corporation Kalamazoo Mill.

The Willow Boulevard Site was acquired by Georgia-Pacific from the Kalamazoo Paper Company and used for the disposal of process residuals from the plant's paper recycling process. The Willow Boulevard Site received dewatering lagoon residuals from the King Highway lagoons, from the mid 1960s until disposal operations ceased in 1975 with the opening of the A-Site. Since 1975, the Willow Boulevard Site has received only an occasional load of paper residuals or cinders (Wilkins & Wheaton, 1981).

The Willow Boulevard Site is located within the area where the Kalamazoo River Valley cut into a bedrock of Coldwater Shale (Dell Engineering, April 1988). This valley was subsequently filled with 100 to 125 feet of glacial outwash consisting of sand and gravel. These glacial outwash deposits have been reworked by the Kalamazoo River along its present course. More recent fluvial deposits have been subsequently deposited and reworked in the river valley. Overlying these deposits are paper process residuals ranging in thickness between 10 and 26.5 feet, with a total volume estimated at roughly 256,000 cubic yards (Dell Engineering, February 1988). A 1938 aerial photograph shows that the present location of the Willow Boulevard Site used to be an open water embayment with islands, which silted in and became vegetated prior to the area being used

for residuals disposal. The mass of PCBs contained in the fill is approximately 45,000 pounds (Creal, 1989).

Three cross-sections were developed for the Willow Boulevard Site; section A-A' is oriented northwest to southwest and sections B-B' and C-C' are oriented south to north (Figure 22). The cross-sections are based on the subsurface logs of the three monitoring wells and 24 borings drilled during previous investigations. The elevations are referenced to mean sea-level (MSL) based on a topographic survey conducted in 1987. Residuals encountered in the soil borings and well boreholes were described as silty clay. Another descriptive term in the subsurface logs was the term fill; the assumption was made that the term fill also referred to residuals. Noted on the logs were occasional lenses of sand and gravel within the fill. At two borings located in the central portion of the area (13A and 17A) a 3-foot layer of slag, sand, and gravel is noted on the logs. The thickness of the residuals is greatest in the central portion of the Willow Boulevard Site and generally thins radially outward from the center. The greatest thickness of residuals at the soil borings was 26.5 feet and it was encountered at boring location 8A.

A layer of peat or topsoil was encountered at most of the borings between the residuals and the underlying glacial outwash deposits composed of sand or sand and gravel. Ground water was encountered once the residuals were penetrated and the topsoil/peat layer or sand was reached at most of the boreholes. At monitoring well locations MW-2 and MW-3 the ground-water elevation rose in the well after well completion.

The subsurface log for MW-1 does not have enough information to determine whether this occurred there or not. The rise in ground-water elevation indicates that the ground water at the Willow Boulevard Site appears to be under confined conditions, with the residuals acting as a confining or restrictive layer.

Ground water has been encountered in borings at depths of approximately 14.5 feet below grade (Dell Engineering, February 1988). Ground-water flow in the aquifer was determined, using three monitoring wells, to be in a northerly direction toward the Kalamazoo River. The aquifer is estimated to be 80 to 125 feet thick, having a hydraulic conductivity of 94 ft/day and a porosity of 25 percent. A hydraulic gradient of 0.007 ft/ft was calculated from potentiometric surface elevation data. The ground-water velocity was estimated at 950 ft/yr using the calculated gradient and an assumed effective porosity of 25 percent (Dell Engineering, April 1988).

Dell Engineering performed geotechnical parameter testing on fill material and surrounding soils obtained from boring B-1 in 1988. Table 61 presents the results of this investigation. The fill material was found to have a high moisture content (approximately 58 percent) and a hydraulic conductivity of 2.41×10^{-6} cm/sec (Dell Engineering, February 1988). The fill can be classified as an organic soil with a high liquid limit. These findings imply that the fill possesses high compressibility and is impervious when compacted (Holtz, 1981).

An average PCB concentration of approximately 9 mg/kg was found in the worms from the Willow Boulevard Site. Blood serum from local residents who were thought to be digging for worms from the Willow Boulevard Site was taken for PCB analysis. The worm diggers had low blood serum concentrations of PCBs, with an average of 5.1 ug/L.

Soil samples from the neighboring Lakewood residential section were sampled to address possible migration of PCBs from the Willow Boulevard Site as a result of local flooding. All but one sample had non-detectable PCB concentrations. One sample had a PCB concentration of 0.08 mg/kg, a level which is not indicative of contamination.

Polychlorinated dibenzodioxins and polychlorinated dibenzofurans have been detected in residuals samples from the Willow Boulevard Site. Section 5 describes these surveys in more detail.

4.9.2 Potential Exposure to PCB-Contaminated Media

The Willow Boulevard Site is located north of the Lakewood residential section of Kalamazoo Township. To the east lies the A-Site, and to the north, the Kalamazoo River. A non-forested shrub area lies to the west.

Access to the Willow Boulevard Site is restricted by a 6-foot high fence with barbed wire which runs along the south side of the property. The remainder of the property is bordered by the Kalamazoo River. The fencing along the Willow Boulevard side of the property restricts public access from the roadway, but the area is potentially accessible by climbing

the fence or by entering from the river. The perimeter of the property is posted against trespassing.

Under current conditions, the individuals most likely to be exposed on-site are trespassers and Georgia-Pacific employees who occasionally visit the property. The reasons for trespassing on this property could include worm digging, accessing the riverbank for fishing, and other recreational activities. Willow Boulevard is regularly patrolled by security staff from the Georgia-Pacific Corporation Kalamazoo Mill. Regular visits to the area by Georgia-Pacific employees are probably limited to managers and engineers who are interested in inspecting the property. Trespassers and employees may experience direct contact and incidental ingestion exposures to on-site soils during such activities as digging for worms, sitting in the grass, or inspecting the soil, depending on the purpose of the visit.

Trespassing worm diggers probably represented the largest group of on-site receptors at one time.

Individuals most likely to be exposed off-site are nearby residents and people involved in recreational activities (e.g., canoeing, fishing, swimming) on the river. These individuals may be exposed through inhalation of fugitive dust and dermal contact with river water containing PCBs which have migrated from the landfill through soil erosion, surface runoff, or ground-water discharge to the river.

Due to the hydrophobic nature of PCBs and the adsorptive characteristics and low permeability of paper residuals, the potential for leaching of PCBs from residuals is generally low. The well vegetated

condition of on-site soils and gentle slope of the fill area should also reduce overland transport. Recently completed erosion and dust controls further reduce potential exposure to PCBs off-site.

Incidental inhalation of PCBs by trespassers, employees, and off-site residents from fugitive dust is anticipated to be limited due to the vegetative cover currently at the area.

Additional investigations in the area have documented that concentrations of polychlorinated dibenzo-p-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs) in soils are approximately one tenth the 0.001 mg/kg level which is considered by regulatory agencies, such as EPA and the U.S. Center for Disease Control (CDC), to be acceptable for exposure of children and others to tetrachlorodibenzo-p-dioxin (TCDD) in soils in residential areas (Paustenbach, et al., 1986).

4.10 A-Site

4.10.1 Characteristics

The A-Site is bordered by the Kalamazoo River to the north, Davis Creek to the east, and the former Olmstead Creek to the south (Figure 23). The 22.7-acre A-Site is located directly east of the Willow Boulevard Site. The A-Site was originally a paper residual dewatering lagoon for the Allied Paper Company's King Mill (Wilkins & Wheaton, 1981). An earthen dike surrounds most of the A-site. A square manhole is located near the northern end of Riverside Avenue for the former piping system from the

King Mill to the A-Site. It is not known whether this piping system still remains.

Georgia-Pacific purchased the A-Site from Arthur and Shirley Dore in 1975 to replace the Willow Boulevard Site. From 1975 to 1977, the area received excavated residuals from the King Highway dewatering lagoons. Filter presses were installed at Georgia-Pacific in 1977 and the A-Site received material directly from the filter presses until it closed in April of 1987 (SEI, May 1990).

The depth of residuals averages 27 feet in the eastern half of the A-Site and 15 feet in the western half. Ground water is approximately 16 to 18 feet below the surface and flows in a northwesterly direction toward the Kalamazoo River (Dell Engineering, July 1989).

Three cross-sections, oriented west to east across the A-Site, were developed based on subsurface logs from borings SB-1 through SB-10; these cross-sections are presented on Figure 24. The subsurface logs are shown relative to one another horizontally and are referenced vertically in depth below grade. These borings were not surveyed at the time of drilling; the cross-sections will be revised to indicate elevations referenced to MSL once topographic control is established.

As the A-A' cross-section indicates, the thickness of the residuals is greater on the east side of the A-Site than on the west side in the north portion of the area. Along the northern portion of the area, the thickness of the residuals ranges between approximately 12.5 feet at SB-10 and 28 feet at SB-1. Several layers of residuals were identified during the drilling

and are described on the subsurface logs as varying in color. Also noted was the occurrence of a layer of residuals which was described as "wet," whereas most of the residuals were described as "moist". Once topographic control is better established, the significance of the wet layer can be better evaluated, i.e., whether the layer described as wet is at the same elevation across the area and whether it represents a particular horizon.

Cross-section lines B-B' and C-C' (Figure 24) show the same occurrence of a wet layer within the residuals. The thickness of the residuals in the central (B-B' line) and southern (C-C' line) portions of the A-Site appear to be more uniform than the thickness of the residuals observed along the north portion of the A-Site (A-A' line). In the central and southern portions of the A-Site, the residuals were observed to be consistently between 26 feet and 28.5 feet in thickness.

It is important to note that ground water was encountered during drilling at the contact between the residuals and native soil. The wet layer within the residuals described above was generally underlain by residuals which were described as moist. It appears that the residuals are acting as a confining or restrictive unit with respect to ground-water flow. The ground-water monitoring wells at the A-Site were generally installed through the dikes around the filled area (with the exception of MW-1). Based on the depth where ground water was first encountered at the well locations and the depth to ground water measured after well installation, it appears that the aquifer conditions near the site vary from confined (based on data

from wells MW-1, MW-2, and MW-3) to unconfined (based on data from wells MW-4 and MW-5) across the site.

The A-Site will also include, for the purpose of the RI, a 3.5-acre shrub vegetated area located to the east of Davis Creek. An earthen berm is located along the perimeter of this area (SEI, May 1990). Preliminary indications suggest that decant water from the dewatering lagoon at the A-Site was discharged to this area. Georgia-Pacific's records show no evidence that the area east of Davis Creek received residuals from the Georgia-Pacific Corporation Kalamazoo Mill (SEI, May 1990). However, a thin layer of residuals was observed in this area. The thickness of the residuals is generally less than six inches (SEI, May 1990).

Davis Creek, formerly known as Olmstead Creek, originally ran along the southern edge of the area occupied by the A-Site and its outlet was in the area now occupied by the Willow Boulevard Site. In the early 1930s, the creek was diverted so that it ran a straight course from Carleston Avenue north to the Kalamazoo River.

In response to frequent flooding of the Lakewood neighborhood, the Kalamazoo County Drain Commission installed flood-diversion piping in 1972 under the Kalamazoo County Fairgrounds, Lakewood Elementary School, and Lake Street. The piping consists of two 95-inch by 67-inch corrugated metal arch pipes and is only used during periods of high flow.

The piping ends just north of the eastern end of Carleton Avenue, where flow rejoins Davis Creek. From this point, the creek flows north to

the Kalamazoo River. During periods of normal flow, the entire flow passes through Davis Creek (Hanney, 1991).

Surficial soil sampling (0 to 2 feet) at the A-Site and area east of Davis Creek by Georgia-Pacific Corporation under the direction of MDNR has shown PCB concentrations up to 5 mg/kg. A duplicate analysis of one sample from east of Davis Creek had a PCB concentration of 80 mg/kg (MDNR, December 1990).

The cross-sections shown on Figure 24 indicate the results of PCB analyses on the residuals encountered in soil borings SB-1 through SB-10. Generally, one sample was collected from each boring and analyzed in the 0 to 6-foot interval, with most samples being collected and analyzed from the 0 to 4-foot interval. A second sample of residuals was collected from each boring and analyzed for PCBs from the interval 2 to 2.5 feet above the bottom of the residuals. The top interval sample at all the boring locations had non-detectable PCB concentrations (at a detection limit of 1 mg/kg). The second sample from the borings along the north portion of the A-Site (SB-1, SB-5, SB-8, SB-9, and SB-10), all had PCB concentrations of between 1 mg/kg and 5 mg/kg. The PCB concentrations in samples from the remaining borings ranged in concentration from non-detectable (at a detection limit of 1 mg/kg) to 15 mg/kg.

PCBs have been detected in the ground water in MW-1 in the northeast corner of the A-Site at concentrations ranging from 0.59 to 22 ug/L. However, it is suspected that the well was contaminated during installation. MW-4, a replacement well located near MW-1, had a PCB

concentration of 0.2 ug/L. Surface water at the site (i.e., ponded water near MW-1, water in Davis Creek, and water in the former Olmstead Creek) have shown PCB levels of less than 1 ug/L.

These data are described in more detail in Section 5.

4.10.2 Potential Exposure to PCB-Contaminated Media

The A-Site is located in a residential area of Kalamazoo Township. The Lakewood neighborhood is located to the south of the A-Site. Across the Kalamazoo River to the north lies the Georgia-Pacific Corporation Kalamazoo Mill. Access to the area is restricted by fencing around a portion of the perimeter and a lockable gate at the entrance off of Willow Boulevard.

Preliminary investigations have identified PCBs in surface soils, ground water, and surface water.

On-site receptors include trespassers and employees. Possible routes of exposure to on-site receptors include direct contact with or incidental ingestion of PCB-containing soils. Environmental receptors may also be subject to these routes of exposure.

Nearby residents constitute the major off-site receptor population. Another off-site population might include anglers or other individuals pursuing recreational activities near the confluence of Davis Creek and the Kalamazoo River. Receptor exposure to soils, creek water, and sediments may occur through direct dermal contact or through incidental ingestion pathways. The unvegetated condition of the western end of the site also

allows for the possible generation of dusts from on-site soils. Inhalation exposure to on-site soils could occur to nearby residents.

4.11 King Street Storm Sewer

4.11.1 Characteristics

The King Street storm sewer (Figure 19) is defined as area proximal to the outfall of the storm sewer located between the northwest section of the King Highway Landfill and Riverview Park which includes:

- The floodplain soils adjacent to the inlet of the Kalamazoo River which receives the discharge from the storm sewer; and,
- The sediments of the inlet.

The land and outfall structures are apparently owned by the city of Kalamazoo. This area is located within a deciduous forested area.

Two separate outfalls have evidently discharged to the area: 10-foot by 5-foot concrete box culvert with brick headwall and a 48-inch concrete circular culvert. Two abandoned manholes are located to the east of the 48-inch culvert. The larger of the outfalls, which is located to the east of the smaller outfall, appears to be the actual King Street storm sewer outfall. The smaller outfall appears to have been the wastewater outfall from the former King Mill.

Some of the sediment in the inlet as well as the soil adjacent to the inlet have the gray-like appearance and clayey consistency of paper residuals.

PCBs have been detected in the floodplain soils near the storm sewer in concentrations ranging from non-detectable to 99 mg/kg. Past surveys are described in more detail in Section 5.

4.11.2 Potential Exposure to PCB-Contaminated Media

Media which apparently contain PCBs include river water, sediments, and local floodplain soils.

There is a potential for exposure to PCB-containing soil/ sediments near the King Street storm sewer. The area is only easily accessible from the river.

People and/or animals may visit this area and may possibly be exposed to surface soils which potentially contain PCBs. Residents of the area, workers, and anglers would be the most likely human receptor populations. They are most likely to come into dermal contact with surface soils. Animals may also be exposed to subsurface soils if they dig into the ground in the area. Average exposure events are likely to be of infrequent and short duration (i.e., less than four hours per event) due to the isolated nature of the area.

4.12 Simpson Plainwell Paper Company

4.12.1 Characteristics

The Simpson Plainwell Paper Company Mill (Simpson Mill) is located at 200 Allegan Street in Plainwell, Michigan (Figure 25). It is bordered by Scott Street to the northwest and by the Kalamazoo River to the north and east.

The mill has been making paper since the late 1800s. In late 1987, the Plainwell Paper Company was purchased by Simpson Paper Co., Inc., and became the Simpson Plainwell Paper Company.

The Simpson Mill property covers approximately 34 acres. Approximately 77 percent of the drainage area, including paved area and buildings, is drained through storm-drain system outfalls into the Kalamazoo River. The remaining unpaved areas do not contribute to point source discharges.

The lagoons previously used for dewatering residuals were consolidated into four lagoons in 1983. These four lagoons are presently covered with soil and are well vegetated. The other ten lagoons were filled with dirt after being cleaned out. The location of these ten lagoons is now occupied by the mill's present wastewater treatment facility, which consists of a primary and a secondary clarifier and an activated sludge treatment system. The former aeration basin was taken out of service in 1983 and the southern half was backfilled with construction and demolition waste.

4.12.2 Potential Exposure to PCB-Contaminated Media

The Simpson Plainwell Mill is surrounded by a residential area. Pedestrian access to the property is restricted by a chain-link fence around the southern and western perimeter and the Kalamazoo River to the north and east.

Current activities at the property are restricted to product manufacturing. Historical activities included the operation of deinking processes and waste treatment facilities. Deinking processes were discontinued in 1962. The inclined washers and piping associated with the deinking operation have been removed. The hydropulper, bleach tower (now a stock chest), and stock chests are still in service. The drainage system

serving the former deinking area has been reconfigured for the new wastewater treatment process. Drains that were not taken out of service or removed (i.e., external drains) now discharge through an open drain to the mill's wet well.

The remaining four lagoons remain intact and appear to contain residuals. These lagoons have been covered with soil, and now support well established growths of vegetation. The former secondary clarifier is also still present on the property.

Potential on-site receptor populations would be limited to production and maintenance employees at the plant. Maintenance employees may be exposed to site media through dermal contact and incidental ingestion of mill-area soils or contents of the lagoon and clarifier. At this time, off-site migration of mill-area media has not been observed.

4.13 Simpson Plainwell-12th Street Landfill

4.13.1 Characteristics

The 12th Street Landfill is approximately 1/2 mile northeast of the intersection of Highway M-89 and 12th Street in Otsego Township, and 1-1/2 miles northwest of the city of Plainwell (Figure 26). The 6.5-acre property is bordered to the east by the Kalamazoo River, the north and northwest by wetlands, and the southwest and south by moderately vegetated woodlands. It is located adjacent to and downstream of the Plainwell Dam. Also, a gravel pit operation exists to the west.

The landfill overlies the Glendora-Adrian-Granby soil association. This soil is characterized by nearly level, poorly to very-poorly drained soils formed in sandy and organic material. These soils are moderately to rapidly permeable with a slope of less than or equal to two percent.

The landfill area was utilized by former owners of the mill as a depository for paper-mill residuals consisting mostly of water, wood fiber, and mineral matter, some of which may have contained PCBs. Residuals deposition in the area began in 1955 after a newly constructed primary wastewater treatment facility was brought on line. Residuals continued to be deposited at the landfill as late as 1981.

In 1984 the area was covered with soil and seeded. All but the southern side of the area is surrounded by a retaining berm which rises up to 30 feet above the river surface. The area within the berm is well-vegetated and gently sloped. Surface drainage appears to be northward toward the adjacent wetlands. Regional ground-water flow is generally northward. Near the landfill the flow is expected to proceed in a north-to-northeasterly and northwesterly direction.

It appears that at least a portion of the residuals at the 12th Street Landfill contain PCBs. To determine the extent of PCBs, MDNR and Simpson Plainwell collected soil and buried residuals samples during three independent investigations. In all, 24 samples have been analyzed for PCBs, with results indicating a range of concentrations from non-detectable (at a detection limit of 0.1 mg/kg) to 39 mg/kg for 23 of the 24 samples

and one sample at 120 mg/kg. No ground-water or river-water samples have been collected.

In response to an allegation that drums may have been disposed at the landfill by A-1 Disposal, Simpson Plainwell conducted geophysical surveys to evaluate whether metallic objects are present. These surveys consisted of the use of electromagnetic and magnetic geophysical methods and were completed in August 1991. The results of the surveys indicated the presence of possible metallic objects primarily in the southern and eastern portions of the area (Geraghty & Miller, 1991).

These results are described in more detail in Section 5.

4.13.2 Potential Exposure to PCB-Contaminated Media

The 12th Street Landfill is located in a rural section of Allegan County midway between the municipalities of Otsego and Plainwell. The facility straddles the transition zone between the swampy bottomlands of the river floodplain and the low uplands of the river valley. Also, a gravel pit operation exists adjacent to the west side of the property.

Access is limited. Vehicle access is restricted by fencing and a gate which run along the road frontage of the property's southern border. The river, adjacent wetlands, and steep berms make the remaining borders inaccessible to all vehicles, including all-terrain vehicles (ATVs). Pedestrian access is available from the riverbank and possibly from the wetland areas.

Preliminary investigations have identified PCBs in surface residuals at the landfill. It is not presently known if ground water at the property

contains PCBs, or if surface water in the adjacent wetlands has been affected by runoff.

Most of the landfill media are beneath a soil/vegetative cover. Due to the hydrophobic nature of PCBs and the adsorptive characteristics and low permeability of paper residuals, the potential for leaching of PCBs from paper residuals appears to be generally low. However, due to the proximity of the landfill to the river there is a concern regarding the potential for migration of PCBs to ground water, to the adjacent wetlands, and to the river.

At this time, no on-site receptor populations have been identified for the landfill. The facility is currently closed and there is no evidence of trespasser activity. The location of the landfill in a rural area significantly diminishes its attractiveness to trespassing populations who might be looking for open areas for recreational purposes. There are numerous alternate areas available for recreational activities throughout the immediate area. The restricted access (a fence exists around the most easily accessible portion of the perimeter) and relative isolation of the landfill (greater than 1/2 mile from the nearest residence) should be sufficient to keep young children from entering the property. Animal burrows have been identified on the north side of the landfill.

Potential off-site receptor populations include those residents closest to the landfill who obtain their potable water from residential wells. Resident exposure to any ground-water constituents from the 12th Street Landfill is not anticipated since the closest residences to the landfill are

located one-half mile upgradient and ground water originating at the landfill is expected to discharge to the river or to the adjacent wetland area. Additional receptor populations include individuals pursuing recreational activities (e.g., angling, boating, hunting, trapping) along adjacent stretches of the river and the Otsego City Dam Impoundment, or in the adjoining wetland area to the north. Recreationists may be exposed to ground water discharged from beneath the area as they pursue activities in the river or the wetlands.

4.14 Morrow Lake and Ceresco Dam Impoundment

4.14.1 Characteristics

Morrow Lake and Ceresco Dam Impoundment are located upstream of the NPL Site on the Kalamazoo River. Morrow Lake, which is apparently not influenced by current and former operations of the KRSG, would potentially serve as a source of baseline data upstream of the NPL Site. Ceresco Dam Impoundment, located approximately 55 miles upstream of Morrow Lake, could potentially serve as a source of background data during the evaluation of remedial alternatives.

Morrow Lake is located approximately 4.25 miles upstream of the confluence of the Kalamazoo River and Portage Creek (Figure 2). The pond is formed by the impoundment of the Kalamazoo River by Morrow Lake Dam. The dam precludes upstream migration of fish.

The soils surrounding Morrow Lake are described as nearly level and undulating, well-drained or very poorly-drained soils with a sandy or a loamy and sandy subsoil formed in sandy alluvium or glacial outwash.

Fish monitoring in Morrow Lake began in 1971 as part of the MDNR survey of the aquatic environment on the Kalamazoo River (MDNR, 1972). The results of fish monitoring in Morrow Lake are presented in Table 6. Fish were collected using electro-fishing gear and fyke nets. Samples consisted of 20 grams of flesh removed from the side of the fish between the dorsal fin and lateral line. Analyses for chlorinated hydrocarbon insecticides and PCBs were performed by the Water Resources Commission's Pesticide Laboratory in Lansing. Analysis for heavy metals was performed by the Water Resources Commission's Water Quality Laboratory. Total PCB concentrations reported as Aroclor 1254 analyzed for a carp, a white sucker, and a northern pike were 5.1 mg/kg, 5.5 mg/kg, and 18 mg/kg, respectively. Concentrations of total DDT were 0.21 mg/kg, 0.15 mg/kg, and 0.60 mg/kg, respectively.

In 1976, the MDNR collected four fish from Morrow Lake and skinless fillets were used for analysis (NUS, 1986). One carp, one white sucker, and one northern pike were analyzed and contained total PCB concentrations of 2.1, 2.0, and 3.7 mg/kg, respectively. Total PCB concentrations were quantified as Aroclors 1254 and 1260. One bass was also collected with a non-detectable PCB concentration (at a detection limit of 0.20 mg/kg).

In 1981, the MDNR collected specimens from the shallow shoreline areas adjacent to the dam in Morrow Lake (MDNR, October 1982b). Nine carp, one northern pike, and two largemouth and 21 smallmouth bass were collected by trap netting and electro-fishing. Sample preparation included skin-off fillets for carp and pike, and skin-on fillets for bass. Analysis was performed by the MDNR Environmental Laboratory for PCBs and eleven other pesticide and organochlorine substances. The carp, largemouth bass, smallmouth bass, and northern pike had respective mean total PCB concentrations of 1.7, 0.24, 0.35, and non-detectable (at a detection limit of 0.10 mg/kg). The carp contained Aroclors 1242, 1254, and 1260, the smallmouth bass contained Aroclors 1242 and 1254, and the largemouth bass and northern pike contained Aroclor 1254 (MDNR, October 1982b).

The MDNR collected more fish from Morrow Lake in 1985 for PCB analysis (MDNR, 1985). Skin-off fillets for twenty carp, and skin-on fillets for three largemouth and four smallmouth bass had mean total PCB concentrations of 2.6, 1.6, and 1.1 mg/kg, respectively. Both bass and carp contained PCBs reported as Aroclors 1254 and 1260.

Sampling of Morrow Lake was undertaken again during 1986. MDNR collected twenty carp specimens. Skin-off fillets ranged in total PCB concentrations from 0.60 to 12 mg/kg, and had a mean concentration of 3.5 mg/kg identified as Aroclor 1254 (MDNR, 1986b).

The most recent monitoring of resident fish above Morrow Lake Dam was done by the MDNR in 1987 (MDNR, 1987a). In addition to Morrow Lake, fish were collected from the Ceresco Dam Impoundment above Battle

Creek. Skin-off fillets for carp and skin-on fillets for bass were analyzed by the Michigan Department of Public Health (MDPH) for PCBs. Carp from Morrow Lake ranged in total PCB concentrations from 0.26 to 5.8 mg/kg with a mean of 1.4 mg/kg. Ten smallmouth bass collected from Morrow Lake had total PCB concentrations ranging from 0.54 to 1.3 mg/kg, with a mean of 0.82 mg/kg. Total PCBs for nine carp collected from Ceresco Dam Impoundment ranged from 0.04 to 0.24 mg/kg, with a mean concentration of 0.12 mg/kg. One largemouth and one smallmouth bass sampled from Ceresco Dam Impoundment had total PCB concentrations of 0.02 and 0.04 mg/kg, respectively. Bass and carp from both Morrow Lake and Ceresco Dam Impoundment contained only Aroclor 1254. The results of these surveys are shown in Table 6.

Waterfowl were sampled by the United States Fish and Wildlife Service (USFWS) in 1985 from the Kalamazoo River. As part of this study, one adult merganser was collected from Morrow Lake. The bird was plucked, eviscerated, and its feet were removed prior to analysis for PCBs and heavy metals. The sample was found to contain 28 mg/kg PCBs reported as Aroclor 1260.

To further evaluate PCBs contained within and surrounding Morrow Lake, MDNR contracted GZA-Donohue to collect sediment and water-column samples. Sediment cores, surface sediment, and water-column samples were collected in July 1988 at the locations illustrated on Figure 2. The results of the survey are presented in Tables 7 and 8 for sediment and water column results, respectively. The sediment cores showed a decline

in PCB concentration with depth, with concentrations of non-detect (at a detection limit of 0.02 mg/kg) to 4.9 mg/kg at depths between 1 and 2 feet and non-detect (at a detection limit of 0.2 mg/kg) at depths greater than 2 feet. Surface sediment samples collected and analyzed for PCB concentration showed a range from 0.29 to 2.4 mg/kg. PCB concentrations in water-column samples collected at and at 35th Street in Galesburg were non-detectable (at a detection limit of 0.015 ug/L).

Fish and sediment in the vicinity of Ceresco Dam Impoundment were sampled in the late 1970s by Wuycheck (1976) and by the MDNR in 1987. Fish were analyzed for PCBs, and sediments were analyzed for PCBs, organic constituents, and metals. All analyses were non-detectable.

4.14.2 Potential Exposure to PCB-Contaminated Media

Morrow Lake and Ceresco Dam Impoundment are located upstream of the study area. Data from Morrow Lake could be used as a baseline for comparing levels of potential contamination downstream while the Ceresco Dam Impoundment data could be interpreted to represent background conditions. It should be noted that PCBs have been found in fish samples from Morrow Lake and a current MDPH fish consumption advisory recommends that carp taken from Morrow Lake should not be consumed. (For a description of all Kalamazoo River fish consumption advisories see Section 2.6.2).

There is a moderate potential for exposure to soils, sediments, and fish in this area. The area is fairly accessible and has aesthetic value. Water-based recreation includes angling, boating, and possible swimming

activities (Johnson, 1991). Anglers are the most likely receptor population, and possible routes of exposure include dermal contact with surface sediments and consumption of fish from Morrow Lake. On-site exposure events are likely to be of short duration (i.e., less than four hours per event) due to the isolated and undeveloped nature of the area.

SECTION 5 - SUMMARY OF RESPONSE ACTIONS

5.1 Allied Paper, Inc.

The Allied Paper property and its operations is the subject of litigation pending between the State and Allied Paper, Inc. (See Frank J. Kelly et al., versus Allied Paper, Inc., et al., United States District Court, Western District of Michigan, Case #L87-89CAS). Before and during the pendency of that litigation various studies and surveys have been conducted.

5.1.1 Past Surveys

5.1.1.1 HRDLs and Type III Landfill

PCB-related response activities at the Allied HRDLs (Figure 15) were initiated in 1985. Samples of ground-water seeps collected by MDNR from 1985 to 1987 indicated the presence of PCBs (Limno-Tech, January 1990a). From 1985 to 1987, 11 attempts were made by MDNR to sample Seep 1; five were successful. The seep was not flowing during the other six attempts. Results from these sampling events showed PCB concentrations ranging from 1.2 to 4.4 ug/L. Sampling of Seep 1 by Limno-Tech on six occasions showed PCB concentrations ranging from 2.3 to 26 ug/L. Sampling of Seep 2 by MDNR on eight occasions between 1985 and 1987 produced two samples with detectable PCB concentrations. Those samples were collected in October and November 1985, and contained PCB concentrations of 0.015 and 0.051 ug/L, respectively. Sampling of Seep 2 by Limno-Tech on four occasions showed one sample with a

detectable PCB concentration of 0.02 ug/L, and the rest had no detectable PCBs. Table 9 presents the results from these sampling events for both Seep 1 and Seep 2.

Ground-water samples from MW13 and MW14, which monitor floodplain conditions near Seep 1, had PCB concentrations of 0.13 and 0.37 ug/L, respectively. The ground-water elevations are summarized in Table 15.

Soil samples have been collected in the vicinity of the seeps between 1986 and 1989 (Figure 15). Results from these sampling events are presented in Table 10. Soils located in the wetlands area near Seep 1 were sampled three times between 1986 and 1988. Results from these events showed PCB concentrations ranging from non-detectable (at a detection limit of 0.5) to 59 mg/kg (Limno-Tech, January 1990a). Soil samples taken from SB515 near Seep 2 were selectively sampled during Limno-Tech's 1989 investigation at the locations shown on Figure 15. PCB concentrations in samples from this boring were not detected at the detection limit of 0.5 mg/kg.

The Bryant and Monarch HRDLs were investigated by Limno-Tech and Wilkins & Wheaton in order to determine the range of PCB concentrations in deposited paper residuals. Between 1985 and 1986, 12 samples were collected from the Bryant HRDLs at various depths between the surface and a depth of 7 feet. The results of these sampling events showed residuals with PCB concentrations ranging from non-detectable to 20 mg/kg. During the 1989 HRDL investigation,

samples were collected from both the Bryant and Monarch HRDLs. Samples were collected from 5- to 40.5-foot depths and analyzed for total PCBs. Sample locations (SB500-series and SB23) are shown on Figure 15. As shown in Table 11, PCBs detected in these samples ranged in concentration from non-detectable (at a detection limit of 0.005 mg/kg) to 1,200 mg/kg with a mean concentration of 120 mg/kg (Limno-Tech, January 1990a).

In May 1988, Wilkins and Wheaton investigated the Type III Landfill on behalf of Allied. Soil borings A through F were placed within the boundary of the landfill and borings G, H, and J were placed outside the landfill perimeter (Figure 15). PCBs were not detected at a detection limit of 0.5 mg/kg in any of the samples taken from within the landfill boundary. A sample from boring J at a depth interval of 14-15.5 feet had a PCB concentration of 0.012 mg/kg (Table 12).

Twenty-six soil borings (SB1000 Series) from an area east of the landfill around monitoring well MW5 were collected (Limno-Tech, January 1990b). Thirteen samples from 10 borings ranging in depth from 1.0 to 4.5 feet were analyzed for PCBs. The resulting PCB concentrations ranged from 0.060 to 37 mg/kg (Table 12). PCBs were detected at all depths. The PCB mixture was identified as Aroclor 1242 which was consistent with previous analyses.

Ground-water sampling at the Type III Landfill was initiated in 1982 at monitoring wells MW1, MW2, MW3, and MW5. Ground-water

sampling at these locations was generally performed two to four times a year between May 1982 and June 1991 (Table 13.) Ground-water samples have been collected at the Type III Landfill and HRDL perimeter since 1985 as part of the Quarterly Monitoring Program. Monitoring wells MW1 through MW3, MW5, MW-15, MW16B, MW16C, MW17A, MW17B, MW-18, MW19B, MW19C, MW19D, MW20, MW21, and MW112 constitute the Type III Landfill monitoring wells; however, MW15, MW16B, MW16C, MW18, and MW20 are not monitored quarterly as the other listed wells are. Ground-water samples collected and analyzed during the landfill monitoring program showed non-detectable PCB concentrations (at a detection limit of 0.01 ug/L) except at MW5, MW17A, and MW19B, which had total PCB concentrations ranging from non-detectable (detection limit of 0.01 ug/L) to 3.3 ug/L (Tables 13 and 14). However, no dissolved PCBs were detected in MW17A and MW19B. Additional wells monitored on occasion which relate to the Bryant HRDL are MW9 through MW12, and MW22 through MW26. At these wells, all ground-water samples analyzed for PCBs except those from MW12 had non-detectable levels (at a detection limit of 0.01 ug/L) (Tables 13 and 14). Ground-water samples from MW12 ranged in total PCB concentration from non-detectable (at a detection limit of 0.01 ug/L) to 0.35 ug/L. No dissolved PCBs were detected in MW12. Further, MW12 may have been impacted during installation and therefore will be replaced in the RI. Ground-water elevations are summarized in Table 15.

During several sampling events, samples were also analyzed for other chemicals including purgeable halocarbons (MDNR Scan 1), purgeable aromatic hydrocarbons (MDNR Scan 2), chlorinated hydrocarbons, PCBs, and organochlorine pesticides (MDNR Scan 3), and polynuclear aromatic hydrocarbons (MDNR Scan 7). Table 13 presents the results of these analyses.

5.1.1.2 Wastewater/Storm Water

A grab sample from the line to the Kalamazoo wastewater treatment plant interceptor system (assumed to be from the Bryant Clarifier) was sampled and analyzed for PCBs in 1973 by the MWRC, and showed a PCB concentration of 6.9 ug/L (Michigan Bureau of Water Management, 1973).

Effluent from the Monarch Clarifier (outfall 002) was sampled for PCBs on 11 occasions during 1985 and 1986. Ten of the samples had non-detectable PCB concentrations at detection limits of 0.01 ug/L for four of the samples, 0.1 ug/L for five, and 0.020 ug/L for one. The higher detection limits were due to matrix interferences. One sample showed a PCB concentration of 0.069 ug/L (Peterson, 1991; MDNR, August-September 1985).

In September 1985, sediments from the storm sewers that discharge into Portage Creek were sampled for PCBs. PCB concentrations at both the storm sewer at Alcott Street and one at Inkster and Burdick Roads were non-detectable at the 0.5 mg/kg (wet weight) detection limit (Peterson, 1991).

In a waste characterization study done by Wilkins & Wheaton Testing Laboratory in September 1985, samples of the Monarch Clarifier's effluent (outfall 002) were taken and tested for purgeable halocarbons, 1,2-dichlorobenzene and 2-chloronaphthalene. The compounds 1,2-dichlorobenzene and 2-chloronaphthalene were not detected in any of the samples. Chloroform was detected in three samples with an average concentration of 2.4 ug/L. Trans-1,2-dichloroethene was detected at a concentration of 1.3 ug/L in one sample, and 1,1,1-trichloroethane was detected in two samples with an average concentration of 4.7 ug/L (Wilkins & Wheaton, November 1985). The results of these analyses are presented in Table 16.

Several toxicity evaluations were conducted between 1979 and 1987 by MDNR. In March 1982, the Monarch Clarifier effluent (outfall 002) was found to be acutely toxic to Daphnia magna. In October 1982, the effluent was acutely toxic to fathead minnows, and slightly toxic to D. magna. In October 1987, the effluent was slightly toxic to D. magna. Tests run in March 1979 and January 1986 demonstrated that the effluent was not acutely toxic and satisfied the requirements of the Michigan Water Quality Standards (MDNR, March 1979, March 1982, June 1987, October 1988; Erickson, 1982). The results of these tests are presented in Table 17.

Wastewater surveys were conducted by MDNR at the Allied facility in June 1968, January 1987, and October 1987, and at the Performance Paper facility in April 1989 (MDNR, 1968, January 1987,

October 20-21, 1987, April 1989). Samples were tested for PCBs in the last two surveys. In both surveys, PCBs were not detected at a detection limit of 0.05 ug/L. The results of these analyses are shown in Table 18. In the January 1987 survey, outfall 001 (Bryant Clarifier effluent) was analyzed for MDNR Scan 1 (Purgeable Halocarbons) and Scan 2 (Purgeable Aromatic Hydrocarbons) compounds. In October 1987, outfalls 001 and 002 were analyzed for Scan 1 and Scan 3 (Chlorinated Hydrocarbons, PCBs, and Organochlorine Pesticides) compounds. Outfall 002 was also analyzed for Scan 8 (Phenols) compounds. In the April 1989 survey, both outfalls were again analyzed for Scan 1 and Scan 3 compounds. The constituents that were detected in these surveys are presented in Table 19.

EP Toxicity and ASTM Leachate analyses were performed on the residuals from the mill in 1983 and 1986 (Wilkins & Wheaton, 1983, 1986). The results of these tests are presented in Table 20. In the 1983 ASTM Leachate analysis, the leachate was analyzed for PCBs and none were detected at a detection limit of 1 ug/L.

Storm water generated in the Allied mill area from roof drains and parking lots is collected at the mill sumps. When the system is operational, it is then pumped to the Gray Tank and then to the Bryant Clarifier. A sample from the Gray Tank was collected on December 7, 1990, together with water samples from the farthest northeast dewatering lagoon and analyzed for various water quality

parameters. Only the lagoon sample was analyzed for PCBs, and none were detected at the detection limit (0.01 ug/L).

5.1.1.3 Former Bryant Mill Pond

Numerous investigative studies of the Kalamazoo River and its tributaries have been performed since the Michigan Water Resources Commission (MWRC) determined that fish collected from certain sections of the Kalamazoo River contained significant levels of PCBs (Hesse and Wilson, 1972). Numerous studies have been performed since 1971 by various agencies in an attempt to characterize the associated media of these areas. The results of these studies are compiled and presented below.

Sediment Surveys

A significant data base exists for the former Bryant Mill Pond sediment (Figure 14). This data base includes data related to both the impounded and unimpounded pond areas, prior to and after the drawdown of Bryant Mill Pond in 1976. These sediments have been shown to contain PCBs (mainly Aroclor 1242). The PCBs appear to be located predominately in the former pond sediments, which now constitute the area's floodplain. A comprehensive summary of the sediment PCB data collected between 1972 and 1988 for this area is presented in Table 21.

In August 1972, the MWRC collected sediment cores from four locations within the impounded Bryant Mill Pond area. Samples were collected from depths ranging from 0 to 18 inches

and analyzed for PCBs using an Aroclor 1242 standard. PCB concentrations in the 16 samples collected ranged from non-detectable (at a detection limit of 0.5 ug/L) to 370 mg/kg. The average PCB concentration was 58 mg/kg. Three of the four boring locations exhibited significantly higher PCB concentrations in the upper 0 to 3.5 inches of sediment (averaging 190 mg/kg) when compared to samples collected at greater depths (averaging 29 mg/kg).

In 1983, sediment samples were collected during July and November at 9 locations. Surface grab samples were collected at three in-stream and eight stream-bank locations. Core samples were collected to depths of up to 16 inches at one stream-bank location and 24 inches at another. In-stream sediment samples exhibited PCB concentrations ranging from 3.2 to 110 mg/kg with a mean concentration of 39 mg/kg. Surface stream-bank samples ranged in PCB concentration from 8.1 to 580 mg/kg. The average stream-bank surface sample PCB concentration (excluding core samples) was 180 mg/kg. Core-sample (0-24 inches) PCB concentrations ranged from 1.4 to 210 mg/kg and averaged 64 mg/kg approximately 160 feet downstream of the upper pond constriction, while PCB concentrations ranged from 1.2 to 28 mg/kg and averaged 15 mg/kg approximately 600 feet upstream of the dam.

During April 1984, MDNR collected sediment samples from the stream-bank surface and Portage Creek in the Bryant Mill Pond area. Two in-stream samples were collected approximately 3,500 feet downstream of Cork Street and were found to contain PCB concentrations of 0.22 and 57 mg/kg. The stream-bank samples were found to contain PCBs at concentrations ranging from 0.9 to 900 mg/kg. In July of 1985, 23 locations (3S1 through 3S5, 4S1 through 4S15, 5S1, 5S2, and 9S1, shown on Figure 14) were sampled for PCBs. These samples had PCB concentrations ranging from non-detectable concentrations to 160 mg/kg. Of the two samples collected and analyzed in September 1985, Sed 4 had a PCB concentration of 7.0 mg/kg and no PCBs were detected in Sed 5, at a detection limit of 1.1 mg/kg.

During October 1985, a total of two in-stream and eight stream-bank surface samples were collected from nine locations within this area. One in-stream sample collected approximately 150 feet upstream of Alcott Street Dam exhibited a PCB concentration of 36 mg/kg, while the other in-stream sample collected approximately 1,400 feet upstream of the dam exhibited a concentration of 85 mg/kg. The stream-bank samples ranged in concentration from non-detectable (at a detection limit of 1.1 mg/kg) to 530 mg/kg and averaged 150 mg/kg.

In 1986, sediment sampling conducted by MDNR included the collection of two in-stream and seven stream-bank surface

samples approximately 150 feet upstream of the Alcott Street Dam (Figure 14). In-stream sediment samples were found to contain PCB concentrations of 24 mg/kg and 150 mg/kg. The stream-bank samples were found to contain PCB concentrations ranging from 11 to 980 mg/kg. The average bank sediment PCB concentration was found to be 330 mg/kg. In addition, core samples were collected from two locations approximately 900 feet upstream of the dam. The east bank was sampled to a depth of 8 inches while the west bank was sampled to only 5 inches. PCB concentrations ranged from non-detectable (at a detection limit of 0.91 mg/kg) to 160 mg/kg. The average concentration was found to be 40 mg/kg. Seven other sediment samples (Sed 10, S1-1R, S1-1L, S1-3L, STR-1, 10MS1 and 10MS2) collected by Limno-Tech in 1986 had PCB concentrations ranging from non-detectable to 700 mg/kg. These samples ranged in depth from 0 to 8 inches.

Further sediment sampling in this area was conducted during July and August 1988. These efforts included the collection and analysis of 249 core samples (ranging in depth from 0 to 11 feet) from 63 locations, numbered 1 through 63. During this event, only the stream-bank and floodplain areas were sampled and subsequently analyzed for PCBs and percent total solids. These results are presented in Table 22. A total of 11 samples were selected for total organic carbon analysis and nine samples were

selected for percent volatile solids analysis. The results of these analyses are presented in Table 23. A total of 11 samples were also selected for total unit weight measurements. These results are presented in Table 24. In addition, three samples were selected for analysis of constituents contained in MDNR Scans 1 and 2.

PCB concentrations in the 249 samples range from non-detectable (at a detection limit of 1.0 mg/kg) to 1,000 mg/kg (Table 22). Core samples were collected at most of the locations to a depth of 5 feet or greater. The overall average depth exhibiting detectable concentrations of PCBs was approximately 3 feet. Forty-six of the 63 locations were sampled to a depth such that non-detectable concentrations were observed. The overall volume weighted estimate of average PCB concentration (excluding non-detects) was approximately 110 mg/kg.

Of those samples analyzed for total organic carbon, percent volatile solids, and total unit weight, the results indicate that total organic carbon concentrations ranged from 3,000 to 24,800 mg/kg and averaged 14,400 mg/kg (Table 23). Percent volatile solids ranged from 6 to 51 percent and averaged 27 percent (Table 23), and total unit weight ranged from 0.892 grams per cubic centimeter (g/cc) to 1.907 g/cc and averaged 1.3 g/cc (Table 24).

The results of MDNR Scans 1 and 2 performed on three samples indicated all constituents to be below detection with the

exception of xylene which was quantified at concentrations ranging from 18 to 230 ug/kg. Total hydrocarbons were found to range from 100 to 230 mg/kg.

Soil samples (RP1 through RP5, shown on Figure 14) were collected from residential properties along the east bank of the former Bryant Mill Pond in October 1991 (Blasland & Bouck Engineers, P.C., 1992). The locations were selected for sampling based upon site reconnaissance and the interpretation of historic air photos which together indicate that sampled areas had formerly been low areas which were adjacent to or part of Bryant Mill Pond but had received fill in their development as residential properties. Observations made during sample collection confirmed the presence of fill upon underlying soils (i.e., former sediment or native soil). Samples were collected at the current surface and just below the interface of the fill and underlying soil. The results of PCB analyses of the surface soils (0.025 to 0.34 mg/kg) are all below levels considered to be significant.

PCBs were reported for two of the five subsurface samples at a concentration greater than 1 mg/kg. The sample collected at a depth of 4.5-5.0 feet below the surface of a vacant lot had a reported PCB concentration of 16 mg/kg. The sample collected on another lot at a depth of 4.0-4.5 feet had a reported concentration of 1.4 mg/kg. Considering the relatively low concentrations and the isolated nature of the associated

subsurface soil layer, the results do not suggest a significant risk to residents. The results of this survey are presented in Table 25.

Water Column Surveys

Like the sediments and soils of the former Bryant Mill Pond area, a significant amount of surface water data has been collected since 1972. This data base consists of both PCB concentrations and other water quality parameters.

Two samples collected at Cork Street in 1972 had non-detectable PCB concentrations at a detection limit of 0.10 ug/L. Samples collected at Alcott Street in 1972 had PCB concentrations ranging from non-detectable (at a detection limit of 0.10 ug/L) to 0.16 ug/L. One water-column sample taken from the upper Bryant Mill Pond had a non-detectable PCB concentration at a detection limit of 0.10 ug/L. These results are presented in Table 26.

A majority of the PCB concentration data was collected between April 1985 and August 1991. The data resulted from regular sampling at Cork Street and Alcott Street. A summary of this data base is presented in Tables 27 and 28. These data show that nearly all samples collected at Cork Street exhibited no detectable PCBs. However, one sample taken in 1987 did exhibit a concentration greater than the detection limit at 0.017 ug/L.

The 1985 to 1987 results associated with the Alcott Street location indicate levels of PCBs ranging from 0.032 to 0.34 ug/L. The average concentration of the 27 samples collected at this location was calculated to be 0.13 ug/L. Samples collected at Alcott Street in 1989 indicate significantly lower concentrations ranging from non-detectable (at a detection limit of 0.01 ug/L) to 0.06 ug/L. Four samples collected at Alcott Street in the Fall of 1990 had non-detectable total PCB concentrations (at a detection limit of 0.01 ug/L) and eight samples collected in 1991 had total PCB concentrations ranging from non-detectable (at a detection limit of 0.01 ug/L) to 0.16 ug/L (Table 28).

From 1985 to 1987, water-column samples were taken from seven other locations in the former Bryant Mill Pond area. These ranged in PCB concentration from non-detectable (at a detection limit of 0.010 ug/L) to 0.33 ug/L. These results are presented in Table 27.

From 1984 to 1985, water samples were collected at six other locations from Cork Street to Alcott Street and analyzed for various water quality parameters, not including PCBs. The results of these analyses are presented in Tables 29 and 30.

Table 31 presents MDNR data associated with various inorganic and metals data collected in October 1989 in relation to the stream diversion design feasibility field studies at the former Bryant Mill Pond. The samples collected were taken from

Portage Creek at Cork Street and at Alcott Street, test pit seep water, test pit water prior to treatment, and two samples after treatment.

Fish Monitoring

Collection of fish from Portage Creek for PCB analysis was performed by the MDNR in 1985, 1986, and 1987, and in 1985 by Limno-Tech, Inc. The results of these studies are summarized in Table 32.

The identification of PCB concentrations in fish of the former Bryant Mill Pond area began in July 1985 with the collection of 10 carp. Analysis of skin-off fillets was performed by the MDNR. Analysis for PCBs revealed total PCB concentrations ranging from 1.7 to 4.8 mg/kg with an average of 3.5 mg/kg (Aroclors 1242, 1248, and 1254). Average PCB concentrations reported as Aroclors 1242 and 1254 were 2.1 mg/kg and 0.89 mg/kg, respectively. PCB concentrations were reported as Aroclor 1248 for three of the samples with an average concentration of 1.6 mg/kg (MDNR, 1985).

In 1985 Limno-Tech, Inc. conducted another fish survey of Portage Creek from Cork Street to Alcott Street. Skin-off fillets from four carp were analyzed for PCBs and showed concentrations ranging from 0.43 to 2.4 mg/kg, reported as Aroclor 1254, and 3.1 to 5.0 mg/kg, reported as Aroclor 1242. Average PCB

concentrations reported as Aroclors 1254 and 1242 were 0.93 and 3.8 mg/kg, respectively.

In 1986, the MDNR collected 21 carp from the former Bryant Mill Pond. Fish collection targeted a specific size range (15 to 23 inches) in an effort to reduce sample variance. Skin-off fillets were analyzed by the Michigan Department of Public Health (MDPH). Analysis for PCBs yielded a concentration range of 0.81 to 27 mg/kg, with an average concentration of 4.0 mg/kg. Concentrations were reported as Aroclor 1248 and, to a lesser extent, Aroclor 1260 (MDNR, 1986b).

The MDNR collected fish from the former Bryant Mill Pond again in July 1987. Skin-off fillets from 10 carp were analyzed by the MDPH for PCBs. Total PCB concentrations ranged from 0.54 to 5.5 mg/kg, with an average of 1.9 mg/kg.

Ground-Water Surveys

A hydrogeologic investigation was performed in the former Bryant Mill Pond area by Limno-Tech (February 1990) to obtain ground-water information related to possible remedial alternatives. Fifteen ground-water monitoring wells (MW101 through MW112, MW113A, MW113B, and MW114) and two test wells (TW1 and TW2) were installed as part of a Phase I investigation of the area. MW112 was installed in the landfill area, although it was part of this investigation. The wells were installed to characterize three general stratified zones in the pond area. These zones

included: 1) the surficial saturated zone (2 to 5 feet deep) within the floodplain sediments which include a peat layer (MW101 and MW110); 2) the saturated sand and gravel units (5 to 15 feet below the ground surface) directly beneath the floodplain sediments and peat layer (MW102, MW103, MW104, MW105, MW106, MW108, MW111, and MW112); and 3) the saturated sand and gravel units adjacent to the former Bryant Mill Pond (MW107, MW113A, MW113B, and MW114). Ground-water sampling and analysis, ground-water elevation measurement, in-situ hydraulic conductivity testing at seven wells (MW101, MW102, MW104, MW106, MW108, MW110, and MW111), and pump tests (at TW1 and TW2) were performed as part of the Phase I investigation.

A Phase II investigation of the former Bryant Mill Pond area included the installation of two additional ground-water monitoring wells adjacent to the pond (MW115 and MW116) and one ground-water monitoring well at the downstream end of the pond (MW30), additional ground-water sampling and analysis, and ground-water elevation monitoring. The wells installed during both phases of the investigation are shown on Figure 14.

Ground-water sampling and analyses were performed at 16 of the wells (MW101 through MW104, MW106 through MW108, MW110 through MW112, MW113A, MW114 through MW116, MW30, and TW2) in July, October, and December 1989. These data are summarized in Tables 33 and 34. Ground-water elevations are

presented in Table 35. Results indicated PCBs were detected only one time at well MW111 (0.07 ug/L in October). Two subsequent sampling events at this well did not detect any PCBs. Many of the wells were also sampled and analyzed for MDNR Scan 1 (Purgeable Halocarbons), Scan 2 (Purgeable Aromatic Hydrocarbons), and Scan 7 (Polynuclear Aromatic Hydrocarbons). One compound on the MDNR Scan 1 list (tetrachloroethene) was found at wells MW111, MW113A, MW114, and TW2. Certain MDNR Scan 2 compounds (toluene, ethylbenzene, xylene) were detected at well MW30. Pentachlorophenol was also detected at MW30. MW30 monitors Strebor, a separate Act 307 site.

Several conclusions were made by Peerless-Midwest, Inc., (1989) with respect to the hydraulics of the material underlying the former Bryant Mill Pond area based on the aquifer performance test performed at TW2. These conclusions included: 1) the wells located in the floodplain receive recharge sooner than the wells outside of the floodplain (i.e., drawdowns in the shallow floodplain wells were less than in other deeper wells); 2) Portage Creek is unlikely to be a source of recharge because poor hydraulic connection between the stream and the aquifer was observed during the test; and 3) the peat layer underlying the floodplain sediments may be acting as an aquitard.

Soil Surveys

Between July and November 1989, 13 soil borings (LP1, LP2, MW107, MW113B, MW114 and the 2000 series) were collected as part of a stream diversion plan. Borings were drilled on the perimeter of the former Bryant Mill Pond (Figure 14) using a hollow stem auger. A total of 23 borings were drilled; 15 samples from 10 borings were analyzed for PCBs, and 21 samples were analyzed for organic constituents. These samples were chosen for analysis based on their physical appearance, odor, and discoloration (Limno-Tech, Inc., February 1990). The results from the analysis of the samples at different depth intervals, ranging from 0 to 20 feet, indicated total PCB concentrations ranging from non-detectable (at a detection limit of 0.5 mg/kg) to 8.0 mg/kg (Table 12), as well as low levels of several organic constituents (Table 36).

Also in November 1989, six samples from four soil borings (ranging in depth from 1.8 to 6.5 feet) taken in the upstream end of the former Bryant Mill Pond (3000 Series) were analyzed for PCBs (Limno-Tech, Inc., February 1990). The samples ranged in PCB concentration from non-detectable (at a detection limit of 0.5 mg/kg) to 1.5 mg/kg (Table 12).

USEPA on May 23, 1990, conducted soil sampling at the Allied Paper site to assess the need for a fence. A total of 15 surficial soil samples (S12 through S26), at depths of 0 to 6

inches, were collected at locations ranging from the residuals at the HRDLs to the floodplain sediments along the former Bryant Mill Pond and Portage Creek (Figure 14). The PCB concentrations from these samples ranged from non-detectable (at a detection limit of 1.0 mg/kg) to 210 mg/kg (Table 37).

5.1.2 History of Response Actions

As part of the March 1986 study commissioned by MDNR entitled "Feasibility Study of Alternatives" for the Kalamazoo River PCB Project, NUS developed a fairly simple steady-state, one-dimensional PCB model that was used to screen remedial technologies and evaluate remedial actions.

The following remedial actions were evaluated for the former Bryant Mill Pond area: no action; channel lining and soil cap; channel lining and impermeable cap, excavation and off-site disposal; and permanent diversion and soil cap. Based on the results of the NUS PCB model, the MDNR recommended that a remedial action be implemented at the former Bryant Mill Pond. It was determined by MDNR that remediation of the former Bryant Mill Pond would have the greatest effect in reducing human exposure to PCBs and would decrease PCB concentrations in fish throughout the downstream reaches.

MDNR evaluated the feasibility of remedial alternatives for this area between 1984 and 1986, and recommended that some remedial action be taken (MDNR, December 1987).

In 1990, the USEPA proposed a removal action at the request of the MDNR and MDPH. This proposal included fencing the entire Allied property

south of Alcott Street. The USEPA notified Allied of their intentions and inquired if Allied would be willing to conduct the work themselves.

Allied Paper, Inc., entered into an Administrative Order by Consent, dated November 1, 1990, with USEPA. As part of this Order, Allied erected a fence along the perimeter of the Allied and nearby Panelyte properties. (The Panelyte property is an unrelated Superfund site which is not owned by any of the KRSG members).

5.1.3 History of Litigation

In June 1984, the MDNR notified Allied that it had been sampling sediments in Portage Creek and the former Bryant Mill Pond and had found PCBs. The MDNR indicated it believed Allied was responsible for the contamination and should "remove and/or contain these sediments..."

Following the MDNR notification, Allied investigated the site to determine the sources and extent of the PCBs in the former Bryant Mill Pond/Portage Creek area and the data collected in that investigation is summarized in this report. As a result of the study, Allied submitted three remediation proposals to the MDNR. All three proposals were rejected by the MDNR.

In November 1987, the State filed suit against Allied Paper and others in the U.S. District Court, Western District of Michigan. Since the filing of the suit, Allied Paper performed additional studies under the supervision of the Court.

In May 1989, Allied proposed a study for diversion of Portage Creek. Allied commenced the diversion field study in the summer of 1989.

In April 1989 and February 1990, Allied filed motions to require the USEPA to enter the MDNR's lawsuit against Allied because the former Bryant Mill Pond area was being considered for the USEPA's National Priorities List (NPL) and there was a risk that the two agencies would require conflicting actions by Allied. The court denied the motions and Allied continued with the diversion studies.

In July 1990, the court entered an order staying the litigation. In January 1991, June 1991, and February 1992, both the State and Allied requested that the stay order be continued. The stay order is still in effect at this time.

In June 1990, the MDNR issued a letter to HM Holdings/Allied Paper, Inc., Georgia-Pacific Corporation, and Simpson Plainwell Paper Company indicating that under Superfund and other laws the three companies were potentially responsible parties (PRPs) for the contamination of the portion of Portage Creek and the Kalamazoo River listed on the NPL. This letter also informed the PRPs that if they were unwilling to fund and conduct the RI/FS, the MDNR would conduct it and recover the cost from the PRPs.

As stated previously, in September 1990, members of the KRSG negotiated an Administrative Order with the State whereby the KRSG agreed to conduct a RI/FS for the Superfund site. That Administrative Order went into effect on December 28, 1990.

5.2 Portage Creek, Alcott Street to the Confluence with the Kalamazoo River

5.2.1 Past Surveys

Investigation of this segment of Portage Creek is limited to several studies. Most of the available information was collected by the MDNR in 1972 (Lauer, 1973), subsequent to an earlier study (Hesse and Wilson, 1972) which indicated the presence of PCBs in fish collected from portions of the Kalamazoo River. The 1972 study was performed in an attempt to identify possible point sources of the elevated PCB levels. The 1972 study data as well as other available data are presented below.

5.2.1.1 Sediment Surveys

Surface grab samples were collected during July 1972 from bottom sediments at five locations along this stretch of Portage Creek. The results of these analyses, presented in Table 38, indicate PCB concentrations (on a wet-weight basis) ranging from 12 to 26 mg/kg, with an average concentration of 20 mg/kg. One sediment sample collected in 1972 had a dry-weight PCB concentration of 120 mg/kg.

Three samples collected at two locations in 1976 and analyzed (on a dry-weight basis) exhibited PCB concentrations ranging from 0.50 to 56 mg/kg. Samples collected in 1982 and 1983 exhibited concentrations ranging from 10 to 85 mg/kg on a dry-weight basis. In 1983, stream-bank samples were collected and showed PCB concentrations of 11 mg/kg and 15 mg/kg at Portage Street and Michigan Avenue, respectively.

5.2.1.2 Water Column Surveys

Studies conducted during 1972 and 1976 have produced most of the available water column data for this stretch of Portage Creek. During 1972, a total of 13 water-column samples were collected from seven different locations along Portage Creek from Alcott Street to the Kalamazoo River. The analytical results of these samples, presented in Table 26, indicate PCB concentrations ranging from 0.22 to 3.6 ug/L and averaging 0.94 ug/L. Settleable solids were retained from samples collected at two locations and analyzed for PCB content. Results using an Aroclor 1242 standard showed PCB concentrations at Reed Avenue and Michigan Avenue to be 1.3 and 2.6 mg/kg, respectively.

During March and April 1976, Allied Paper collected water column samples at Reed Avenue as part of activities related to the drawdown of Bryant Mill Pond. A total of six samples were collected and analyzed for PCB content. The results of these analyses are presented in Table 39 and show that PCB concentrations ranged from 93 to 290 ug/L. Results are also shown for three split samples which were analyzed by the MWRC. These results indicate PCB concentrations ranging from 0.17 to 51 ug/L. Table 39 also presents data associated with a number of miscellaneous water quality parameters. Table 29 presents the results of analyses of various miscellaneous water quality parameters of samples collected at Reed Avenue in 1984 and 1985.

Two water column samples collected in July 1985 at Reed Avenue and the mouth of Portage Creek had PCB concentrations of 0.16 and 0.08 ug/L, respectively (Limno-Tech, Inc., unpublished data).

5.2.1.3 Fish Monitoring

Resident fish populations in Portage Creek were sampled in 1981 and 1985 and analyzed for PCBs. In addition, a caged-fish study evaluating PCB bioavailability in Portage Creek was performed in 1989.

The initial investigation of PCB concentrations in the fish of Portage Creek was undertaken by the MDNR in September 1981. Samples were collected between the confluence of Portage Creek with the Kalamazoo River and a point one-quarter mile upstream. Carp and white suckers were collected by trap netting and electro-fishing. Standard edible-portion fillets, skin-on fillets for suckers and skin-off fillets for carp; were analyzed by the MDNR Environmental Laboratory for PCBs and 11 other pesticide and organochlorine constituents.

Total PCB concentrations for carp in Portage Creek, as shown in Table 40, ranged from 0.19 to 1.0 mg/kg, with an average concentration of 0.72 mg/kg (MDNR, October 1982a). Aroclor 1242 was used as the standard for these analyses. Individual white sucker PCB concentrations ranged from 1.9 to 6.6 mg/kg, with an average concentration of 3.8 mg/kg. PCBs were quantified as Aroclors 1242 and 1254. The three composite samples of white sucker had PCB concentrations ranging from 3.1 to 5.6 mg/kg, with an average

concentration of 4.1 mg/kg. Aroclors 1242 and 1254 were used for quantitation.

The second fish survey was performed in 1985 by Limno-Tech, Inc. One carp and three smallmouth bass were collected at the confluence of Portage Creek with the Kalamazoc River. The carp had a PCB concentration of 1.1 mg/kg reported as Aroclor 1254 and 2.0 mg/kg reported as Aroclor 1242. The composite bass sample had a reported PCB concentration of 0.77 mg/kg as Aroclor 1254 and 0.87 mg/kg as Aroclor 1242 (Limno-Tech, Inc., unpublished data). The results of this survey are shown in Table 40.

In August 1989, the MDNR conducted an in-situ caged fish study, the objective of which was to provide background information on the quality of the aquatic environment of Portage Creek prior to the proposed diversion of the creek and issuance of a NPDES Permit allowing discharge of treated ground-water by Strebor, Inc. (MDNR, July 1990).

Prior to initiating the study, five channel catfish were randomly selected and analyzed for use as a control population. The PCB concentration of this control group was 0.029 mg/kg. Two cages were placed in the creek at Crosstown Parkway. At the start of the study (August 23, 1989), each cage contained 20 juvenile channel catfish. Five catfish were collected on the 2nd, 8th, 16th, 28th, and 52nd day of the study. Composite samples for five whole fish on each sampling

day were analyzed for total PCBs. The results are summarized as follows:

Day of Study	PCB Concentration (mg/kg)
2	0.24
8	0.31
16	0.62
28	0.71 (dup = 0.27)
52	0.50 (dup = 0.54)

5.2.1.4 Macroinvertebrate and Fish Population Studies

In the summer of 1971, MDNR performed an evaluation of the aquatic environment of the Kalamazoo River watershed to characterize the water quality of the river system. During June and August, water quality studies were conducted on the Kalamazoo River from its headwaters to the river's mouth. This study included sampling of fish populations, as well as qualitative and quantitative sampling of invertebrate species at 33 locations in the Kalamazoo River and five tributary streams. One of the tributary sampling stations of invertebrate species was Michigan Avenue on Portage Creek (Figure 3).

Macroinvertebrates were collected using two methods: Hester-Dendy artificial substrates and long-handled dip nets. Two artificial substrates were suspended in Portage Creek for colonization by stream macroinvertebrates. After approximately seven weeks in the creek, the substrates were removed and the organisms were collected, sorted, and identified. Each substrate was colonized by a total of seven

species. The total number of individual organisms per sampler was 314 and 439. Snails, leeches, damselflies, caddisflies, and midges were represented, with the bulk of the organisms being sludge worms. Qualitative analysis using the dip nets and handpicking identified 10 species. Snails and midges were the most abundant, followed by oligochaetes and damselflies. Results of both methods of analysis for benthic macroinvertebrates in Portage Creek reflected very poor water quality (MDNR, 1972). Fish were not sampled from Portage Creek during this investigation.

5.3 Kalamazoo River and Floodplain, Morrow Lake Dam to Lake Michigan

5.3.1 Past Surveys

As a result of the numerous studies conducted during the 1970s and 1980s, a significant data base has been generated regarding various media of the Kalamazoo River. Beginning in 1971 with a study performed by the MDNR (Hesse and Wilson, 1972), numerous studies have been conducted which have produced data associated with fish and other biota, water column, in-stream sediments, and floodplain soils. Although information associated with these studies is limited, this information has been compiled to the extent available, summarized, and reviewed. A discussion of this data base is presented below.

5.3.1.1 Sediment Surveys

1976 Sediment Survey

In August 1976, surface sediment samples were collected from locations between the Morrow Lake Dam and the Otsego Dam, and between the Trowbridge Dam and the Lake Allegan Dam (Figures 3 through 9). This investigation included the collection of 11 samples from above the water line. Six of the 11 samples were collected along the river between River Street and Main Street, Plainwell, and as presented in Table 41, show PCB concentrations ranging from non-detectable (at a detection limit of 0.5 mg/kg) to 12 mg/kg and averaging 7.5 mg/kg. Two samples collected between Main Street, Plainwell, and the Plainwell Dam exhibited PCB concentrations of 3.1 and 8.1 mg/kg (Table 42). The three remaining samples were collected along the river, one between the Plainwell and Otsego dams and two in Lake Allegan. PCB concentrations of these samples were 67, 25, and 5.6 mg/kg, respectively (Tables 43 and 44) (MDNR, December 1987).

1982 Sediment Surveys

During the summer of 1982, a study was performed to investigate the distribution of PCBs and dieldrin within sediments from impounded or formerly impounded areas of the Kalamazoo River (Bhaskar et al., 1983). This investigation included the analysis of in-stream surface sediment and core samples for PCBs and dieldrin. Five impoundments were included in this study: the former Plainwell Impoundment (Table

45); the Otsego City Impoundment (Table 46); the former Otsego Impoundment (Table 46); the former Trowbridge Impoundment (Table 47); and the Allegan City Impoundment (Table 48).

At each impoundment, surface samples were collected at two locations; approximately 300 feet and one-quarter mile upstream of the dam. In addition to the collection of surface samples, one 20-inch core sample was collected near the dam of each impoundment. PCB concentrations in surface sediments ranged from 0.14 mg/kg 1/4-mile upstream of the Otsego Dam to 36 mg/kg 200 feet upstream of the Allegan City Dam. Core samples from the former Plainwell Impoundment, Otsego City Impoundment, and former Otsego Impoundment all had non-detectable PCB concentrations at the 0.15 mg/kg detection limit. Cores from the former Trowbridge Impoundment and Allegan City Impoundment ranged in PCB concentration from 32 to 57 mg/kg.

Surface sediment samples were also collected and analyzed for PCBs in July and November 1982 (MDNR, December 1987). This sampling event included the collection of seven surface samples from above the water line along the river between King Highway and the Plainwell Dam (Tables 41 and 42). The results of laboratory analysis indicate PCB concentrations ranging from non-detectable (at a detection limit of 0.05 mg/kg) to 57 mg/kg (MDNR, December 1987). Also in 1982, sediments from the lower Kalamazoo River from New Richmond to Lake Michigan were sampled at ten locations (Horvath,

1984). Analysis of these samples showed a range of PCB concentrations from 0.031 mg/kg at New Richmond to 1.7 mg/kg in the deepest part of Kalamazoo Lake (Table 49).

In addition, according to MDNR (December 1987), one additional surface sample was collected July 22, 1982, between the Otsego City and Otsego dams (Table 43). This sample exhibited a PCB concentration of 27 mg/kg.

1983 Sediment Surveys

In 1983, extensive coring and surface sampling was performed along the river between Main Street, Plainwell, and the Trowbridge Dam. This sampling, performed in March and June of 1983, included the collection of mostly riverbank sediments located above the water line, with a limited number of samples also being collected from within the river channel (Harrison and Yerkes, 1983; Creal, 1983; Miller, 1983).

Sampling performed in March 1983 included the collection of a total of 10 core samples from eight locations (at two locations cores were split into two parts) within the exposed floodplain sediments of the former Otsego Impoundment. This sampling was performed to determine if organochlorine constituents were present and to assess the effects on the water and biota of the river and Lake Michigan if the area was reimpounded (Miller, 1983). PCB concentrations ranged from 0.79 to 28 mg/kg (as Aroclor 1248) (Table 50). Chlordane,

nonachlor, DDE, DDD, dieldrin, and HCB (hexachlorobenzene) were also detected (Miller, 1983).

In June 1983, a total of 28 surface and core sediment samples were collected from the riverbank at 22 locations. In addition, 10 samples were collected at six locations within the river channel or at the edge of the water line. The results of these studies are discussed with reference to specific river reaches in the following paragraphs.

Table 42 presents results of laboratory analyses for PCBs from sediment samples collected along the Kalamazoo River between Main Street, Plainwell, and the Plainwell Dam. Core samples collected above the water line at various depths were found to contain PCB concentrations ranging from 0.27 to 37 mg/kg. PCB concentrations of in-stream and edge-of-water sediment samples were found to range from 16 to 56 mg/kg (Harrison and Yerkes, 1983; Creal, 1983).

Table 43 summarizes the analytical results of sediments collected from the stretch of river located between the Plainwell and Otsego dams. These results consist of analyses performed on four core samples collected above the water line and analyzed using Aroclor 1248 and 1254 standards. Total PCB concentrations were found to range from non-detectable (at a detection limit of 0.12 mg/kg) to 8.5 mg/kg (Harrison and Yerkes, 1983).

The stretch of river located between the Otsego and Trowbridge dams was sampled in June 1983 at 11 locations above the water line with a total of 14 surface and core samples collected. The results of

laboratory analysis, presented in Table 51, showed PCB concentrations ranging from 1.1 mg/kg to 51 mg/kg (Harrison and Yerkes, 1983; Creal, 1983).

In addition, Table 51 presents data associated with analysis of one in-stream core sample and two grab-samples collected at the edge of the water line. These samples contained PCB concentrations of 44, 65, and 81 mg/kg, respectively. Two samples from one core collected in the river channel 150 feet upstream of the Trowbridge Dam had PCB concentrations of 8.4 and 13 mg/kg (Creal, 1983).

In July 1983, MDNR sampled sediments in Lake Allegan for PCBs (Creal, 1983). The results are presented in Table 44. Samples were taken along three transects, with five to six cores, 12 to 16 inches deep, taken along each transect in order to determine average sediment PCB concentrations. The upper and lower 4 inches of all the cores, within a given transect, were composited for analysis. Data from one of the upper composites were not reported. The upper composites of the other cores had PCB concentrations of 14 and 16 mg/kg. PCB concentrations in the lower composites were slightly higher at 14, 25, and 20 mg/kg. Additionally, three single cores were taken and the upper and lower 4 inches were analyzed. The upper 4 inches had PCB concentrations of 11, 24, and 18 mg/kg, while those of the lower 4 inches of the latter two samples had 42 and 28 mg/kg each. Total solids contents were also determined and ranged from 21 to 47.2 percent.

1984 Sediment Surveys

Sediment sampling along the river in 1984 included the collection of a total of 45 core samples from various depths at seven locations between Main Street, Plainwell and the Trowbridge Dam. These samples were collected during June and August 1984 from the river channel or the edge of the water line in the Plainwell, Otsego, or Trowbridge impoundments (MDNR, December 1987; Creal, June 1984; Anon., 1984; Creal and Wuycheck, 1984).

A total of four locations were sampled with reference to the Plainwell Dam, producing 20 core samples collected from depths ranging from 1 to 10 feet. The results presented in Table 42 show that PCBs were not detected in a majority of the samples, with the other samples exhibiting concentrations only as high as 0.94 mg/kg quantified as Aroclors 1242 and 1254 (MDNR, December 1987; Creal, June 1984).

In June 1984, one location was sampled near the Otsego Dam producing a total of six samples collected to a depth of 7 feet. These samples exhibited PCB concentrations up to 0.29 mg/kg (Table 43) (Anon., 1984).

In August 1984, sampling performed near the Trowbridge Dam, including two locations at the edge of the water line, produced 19 samples up to a depth of 12 feet. The results (Table 51) indicate PCB concentrations ranging from non-detectable (at a detection limit

of 0.13 mg/kg) to 64 mg/kg using Aroclors 1242, 1254, and 1260 for quantitation (Creal and Wuycheck, 1984).

In addition to the various sediment samples collected in June and August 1984, one surface sediment sample was collected in May 1984 from the riverbank near Paterson Street in the city of Kalamazoo, which exhibited a PCB concentration of 13 mg/kg (Table 41) (MDNR, December 1987).

1985 Sediment Surveys

During January and May of 1985, surface sediment and core samples were collected from three locations just upstream of the Otsego City Dam and five locations just upstream of the Allegan City Dam. The results of laboratory analysis of these samples are presented in Tables 43 and 52, respectively. These results show PCB concentrations at both locations ranging from 0.91 to 57 mg/kg (Anon., January 1985; Anon., May 1985).

In August 1985, core samples were collected from both the Plainwell and Trowbridge impoundments (one location per impoundment). Samples were collected to a depth of 8 feet from the Plainwell Impoundment, and to a depth of 11 feet from the Trowbridge Impoundment. The sampling location associated with Trowbridge Dam was positioned approximately 1.4 miles upstream of the dam. However, the precise locations of samples associated with the Plainwell Dam are not known. Each of these samples (a total of 19) were analyzed for PCBs, phenols, mercury, and PAHs. These results,

presented in Table 53, show PCB concentrations ranging from non-detectable (at a detection limit of 0.7 mg/kg) to 15 mg/kg, mercury ranging from non-detectable (at a detection limit of 0.5 mg/kg) to 5.3 mg/kg, phenols ranging from 1.0 to 8.2 mg/kg, and PAHs at low levels (Anon., August 1985; MDNR, December 1987).

In January and June of 1985, 23 sediment core samples were taken between Lake Allegan Dam and New Richmond and analyzed for PCBs and total solids. Sampling depth ranged from surficial to 7 inches. Six samples taken in January ranged in PCB concentration from non-detectable (at a detection limit of 0.13 mg/kg) to 1.1 mg/kg and total solids from 37.4 to 70.8 percent. The 17 samples collected in June had PCB and total solids ranges from non-detectable (at a detection limit of 0.037 mg/kg) to 1.4 mg/kg and 35.8 to 76.5 percent, respectively. The average PCB concentration and percent total solids for the 23 samples were 0.34 mg/kg and 57.2 percent, respectively. The results of the PCB analyses are presented in Table 49.

1986 Sediment Survey

In a survey conducted in May 1986, six sediment samples were collected between Paterson Street and D Avenue, upstream of Plainwell. The samples were analyzed for PCBs (wet weight basis), total solids, mercury, cadmium, and lead. PCB concentrations ranged from non-detectable (at a detection limit of 0.5 mg/kg) 66 feet upstream of the Kalamazoo wastewater treatment plant and at D Avenue to 8.1 mg/kg at Paterson Street. Aroclors detected were 1242

average accumulation rates be used to predict the burial rate of existing sediments (GZA-Donohue, June 1990).

As mentioned above, sediment/water partition coefficients for PCBs were also assessed as part of the October and November 1987 data collection activities. Composite sediment samples were collected from each of the referenced impoundments with duplicate samples being collected within Bryant Mill Pond. These samples were analyzed for PCB content along with other parameters such as organic carbon content, percent solids, and particle size distribution. The results of these analyses are presented in Table 56 (GZA-Donohue, June 1990).

Water was centrifugally separated from sediment in the experiments. Following the initial analyses of the water and sediment samples, partition coefficients were found for each composite sample based on batch adsorption experiments. Freundlich isotherms were evaluated based on the adsorption data. Langmuir isotherms were also evaluated, but provided no additional correlations over the Freundlich isotherms. Using the Freundlich adsorption equation, adsorption coefficients (K_f values) were found for each composite. These values were found using the standard form of the equation as well as the log-transformed form. The results of these experiments are presented in Table 57. Using these two forms of the Freundlich equation, K_f values of the composite samples were found to range from 61 to 409 and 25 to 300, respectively. Adsorption coefficients

based on the organic content (K_{oc} values) were also found for each of the composite samples (Table 57) (GZA-Donohue, June 1990).

Interpretation of the study results indicates that during the experiments, a low precision of analysis was evident regarding PCB analyses of water and sediment. In consideration of this, GZA-Donohue recommended that the results found using the untransformed Freundlich equation be used over the results of the log-transformed equation, but the use of these values should include consideration for the inherent imprecision (GZA-Donohue, June 1990).

More recent investigations of the Kalamazoo River sediment included extensive studies performed in association with the former Plainwell, Otsego, and Trowbridge impoundments during January and August 1988. These studies, performed by GZA-Donohue, were designed to identify sludge deposits associated with these impoundments which contained levels of PCBs above background, and to assess the distribution of these deposits with respect to spatial variation and depth (Anderson, 1989).

These investigations included sediment sample collection at 282 locations within the three former impoundments. Sediment coring was performed at 179 of these locations to facilitate sediment description. At the remaining 103 locations, sediment samples were collected and retained for subsequent PCB analysis and sediment classification. However, only 74 samples collected from 19 locations have been analyzed for PCBs (Anderson, 1989).

Presented in Table 58 are the results of these investigations, including the geomorphic descriptions and PCB concentrations of the samples analyzed for PCBs.

The results of the January and August 1988 investigations identified gray silty sludge-like deposits, which covered the surface of many locations up to a depth of 9 feet with brown to reddish-brown oxidized, silty, sandy native soils underlying these deposits. The distribution of these deposits is described as non-uniform and of a variable depth (Anderson, 1989). The deposits have also been described as concentrating in specific locations of the three referenced reaches.

In 1991, the MDNR collected a surface sediment sample just upstream of the Otsego City Dam. The sample had a PCB concentration of 180 mg/kg as Aroclor 1242. A sample collected at a depth of one foot had a PCB concentration of 1.0 mg/kg (Aroclor 1242) (MDNR, October 1991).

5.3.1.2 Water Column Surveys

A number of studies have evaluated the water quality of the Kalamazoo River. In August 1930, the Michigan Stream Control Commission conducted a water quality survey which revealed that dissolved oxygen (DO) concentrations ranged from 90 percent of saturation at Comstock to zero percent downstream of Kalamazoo. Again in 1942, decreased DO levels were observed by Eldridge, between Comstock and the downstream areas of Kalamazoo. In 1946,

1981, with PCB concentrations ranging from 0.013 to 0.090 ug/L. The highest PCB concentration came from the last sample taken in May (0.090 ug/L) and the lowest concentration was in February 1981 (0.013 ug/L). The average total PCB concentration was 0.04 ug/L (Marti, 1984). The results of this survey are presented in Table 59.

In 1982, water-column samples of the lower Kalamazoo River between New Richmond and Lake Michigan were collected and analyzed for PCBs (Horvath, 1984). Samples collected at four locations showed a range of PCB concentrations of non-detectable (at a detection limit of 0.030 ug/L) to 0.12 ug/L, quantified as Aroclor 1242. The results of this survey are shown in Table 59.

Between April and October 1984, physical, chemical, and biological monitoring of the river was conducted between Comstock and Plainwell (Suppnick and Creal, 1986). This investigation was performed mainly to establish nuisance aquatic weed growth baselines in the river for comparisons with subsequent studies.

Between 1985 and the present, several sampling events have been undertaken in association with the Kalamazoo River in order to determine water column PCB concentrations at various locations. Data specific to these sampling events are summarized in Tables 59 and 60. These data indicate that 118 samples were collected from 17 locations along the river between the Morrow Lake Dam and between Lake Michigan from 1985 to 1988. PCB concentrations were shown to

range from non-detectable (at a detection limit of 0.010 ug/L) to 0.19 ug/L.

Analyses were also performed by MDNR (December 1987) on water samples taken from Lake Allegan in 1985 and 1986, and are presented in Table 61. Total PCBs ranged from 0.057 to 0.19 ug/L.

5.3.1.3 Fish Monitoring

From 1971 to 1990, the MDNR collected fish from the Kalamazoo River for analysis of PCBs and other constituents. Analytical results for fish collected from below Morrow Lake Dam to Lake Michigan are presented in Table 62, and shown on Figures 2 through 7, 9, 11, and 12.

1971 Fish Monitoring

In 1971, as part of an intensive biological survey, the MDNR collected fish from the Kalamazoo River at seven sampling stations located between the Morrow Lake Dam and Lake Michigan. Fish were collected using electro-shocking equipment and fyke nets. Twenty grams of fish flesh were removed from the sides of each fish between the dorsal fin and lateral lines and were analyzed for organochlorine insecticides, mercury, and PCBs (MDNR, 1972).

From the Morrow Lake Dam downstream to King Highway in Kalamazoo one specimen each of carp, white sucker, rock bass, and bullhead were collected. Results showed PCB concentrations, as Aroclor 1254, of 8.9, 18, 2.3, and 3.3 mg/kg, respectively.

Within Lake Allegan, reported PCB concentrations in single specimens of carp, northern pike, white sucker, and bullhead were 7.3, 13, 14, and 11 mg/kg, respectively. Concentrations of total DDT were measured at 0.026, 0.047, 0.059 and 0.039 mg/kg, respectively (MDNR, 1972).

From the Lake Allegan Dam to the mouth of the Kalamazoo River at Saugatuck, one specimen each of carp, white sucker, rock bass, bullhead, and northern pike were collected. Total PCB concentrations ranged from 8.7 mg/kg in the northern pike to 46 mg/kg in the white sucker. Total DDT concentrations ranged from 0.02 mg/kg in the rock bass to 0.22 mg/kg in the northern pike (MDNR, 1972).

1976 Fish Monitoring

Fish were again collected from the Kalamazoo River by the MDNR in 1976 (NUS, 1986). Specimens were collected from below the Morrow Lake Dam at River Street, Mosel Avenue, the Plainwell and Otsego impoundments, Lake Allegan, and Saugatuck. Skin-off fillets were used for analysis.

One smallmouth bass and one largemouth bass were collected from the River Street location. Total PCB concentrations, as Aroclor 1254, were 1.2 and 0.40 mg/kg, respectively. From Mosel Avenue a single carp was collected, with a total PCB concentration of 8.0 mg/kg (as Aroclor 1242 and 1254). Fish sampled from the Plainwell Dam Impoundment included two carp and one white sucker. Analysis of the two carp revealed total PCB concentrations of 13 mg/kg (as Aroclor

1242 and 1260) and 14 mg/kg (as Aroclor 1242 and 1254), and the white sucker had a total PCB concentration of 4.3 mg/kg (as Aroclor 1254 and 1260).

Fish collected from the Otsego Dam Impoundment included a carp, a bass, and a white sucker. Total PCB concentrations of 12 mg/kg (as Aroclor 1242, 1254, and 1260), 1.5 mg/kg (as Aroclor 1242 and 1254), and 4.0 mg/kg (as Aroclor 1242 and 1254), respectively, were reported. In Lake Allegan, total PCB concentrations for one carp (7.4 mg/kg), one bass (2.4 mg/kg), one northern pike (2.1 mg/kg), and one white sucker (7.4 mg/kg) were quantified as Aroclors 1242 and 1254. At Saugatuck, one each of carp, bass, northern pike, and tiger muskie were collected. Total PCB concentrations of 36, 34, 4.7, and 2.4 mg/kg were recorded, respectively. Each sample was reported as Aroclors 1242 and 1254. A portion of the bass PCB concentration was also reported as Aroclor 1260.

1978 Fish Monitoring

In May 1978, a follow-up fish sampling of the lower Kalamazoo River was performed by the MDNR (1978). Fish were collected to determine if PCB concentrations warranted maintaining the 1977 health advisory. Skin-off fillets from Lake Allegan, New Richmond, and Saugatuck were analyzed by the MDNR laboratory for PCBs. From Lake Allegan, three carp, six white suckers, and one northern pike were collected. Mean total PCB concentrations were 51 mg/kg (Aroclors 1242, 1254, and 1260), 6.3 mg/kg (Aroclors 1242, 1254, and

1260), and 4.1 mg/kg (Aroclors 1242 and 1254), respectively. At New Richmond, three carp and two northern pike were analyzed and had mean total PCB concentrations of 63 mg/kg (Aroclors 1242 and 1254) and 7.2 mg/kg (Aroclors 1242, 1254, and 1260), respectively. At Saugatuck three carp, three white suckers, and one northern pike were collected with mean total PCB concentrations (Aroclors 1242 and 1254) of 37, 6.4, and 4.9 mg/kg, respectively.

1981 Fish Monitoring

In September 1981, the MDNR (October 1982b) resumed the monitoring of fish in the Kalamazoo River to update the Public Health Advisory list issued in 1977. Fish were collected by trap netting and electro-fishing at eight sites along the river, and standard edible portion fillets were analyzed for PCBs and organochlorine pesticides.

From Mosel Avenue to D Avenue in Kalamazoo, 18 carp were collected with a mean total PCB concentration (Aroclors 1242 and 1254) of 2.3 mg/kg. Additional species collected include smallmouth bass, largemouth bass, rock bass, bluegill, and black crappie. Mean total PCB concentrations ranged from 0.36 mg/kg in two smallmouth bass to 3.0 mg/kg in a single black crappie.

From Douglas Avenue to just below the Plainwell Dam, nine species of fish were collected. Mean total PCB concentrations ranged from 0.36 mg/kg in two yellow bullhead (Aroclor 1242) to 3.2 mg/kg in six carp (Aroclors 1242 and 1254). Fish collected from Lake Allegan included carp, smallmouth bass, and largemouth bass. Mean

total PCB concentrations (Aroclors 1242 and 1254) ranged from 0.64 mg/kg in three largemouth bass to 8.0 mg/kg in 20 carp.

At New Richmond, carp, largemouth bass, and bowfin were collected and showed mean total PCB concentrations of 4.8, 1.7, and 2.3 mg/kg, respectively. At Douglas, four carp and two largemouth bass were collected. Both species had mean total PCB concentrations of 8.3 mg/kg. At Saugatuck, four carp and two largemouth bass were collected with mean total PCB concentrations of 6.2 and 3.0 mg/kg, respectively. Aroclor-specific PCB results were not available for these three sections of the river.

1983 Fish Monitoring

In May 1983 the MDNR collected five largemouth bass and three bluegills from Lake Allegan as part of a dioxin study. Samples were analyzed for several chemicals including PCBs. Three of the five bass analyzed contained levels of PCBs over the detection limit of 0.20 mg/kg and had an average total PCB concentration of 0.44 mg/kg. The bluegills were analyzed as a three-fish composite sample and contained a total PCB concentration of 0.48 mg/kg (Forney, 1983). PCBs in the bass were quantified as Aroclors 1242 and 1254, while PCBs in the bluegills were quantified as Aroclor 1242.

As noted above, the original impetus for the May 1983 sampling activities in Lake Allegan was to investigate the dioxin levels in resident fish (if any). Five carp were collected for this purpose and combined into one composite sample and analyzed for the 2,3,7,8-

TCDD dioxin isomer. Duplicate analyses by the MDNR found a mean concentration of 0.0000028 mg/kg 2,3,7,8-TCDD (MDNR, 1984a).

In July 1983, MDNR resumed monitoring of Kalamazoo River fish with a study of PCB and mercury concentrations in carp from four locations on the river including Mosel Avenue, downstream of the Plainwell Dam, Lake Allegan, and Saugatuck. Carp were selected because they are a common fish at all locations. Skin-off fillets were used for analysis (MDNR, 1984b). Aroclor-specific PCB concentrations were not available for the 1983 data.

Eleven carp sampled from Mosel Avenue had a range of total PCBs from 0.98 mg/kg to 6.5 mg/kg, with an average of 3.5 mg/kg. Eleven carp sampled from the downstream of the Plainwell Dam ranged in PCB concentration from 0.87 mg/kg to 16 mg/kg, with an average of 5.5 mg/kg. Mercury concentrations in fish from the two areas averaged non-detectable (at a detection limit of 0.12 mg/kg) and 0.52 mg/kg, respectively.

Skinless fillets from three Lake Allegan carp were analyzed for total PCBs with concentrations ranging from 1.6 mg/kg to 5.0 mg/kg, with an average of 2.8 mg/kg. Eleven carp collected from Saugatuck ranged in total PCB concentration from 1.0 mg/kg to 25 mg/kg, with a mean of 8.5 mg/kg.

1985 Fish Monitoring

In July 1985, the MDNR again sampled the Kalamazoo River, this time between Morrow Lake and Saugatuck including sampling locations

at Mosel Avenue, downstream of the Plainwell Dam, Lake Allegan, and Saugatuck. Skin-off fillets for carp and skin-on fillets for bass were analyzed for PCBs (MDNR, 1985). Also in 1985, carp were collected from Mosel Avenue by Limno-Tech, Inc. and analyzed for PCBs (Limno-Tech, Inc., unpublished data).

Twenty-five carp sampled from Mosel Avenue (19 by MDNR and six by Limno-Tech) ranged in total PCB concentrations from 1.4 to 11 mg/kg, with an average of 4.9 mg/kg (Aroclors 1242, 1248, 1254, and 1260). Two smallmouth bass sampled from the area had a mean total PCB. concentration of 1.7 mg/kg (Aroclors 1254 and 1260). Samples from downstream of the Plainwell Dam consisted of 20 carp ranging in total PCB concentrations from 1.6 to 13 mg/kg, with an average of 5.3 mg/kg (Aroclors 1242, 1248, 1254, and 1260). One smallmouth bass was also analyzed with a total PCB concentration of 3.3 mg/kg (Aroclors 1242, 1254, and 1260). Total PCB concentrations in 19 carp collected from Lake Allegan ranged from 1.5 mg/kg to 14 mg/kg, with an average of 4.4 mg/kg (Aroclors 1242, 1254, and 1260). Mean total PCB concentrations for three smallmouth bass and seven largemouth bass from Lake Allegan were 2.1 and 3.1 mg/kg (Aroclors 1242, 1254, and 1260), respectively. Mean total PCB concentrations in 20 carp, 9 largemouth bass, and 1 smallmouth bass from Saugatuck were 3.6, 1.3, and 1.7 mg/kg (Aroclors 1242, 1254, and 1260), respectively.

1986 Fish Monitoring

In May and June 1986, a single specimen each of six species of fish were retained during a population study for analysis of PCBs and certain metals (Gaule, 1987). Fish were collected with fyke nets from above and below the outfall from the Kalamazoo wastewater treatment plant. Total PCB concentrations ranged from 0.41 mg/kg (Aroclor 1254) in a yellow bullhead to 1.9 mg/kg (Aroclors 1016, 1242, and 1254) in a rock bass. Sample preparation techniques are not available. All mercury concentrations were non-detectable at a detection limit of 0.5 mg/kg. Cadmium and lead concentrations ranged from non-detectable (at a detection limit of 0.1 mg/kg) to 0.2 mg/kg and 0.48 to 1.3 mg/kg, respectively.

In July 1986, the MDNR sampled the Kalamazoo River at six locations, including Mosel Avenue, the Plainwell Dam Impoundment, Lake Allegan, and Saugatuck. Skin-off fillets for carp and skin-on fillets for bass were analyzed for PCBs and organochlorines.

Twenty carp collected at Mosel Avenue ranged in total PCB concentration from 1.5 to 11 mg/kg, with an average of 4.7 mg/kg. Twenty-one carp collected from the Plainwell Dam Impoundment ranged in total PCB (as Aroclor 1248, 1254, and 1260) concentration from 0.50 to 9.5 mg/kg, with an average of 4.1 mg/kg (MDNR, 1986b). A total of 81 carp were collected from Lake Allegan on the basis of length in an attempt to obtain four different age classes. Fish were identified by age group and sex. Total PCB concentrations for the

entire sample population ranged from 0.09 to 24 mg/kg, with an average concentration of 4.3 mg/kg. The analyses showed no bias by age or sex (MDNR, May 1987). Twenty-four carp and five largemouth bass collected from Saugatuck had mean total PCB concentrations of 4.3 mg/kg (Aroclors 1248, 1254, and 1260) and 0.58 mg/kg (Aroclors 1254 and 1260), respectively.

1987 Fish Monitoring

In March 1987, MDNR collected 107 game fish from the lower Kalamazoo River area at Saugatuck. Included in this sampling was the collection of 13 species. Skin-on or skin-off fillets were analyzed depending on the species. Mean total PCB concentrations (Aroclor 1248 and 1254) ranged from 0.37 mg/kg in skin-on fillets from ten rock bass to 13 mg/kg in skin-off fillets from three flathead catfish. Additionally, a sample of northern pike eggs was analyzed and had a total PCB concentration of 0.65 mg/kg (Aroclor 1242, 1254, and 1260).

In July 1987, MDNR sampled the Kalamazoo River at six locations including the Plainwell Dam, Lake Allegan, and Saugatuck. Skin-on or skin-off fillets were analyzed, depending on the species. PCBs for all the fish collected in 1987 (except the northern pike eggs) were quantified as Aroclor 1248 and 1254 (MDNR, 1987a). From the Plainwell Dam area, nine carp ranged in total PCB concentration from 1.7 to 17 mg/kg, with an average of 5.2 mg/kg. From Lake Allegan, ten carp were collected and ranged in total PCB concentrations from 1.2 to 6.1 mg/kg, with an average of 3.2 mg/kg. PCB concentrations

in three northern pike from Lake Allegan ranged from 1.7 to 3.1 mg/kg, with an average of 2.4 mg/kg. Ten smallmouth bass from Lake Allegan ranged in PCB concentrations from 1.4 to 5.1 mg/kg, with an average of 3.1 mg/kg. At Saugatuck, nine carp were collected with a mean total PCB concentration of 4.5 mg/kg.

From July 8 to August 5, 1987 the MDNR conducted caged fish studies on several Michigan rivers, including the Kalamazoo River at Saugatuck. The primary objective of this research was to determine the extent of bioaccumulation of selected contaminants in fish from the river. The study was part of a state-wide program to monitor surface water quality trends of major river systems (MDNR, November 1989).

Channel catfish were used for the study. Fish were placed in two cages and specimens were removed, composited, and analyzed at 5, 9, 16, and 28 days of exposure. Results of the study showed that the concentration of PCBs in channel catfish from the Kalamazoo River increased from non-detectable (at a detection limit of 0.025 mg/kg) to 0.47 mg/kg with increased exposure time. Additionally, the DDT degradation product DDE also increased slightly in caged fish. Other substances including mercury and chlorinated pesticides were not detected in the caged channel catfish (MDNR, November 1989).

1990 Fish Monitoring

In October, 1990, MDNR collected 20 carp from Lake Allegan. Ten samples were prepared as skin-off fillets and ten were prepared as whole fish. Samples were analyzed for PCBs, organochlorine

pesticides, mercury, and other constituents. Mean PCB concentrations for the skin-off fillet and whole fish samples were 3.7 and 12 mg/kg, respectively. For the skin-off fillet samples, the other constituents found were mercury, dieldrin, chlordane, DDD, DDE, and heptachlorepoxide. These compounds were present in mean concentrations ranging from 0.003 to 0.27 mg/kg. In the whole fish samples, the same compounds were detected, with the addition of DDT. Concentrations ranged from 0.008 to 0.49 mg/kg (Waggoner, 1991).

5.3.1.4 Macroinvertebrate and Fish Population Studies

1966 Fish Population Study

Investigation into the aquatic biological communities of the Kalamazoo River began in 1966. As part of this survey, fish populations were recorded in seven sections of the river from Comstock City Park upstream of the city of Kalamazoo to Saugatuck. Fish were collected with gill nets, seines, and electro-fishing gear.

At the Comstock City Park upstream of Kalamazoo, the River supported diverse species of both game and nongame fish. Of the 13 species recorded, 54 percent were game fish and 46 percent were nongame species (untitled report).

The next three stations to be sampled were south of the city of Parchment near the Mosel Avenue Bridge, the railroad trestle in Plainwell, and the Plainwell Dam Impoundment. Fish collected from these areas were all tolerant nongame species and included white

sucker, brook stickelback, central mudminnow, and European carp (untitled report).

At the Trowbridge Impoundment five species of fish were observed, and bluegill (20 percent of the individuals) were the only game species present. At Lake Allegan, eight species were identified and 25 percent of the individuals were game fish species, including bluegill, green sunfish and black bullhead. At the Highway 31 bridge in Saugatuck, 15 species were collected and 40 percent of the individuals were game fish. Game fish present in the Saugatuck area included northern pike, largemouth bass, green sunfish, and rock bass (untitled report).

1966 Macroinvertebrate Study

Populations of benthic macroinvertebrates were also investigated as part of the 1966 survey (untitled report). Benthos were sampled during the summer of 1965 and 1966. Collection methods included use of an Eckman dredge, a Peterson dredge, and a can sampler. The materials obtained from the sampling were placed in containers, preserved, and subsequently examined in the laboratory.

Populations of macroinvertebrates observed at the Comstock City Park upstream of Kalamazoo were diverse, with 17 orders and 31 genera identified. At the Mosel Avenue Bridge, south of Parchment, seven genera and four orders were identified. Benthos were nearly all oligochaetes, and to a much lesser extent leeches, moth flies, flower flies, and snails. Extensive growths of sewage fungus were also

reported at this location (untitled report). At the next two stations downstream, Cooper Road and the Plainwell railroad trestle, the only organisms found were oligochaetes and other tolerant species. Three genera and two orders were identified from Cooper Road, while two genera and two orders were identified from the railroad trestle.

Benthic organisms were also collected upstream from the Plainwell Dam and at the North Street Bridge in Otsego. Populations of benthos were generally the same as those surveyed immediately upstream, with the addition of a few midges and beetles. Five genera and four orders were identified at the Plainwell dam, while 16 genera and nine orders were identified at the North Street Bridge. Upstream from the Trowbridge Dam, the structure of benthic communities shifted to nearly all midges and beetles. Seven genera and four orders were identified. In the tailwater of the dam, benthos consisted mostly of oligochaetes, leeches, and snails, with some midges and beetles present. Sixteen genera and eight orders were identified from this section.

At the farthest downstream sections of the river (Lake Allegan, the Highway M-89 Bridge downstream of Lake Allegan, New Richmond, and Saugatuck), a wide range of organisms were present. The particular group or groups dominant at a station varied according to its lotic or lentic nature. Insects were prevalent, represented by mayflies, dragonflies, beetles, caddisflies, midges, blackflies, and true bugs.

1971 Fish Population Study

In 1971, the MDNR sampled fish during a survey of the aquatic environment for the entire Kalamazoo River watershed (MDNR, 1972). The survey included fish sampling from seven stretches of the river from below Morrow Lake Dam to the mouth of the river at Saugatuck. Fish were collected from two or three stations within each river reach using electro-fishing gear and fyke nets.

From Morrow Lake Dam to King Highway, 12 species were identified. A total of 176 fish were collected, and 64 percent of the individual fish were game fish. Forage species collected included common and golden shiners, and hornyhead and bluntnose minnows. Many young of the year smallmouth bass were seen in the riffle areas (MDNR, 1972).

From Mosel Avenue to 10th Street in Plainwell 11 species were identified. A total of 45 fish were collected and 44 percent of the individuals were game fish. Few forage species were present and carp, white suckers, goldfish, brown bullhead, pumpkinseed, and smallmouth and largemouth bass were among those species identified (MDNR, 1972).

From the section of river between 10th Street and the Otsego City Dam eight species were identified. Of the 155 individual fish that were collected, 10 percent were game fish. Very few forage species were present and white suckers were abundant. Carp, yellow bullhead,

goldfish, golden and common shiners, northern pike, and other species were also identified (MDNR, 1972).

From the Highway M-89 Bridge to the Otsego Dam, seven species of fish were identified. A total of 82 individual fish were collected, 18 percent of which were game fish. The majority of fish collected were white suckers and carp. Goldfish, mottled sculpin, golden shiner, bluntnose minnow, pumpkinseed, black crappie, yellow perch, and smallmouth bass were among the other species identified (MDNR, 1972).

Between the Otsego Dam and the Highway M-89 Bridge on the southeast side of Allegan twelve species were identified. A total of 316 fish were collected of which 16 percent were game fish. Carp, white suckers, and goldfish were predominant, and in one eddy area approximately 500 carp were seen in a sluggish state (MDNR, 1972). Other species present included redhorse, brown bullhead, satinfin, spotfin, common shiners, bluntnose minnow, pumpkinseed, and northern pike.

In Lake Allegan, 14 species were identified. Of the 654 fish that were collected, 37 percent were game fish including bluegill, black crappie, walleye, northern pike, and bass. Carp were common in the area, but appeared relatively small (MDNR, 1972). More fish were observed in Lake Allegan than any other section of the river.

The farthest downstream section of the river surveyed was below the Lake Allegan Dam to the mouth of the river at Saugatuck. A total

of 18 species were identified, and of the 279 fish collected 60 percent were game fish. The river below Lake Allegan was reported to have the most well-balanced game fish population of any other stretch of the river. Good-sized largemouth bass, black crappie, channel catfish, and northern pike were very numerous (MDNR, 1972).

1971 Macroinvertebrate Study

The 1971 survey of the Kalamazoo River included an investigation into the structure of benthic macroinvertebrate communities (MDNR, 1972). Sampling sites included 14 locations between the Morrow Lake Dam and Lake Michigan. Benthos were obtained using two collection methods. The first method consisted of suspending Hester-Dendy artificial substrates into stream waters. On August 17, 1971, following approximately seven weeks of exposure, the substrates were removed. The structures were then disassembled and the resulting samples were washed, sorted, identified, and tabulated in the MDNR Lansing laboratory. The second method for collection of stream macroinvertebrates was performed during the July 14 to 28, 1971 sampling event that consisted of qualitative samples taken with long-handled dip nets and by hand picking. Collections were performed for a minimum of 15 minutes and were terminated when approximately five minutes of additional sampling failed to produce new species. Identification of aquatic species was made in the field and recorded.

Sampling performed at River Street in Comstock using a Hester-Dendy artificial substrate yielded a mean of eight benthic species and

924 individuals. The community structure was predominantly composed of caddisflies (71 percent) and midges (27 percent). Other macroinvertebrates found at River Street were moss animals, scuds, damselflies, and beetles. According to MDNR (1972), the low number of species and the skewed community structure was the result of plankton rich waters coming from Morrow Lake and the heated water discharged from the Bryce E. Morrow Power Plant.

The macroinvertebrate numbers found on the artificial substrate at the Michigan Avenue Bridge on the Kalamazoo River showed a shift in species population as compared to River Street. The mean number of different species represented was eight with an average of 115 individuals. The predominant organisms were midges (76 percent) and caddisflies (13 percent). Other species present were sludgeworms, scuds, damselfly larvae, aquatic moth larvae, and dance fly larvae.

Sampling performed at Paterson Street in Kalamazoo using two artificial substrates resulted in the collection of an average of 100 individuals representing 14 species. Midges predominated the fauna, and flatworms, moss animals, sludgeworms, scuds, mayflies, and caddisflies were also represented. According to the report (MDNR, 1972) the microinvertebrate community of the Kalamazoo River was not affected by waters from Portage Creek. In fact, the diversity of artificial substrate communities increased below the confluence. Collection of benthos with dip nets resulted in the identification of 25

species within the area, with the dominant animals being snails and damselflies. Also present were flatworms, sludgeworms, and leeches.

At Mosel Avenue in Parchment a total of four species and 271 individual organisms were collected by the artificial substrate method. Midges and sludgeworms dominated the colonizing organisms and, according to MDNR (1972), indicated very poor water quality. Dip netting in the area produced eight species with dense collections of sludgeworms, by far the most dominant group. Damselflies, midges, and crayfish were also identified along with low numbers of mayflies and snails.

Artificial substrates placed at D Avenue in Cooper Township were colonized with an average of 42 individual organisms representing a total of four species. Midges and sludgeworms were the most common, followed by snails and leeches. The sharp decline in the number of organisms indicate the probability of acutely toxic conditions in these waters (MDNR, 1972). Collection by dip nets was not performed at this location.

At the sampling station located at the end of B Avenue (two miles downstream of D Avenue), the artificial substrates were lost. Handpicking identified 17 species, with leeches, snails, and damselflies dominating the benthic community. Also present were sludgeworms, scuds, mayflies, beetles, and midges.

Improved conditions were apparent downstream of the railroad trestle in Plainwell (MDNR, 1972). Artificial substrates were colonized

by a mean of 121 individual organisms representing 12 species. Leeches, snails, sow bugs, scuds, water fleas, damselflies, and beetles were evident. The increase in diversity and balance of the artificial substrate community reflects essentially complete recovery and a fauna comparable to cleaner waters further upstream (MDNR, 1972). Handpicking in the area identified 20 species of macroinvertebrates.

At Monachia Street in Otsego, artificial substrate surveys were not performed; however, analysis using the dip nets identified 11 benthic species. Damselflies dominated the benthic community, followed by leeches, snails, crayfish, caddisflies, aquatic moth larvae, and beetles.

Artificial substrates placed at Highway M-89, west of Otsego, were colonized by an average of 95 organisms representing a total of eight species. MDNR (1972) reported a decline in water quality as midges and sludgeworms dominated, followed by low numbers of leeches, snails, sow bugs, scuds, and dance fly larvae. Hand picking identified 11 species.

Artificial substrates placed at the Trowbridge Dam were lost. Handpicking identified only six species of equal representation. The fauna consisted of scuds, damselflies, crayfish, caddisflies, and midges. At the headwaters of Lake Allegan, artificial substrates were lost, and handpicking identified sludgeworms, snails, leeches, damselflies, true bugs, and caddisflies.

A short distance below Lake Allegan Dam, sampling was done using an artificial substrate. The artificial substrate had only three

benthic species represented and 95 individuals with the predominant species being midges (97 percent) and caddisflies (3 percent).

At the next downstream station, off of the Route 89 Bridge, artificial substrates were colonized with an average of five species and 670 individuals. Caddisflies were the predominant invertebrate constituting 86 percent of the individuals. The shift in community structure was caused by the change in the natural environment from a slow river velocity to a higher velocity (MDNR, 1972).

At the sampling station near 57th Street, New Richmond, the artificial substrates were colonized with a mean of eight different species and 576 individuals. Caddisflies constituted 82 percent of the individuals collected with the remainder being flat worms, sow bugs, scuds, and damselflies. The community structure of this station was very similar to that of the previous station with the exception of the increase in the mean number of species.

The farthest downstream location sampled for invertebrates was the US-131 bridge crossing. The species population shifted from a caddisfly dominated community at the previous station to a midge dominated community at this station. Midges were 84.4 percent of the 1123 individuals collected. Also, the diversity of species declined from eight to six between New Richmond and US-131. The major reason for the shift between species is again the velocity of the river (MDNR, 1972). The river widens along this area, reducing the velocity of the

water and making the environment more suitable for midges as opposed to caddisflies.

1982 Fish Population Study

During July and August 1982, the MDNR performed a survey of the Kalamazoo River fishery (MDNR, October 1984) to derive estimates of the total standing crop of fish and assess any changes that had taken place since the 1971 survey. Among the locations sampled, seven areas were located between the Morrow Lake Dam and the mouth of the river at Saugatuck. Three principle forms of fish sampling were used: rotenone treatment, electro-fishing, and fyke netting. Comparison of the sampling techniques found rotenone treatment to be the most effective (MDNR, October 1984).

At the sampling location immediately below the Morrow Lake Dam 21 species were identified. This area had the highest smallmouth bass population of all sampled sites, and the second highest standing crop of game fish in the entire survey. Sampling performed one-half mile upstream from Mosel Avenue in Kalamazoo resulted in the identification of 10 species. These included rock bass, white suckers, carp, and smallmouth and largemouth bass. Carp and white suckers were the dominant fish in this location and at the next three sampling areas downstream. The carp were noted to have severely eroded fins from an unknown cause (MDNR, October 1984).

The next sampling location was 400 feet upstream from the Plainwell wastewater treatment plant outlet. Northern pike, white

suckers, bullhead, and carp were among the 16 species identified. Large numbers of young-of-the-year smallmouth bass, largemouth bass, and carp were found at this station. Approximately one mile downstream from the Otsego Dam, sampling identified 23 species of fish, along with an increase in the number of white suckers. In Lake Allegan, one-half mile downstream from Bridge Street, a total of 19 species were identified. In this area carp and white suckers were dominant, however, a remnant game fish population was present.

The sampling location located one-half mile below the M-89 bridge in Allegan had the highest standing crop of any station sampled, and the next station (one mile downstream from 57th Street) had the highest species diversity. Totals of 31 and 37 species were collected from these areas, respectively. Walleye, northern pike, and other game fish species were present in good numbers (MDNR, October 1984).

1982 Macroinvertebrate Study

Analysis of the benthic macroinvertebrates was performed by the MDNR in 1982 (MDNR, November 1982) to assess river water quality between Kalamazoo and Allegan. Included in the survey was the identification of benthos from two locations between the Morrow Lake Dam and the Portage Creek confluence, and from seven locations between the confluence and the Allegan City Dam. Macroinvertebrate samples were obtained using a triangular dip net and handpicking organisms from available substrate. Sampling was continued until no

new taxa were found. Benthos were identified as collected and their relative abundance estimated.

The stations located between the Morrow Lake Dam and the Portage Creek confluence contained macroinvertebrate communities typical of a good-quality warmwater stream (MDNR, November 1982). Macroinvertebrates were diverse, abundant, and dominated by mayflies, caddisflies, scuds, and blackflies. These communities were similar to those found in previous studies.

The benthic communities of the river downstream from Portage Creek were investigated at Paterson Street. The total number of taxa identified at the site was 19, with scuds, mayflies, and caddisflies being most abundant. According to MDNR (November 1982), the slight shifts in community structures compared to above Portage Creek were likely due to reduced macroinvertebrate habitat and predominance of shifting sand substrate.

At Commerce Lane near Mosel Avenue, a total of 16 organisms were identified with midges, sow bugs, and oligochaetes predominating. A total of 14 species were identified at both D Avenue and the railroad crossing at Plainwell. Leeches, sow bugs, and beetles were abundant at D Avenue with sow bugs and crayfish being most abundant in Plainwell.

At the US-131 Bridge in Plainwell, a total of nine species were identified. Abundant organisms included leeches, sow bugs, and blackfly larvae. The location at Highway M-89 in Otsego yielded a

total of seven species in equal abundance, while the station at 26th Street near the Trowbridge Dam yielded 13 species. According to MDNR (November 1982), the presence of these types of communities demonstrates that the wasteload from the Kalamazoo wastewater treatment plant had exceeded the normal biological community's ability to assimilate wastes.

1984 Macroinvertebrate Study

Between April and October 1984, the MDNR performed a study on benthic communities in the Kalamazoo River between Comstock and Plainwell. The survey (MDNR, February 1986) included 13 sampling locations between River Street in Comstock and the Allegan City Dam. Benthic macroinvertebrate samples were collected using a triangular dip net and by hand picking available substrate. Sampling was continued until no new taxa were found. Taxa were identified on site, to the lowest taxonomic level possible, and relative abundance was noted.

Upstream of the Kalamazoo wastewater treatment plant, benthic macroinvertebrate communities were diverse (8-15 taxa) and dominated by scuds, mayflies, and caddisflies (MDNR, February 1986). The aquatic life downstream of the Kalamazoo wastewater treatment plant was dominated by sow bugs, blackflies, midges, and leeches, and is typical of those found in organically enriched streams (MDNR, February 1986). Also noted were growths of Cladophora algae present downstream of the Kalamazoo wastewater treatment plant to Plainwell.

1986 Fish Population Study

In May and June 1986, a fish population study was performed at five stations, from above the Kalamazoo wastewater treatment plant to 0.9 miles downstream (Gaule, 1987). Forty-four individuals were collected, representing 10 species. Game fish represented 52.3 percent of the population. Dominant game fish were bluegill and black crappie. Yellow bullhead and carp dominated the non-game fish.

1986 Macroinvertebrate Study

In June through October 1986, a macroinvertebrate study was performed in the Kalamazoo River between the Morrow Lake Dam and D Avenue (Gaule, 1987). Artificial substrates were placed at five stations and revealed a macroinvertebrate population dominated by midges, scuds, and caddisflies.

The location with the highest number of organisms was below the Morrow Lake Dam, which had a mean of nine families represented. This station was dominated by caddisflies.

The station with the fewest number of organisms was located at Paterson Street, with a mean of seven families represented. This station was dominated by scuds and caddisflies. The low number of organisms was suggested to be a result of a covering of brown organic material on the substrate, low DO content, and a shifting silt and sand substrate (Gaule, 1987).

The station with the largest number of families was at D Avenue. Artificial substrates revealed means of 12 and 10.5 families each. The

large number of families was believed to be a result of large patches of Cladophora algae, a swift current, and higher DO concentrations (Gaule, 1987).

1988 Macroinvertebrate Study

In July 1988, benthic plant and animal communities were sampled by MDNR in the Kalamazoo River between Comstock and Plainwell to document any changes from previous studies. Six river stations were selected, and macroinvertebrate samples were collected with dipnets and by handpicking available bottom substrate. Sampling continued at each station until no new taxa were identified. Taxa were identified to the lowest taxonomic level possible, and relative abundance was noted. Total number of taxa identified at each location ranged from 15 to 18, and the macroinvertebrate and plant communities indicated substantially improved water quality in comparison to 1984 conditions (MDNR, September 1988). Improvements were also observed in the decrease of nuisance growths of Cladophora algae.

1989 Macroinvertebrate Study

On August 16, 1989, benthic plant and animal communities were sampled by MDNR between the city of Kalamazoo and Allegan to compare river conditions to previous surveys. Nuisance growths of Cladophora algae were absent, and the numbers of macroinvertebrate taxa increased. According to MDNR (February 1990), results demonstrated continued improvement of the stream quality conditions downstream of the Kalamazoo wastewater treatment plant discharge.

5.3.1.5 Waterfowl Surveys

In August 1985, the U.S. Fish and Wildlife Service (US FWS) collected waterfowl from five locations on the Kalamazoo River (MDNR, December 1987). Included in the study were birds sampled from the Otsego City and Trowbridge impoundments, Lake Allegan, and Saugatuck. The birds were plucked, eviscerated, and their feet were removed prior to analyses. Samples were analyzed for lead, cadmium, mercury, and PCBs (as Aroclor 1260).

Samples collected from the Otsego City Impoundment included one adult mallard, one immature mallard, and one immature blue-winged teal which had PCB concentrations of 4.8, 2.0, and non-detectable (at a detection limit of 0.25 mg/kg), respectively. Two immature mallards collected from the Trowbridge Impoundment contained PCB concentrations of 1.9, and 0.73 mg/kg (as Aroclor 1260).

One immature wood duck and one immature Canada goose were collected from the Allegan State Game Area. The wood duck was found to contain 1.5 mg/kg PCBs, while PCBs were not detected in the goose at the detection limit of 0.25 mg/kg. At Saugatuck, eight immature mallards, one adult mallard, and one adult wood duck were collected. The immature mallards ranged in total PCB concentrations from non-detectable (at a detection limit of 0.25 mg/kg) to 1.9 mg/kg. The adult mallard and adult wood duck had total PCB concentrations

of 0.98 mg/kg and non-detectable (at a detection limit of 0.25 mg/kg), respectively.

In 1986, mute swan eggs were collected from the Allegan State Game Area in the vicinity of the Kalamazoo River as part of an effort to reintroduce the trumpeter swan. The 14 eggs collected ranged in total PCBs from 0.1 to 1.6 mg/kg with a mean concentration of 0.4 mg/kg (MDNR, December 1987).

In 1988, a statewide waterfowl study was conducted by the US FWS, MDNR, and MDPH (Hesse, 1992). One mallard hen was collected from the Kalamazoo River in Allegan County and two samples, one sample with skin and one without, were analyzed for organochlorines, PCBs, and mercury. Mercury was detected at 0.13 mg/kg in both samples. All other constituents were not detected at their respective detection limits (0.05 mg/kg for PCBs and 0.01 mg/kg for organochlorines) in the skinless sample. PCBs and p,p'-DDE were detected in the skin-on sample at concentrations of 0.29 and 0.01 mg/kg (wet weight), respectively.

5.3.2 History of Proposed Interim Actions by MDNR

As part of the March 1986 study entitled "Feasibility Study of Alternatives" for the Kalamazoo River PCB project, NUS Corporation developed a steady-state, one-dimensional PCB model that was used to screen remedial technologies and evaluate interim action alternatives (NUS, 1986).

Along the section of the Kalamazoo River and floodplain between the confluence and the Allegan City Dam, different interim action alternatives were evaluated, depending on whether the dams were drawndown (Plainwell, Otsego, and Trowbridge) or impounded (Otsego City and Allegan City).

For the drawndown dams, the following interim action alternatives were evaluated: no action; channel lining and soil capping; channel lining and bufferzone establishment; channel lining and impermeable cap placement; and excavation and on-site disposal. NUS predicted that these alternatives would have less of an environmental benefit than remediating Bryant Mill Pond (NUS, 1986).

For the impounded dams, the following interim action alternatives were considered: no action; dredging and/or excavation with upland disposal; channel dredging; channel lining with soil cap (Otsego City Dam); and channel dredging and channel lining with an impermeable cap (Otsego City Dam).

Several other interim action alternatives were evaluated using the NUS model. These alternatives included: reimpoundment of the Plainwell, Otsego, and Trowbridge dams; and reimpoundment of these dams in addition to channel lining and impermeable cap for Portage Creek. The NUS model predicted positive results for both of these alternatives, although NUS noted that caution should be used in assessing the reimpoundment scenarios pending further study.

Based on the recommendations of the NUS Feasibility Study, the MDNR developed an interim remedial action plan. The plan called for isolating

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selected floodplain sediments along the margins of the river through excavation and storing of the sediments on MDNR property. The excavations would be backfilled with clean fill to provide a buffer area between the river and undisturbed contaminated floodplain sediment.

The NUS Feasibility Study recommended removing the remnant dam structures (sills) at the Plainwell, Otsego, and Trowbridge dams. Removal of the sills was thought to lower the impoundments and therefore further isolate the PCB-containing floodplain sediments.

In December 1987, MDNR retained GZA-Donohue to prepare plans and specifications to implement the NUS recommendation in the three drawdown impoundments. The conceptual design effort included the following steps: pre-design investigations; hydraulic modeling; design of the excavation program and containment structures; and development of cost estimates.

A pre-design field investigation was performed to delineate the extent of PCB-containing sediments and soils in the Plainwell, Otsego, and Trowbridge impoundments. Rather than perform extensive PCB analyses, core samples from 282 locations were collected and classified for a variety of parameters. A total of 74 samples from 19 cores were analyzed for PCBs.

The apparent physical characteristics of the samples were intended to provide a general qualitative indication of PCB presence. Based upon the results, it appears that physical characteristics would not be a good quantitative predictor of PCB concentration.

GZA-Donohue used the U.S. Army Corps of Engineers (USACE) HEC-2 hydraulic model to develop a representation of the current conditions on the Kalamazoo River. The HEC-2 model was used to determine the floodplain conditions for the 2-, 5-, 10-, and 100-year recurrence events. A post-construction model was developed to analyze the effect of dam removal, channel dredging above the dams, channel realignment in two oxbow areas, and removal of bank material at select locations.

5.4 King Mill

5.4.1 Past Surveys

Wastewater surveys performed on the King Mill clarifier's effluent by MWRC in 1961, 1967, 1968, 1969, and 1970 included the analysis of various water quality parameters. Table 63 summarizes the results of these surveys.

In May 1987, three soil samples were taken in the area by MDNR (Table 64). The results indicated PCB concentrations of non-detectable (at a detection limit of 0.65 mg/kg), 4.5, and 9.1 mg/kg as Aroclor 1248. The 4.5 mg/kg sample was taken from an old lagoon north of the railroad tracks, and the other two were taken from an area east of the tracks. Specific sampling locations are unknown. No other MDNR Scan 3 compounds were detected (Bohunsky, 1988).

5.5 Georgia-Pacific Corporation Kalamazoo Mill

5.5.1 Past Surveys

In 1973, the MWRC collected an eight-hour composite sample of the Georgia-Pacific outfall discharge to the Kalamazoo wastewater treatment plant. The sample contained a PCB concentration of 4.8 ug/L (MBWM, 1973).

In July 1977, a wastewater survey was conducted by MDNR at the Georgia-Pacific outfalls. Samples were collected from the process wastewater outfall which discharged to the city sanitary system and from the cooling water outfall (003) which discharged to the Kalamazoo River. All samples analyzed in this study had non-detectable PCB concentrations (at a detection limit of 0.1 ug/L) (MDNR, 1977).

Between 1980 and 1989, numerous analytical tests were conducted by Georgia-Pacific on residuals from the mill. In June and July of 1980, three separate analyses were performed on the leachate from the paper mill residuals. The results of these tests (Table 65) all indicated non-detectable PCB concentrations (EDI, 1980; ERG, 1980; WMES, 1980).

EP Toxicity tests were conducted on the residual leachate in April 1983, April 1986, February 1987, December 1987, and August 1988; in May 1990, a Toxicity Characteristic Leaching Procedure (TCLP) Evaluation was also performed on the residuals. The results of the EP Toxicity analyses indicated that the leachate did not exhibit the characteristics of EP Toxicity, and the results of the TCLP evaluation indicated that the residuals were non-hazardous (EDI, May 1983; KAR, May 1986; KAR, March 1987a; WMES,

January 1988b; KAR, September 1988; WMES, 1990). The results of these analyses are presented in Tables 66 and 67.

Residuals samples were tested for PCBs in the December 1987, August 1988, and May 1990 studies. In December 1987, the concentration of PCBs in the residuals sample was 6.5 mg/kg, and the concentration in the leachate was non-detectable (at a detection limit of 1 ug/L) (WMES, January 1988a). In the August 1988 and May 1990 studies, PCB concentrations in the residuals were not detected at detection limits of 0.005 mg/kg and 0.5 mg/kg, respectively (KAR, September 1988; WMES, 1990).

In the April 1986 and February 1987 studies, ASTM Leachate Analyses were also performed on the paper mill residuals in addition to the EP Toxicity tests. The results of both of these tests indicated non-detectable PCB concentrations at a detection limit of 1 ug/L. (KAR, May 1986, March 1987b). The results of these tests are summarized in Table 66.

In the 1989 "Report on Further Characterization of Papermill Residues" prepared by Georgia-Pacific, 16 composite sludge samples were analyzed for metals and chloroform. The results of these analyses are presented in Tables 68 and 69. None of the metals analyzed for were detected in concentrations exceeding the Federal Drinking Water Standards, with the exception of iron (a secondary standard) (Georgia-Pacific Corporation, 1989). The values of iron concentrations in the samples were not outside of concentration ranges normally found in the region. The results of chloroform analyses ranged from 0.009 mg/kg to 0.20 mg/kg. Chloroform

is a by-product of fresh water treatment with chlorine. This is the most probable source of chloroform in the residuals (Georgia-Pacific Corp., 1989).

5.6 King Highway Landfill

5.6.1 Past Surveys

Two samples from the walls of the King Highway Landfill (GP-3 and GP-4) were analyzed for PCBs in June 1986. Table 70 presents the results of these analyses, which show concentrations of 35 and 45 mg/kg at the locations sampled (Creal, 1986).

In April 1987, the MDNR sampled soils and residuals at several locations both inside and outside of the landfill boundary as shown on Figure 19. Analytical results showed PCB concentrations of soils outside of the landfill boundary (sample numbers 21, 23, 24, and 26) up to 3 mg/kg. A sample of historical residuals from Area 2 (sample number 27), identified as deposited prior to 1977, had a PCB concentration of 5.4 mg/kg. New residuals (deposited beginning in 1987) from Area 1 (sample number 25) had non-detectable PCB concentrations (at a detection limit of 1.2 mg/kg) (MDNR, April 1987). These results are presented in Table 71.

During December 1990, shallow borings (less than 4 feet) collected from Area 3 (HA-1, HA-2, HA-3) had PCB concentrations ranging from 1.7 to 3.4 mg/kg. Historical material from Area 2 was sampled and analyzed for PCBs in January 1991. The PCB concentrations in these samples (SB-1 and SB-2) ranged from non-detectable concentrations to 28 mg/kg with an

average of 9.7 mg/kg (ERM, 1991). The results are summarized in Table 72.

Area 2 is currently receiving residuals, and the recent residual material is approximately 13 feet thick. The residuals are dewatered by the belt-filter presses and analyzed annually.

Ground water at the King Highway Landfill was analyzed for PCBs during sampling conducted for the landfill monitoring program in February 1988, March 1988, June 1990, and June 1991 (Table 73). All analyses showed non-detectable PCB concentrations (a detection limit of 0.5 ug/L) (WMES, March 17, 1988; Anderson, 1988; KAR Laboratories, July 12, 1990, July 16, 1991).

Tables 74 and 75 present the results of a variety of general ground-water quality parameters analyzed for during ground-water sampling at the King Highway Landfill for the quarterly monitoring program. Table 76 presents water quality data from ground-water samples taken in Kalamazoo County, for comparison. Most of the parameters analyzed for at the King Highway Landfill were within the normal range for Kalamazoo County. Table 77 summarizes the ground-water elevations measured during well sampling.

During a ground-water sampling event in June 1988, vinyl chloride and cis-1,2-dichloroethene were detected at MW-1, MW-4, and MW-5 (MDNR, June 1988). Table 78 presents the results of this sampling and three subsequent ground-water sampling events, which detected these compounds in MW-7 also. Cis-1,2-dichloroethene was detected at concentrations below the EPA maximum drinking water concentration of 70 ug/L. However, vinyl

chloride concentrations exceeded the EPA's 2 ug/L maximum drinking water concentration (40 CFR 141). The source of these compounds is suspected to be upgradient of the landfill. Vinyl chloride and cis-1,2-dichloroethene may be formed from the anaerobic degradation of tetrachloroethane, a common degreasing agent used by automotive garages and maintenance shops. Past and current uses of the upgradient area include automotive maintenance shops and an unregulated 1940s landfill (Hester, November 3, 1989).

5.6.2 Response Actions

The King Highway Landfill is currently licensed by MDNR to receive dewatered residuals from the Georgia-Pacific Paper Mill. The areas are being filled from west to east. A final closure plan by Georgia-Pacific has been submitted; however, it has not been approved by MDNR. It is anticipated that upon closure of each area, that area will be capped with a soil/geomembrane cover (MDNR, June 1991) or the requirements of Act 641 at that time a closure plan is approved.

5.7 Willow Boulevard Site

5.7.1 Past Surveys

In December 1986, William Creal of the MDNR reported that PCBs were found at concentrations of 44 and 47 mg/kg in two surficial sediment samples (GP-1 and GP-2) he had collected near the Willow Boulevard Site (Figure 21) in June of that year. The material appeared to be eroding into the Kalamazoo River (Creal, 1986).

A surficial and at-depth soil sampling program was conducted by MDNR and Georgia-Pacific during 1987 and 1988 (Table 79). Sampling locations are shown on Figure 21. Forty-one surficial samples (0 to 2 feet) analyzed for PCBs had a range in concentration from non-detectable (at a detection limit of 0.65 mg/kg) to 170 mg/kg with an average of 65 mg/kg. At-depth (2 to 26 feet) samples averaged 66 mg/kg, with a range in concentration from non-detectable (at a detection limit of 0.65 mg/kg) to 170 mg/kg. Geotechnical parameters from selected borings are summarized in Table 80.

Soil samples were collected at 19 locations (Figure 21) in the neighboring Lakewood area in July and August of 1987 (Table 81). All of the samples except one had non-detectable concentrations of PCBs (at a detection limit of 0.050 mg/kg) concentrations of PCBs (MDPH, September 1987). One sample contained a total PCB concentration of 0.080 mg/kg (Aroclors reported were 1016 and 1260) and was considered by the MDPH as not posing a threat to public health (Chadzynski, 1987).

Worms were collected by MDNR from the Willow Boulevard Site on May 19, 1987, near surficial sample locations 2 and 6 (Figure 21). The results indicated that the worms contained PCB concentrations of 8.7 and 9 mg/kg. The Aroclors reported were 1242 and 1254 (approximately 85 and 15 percent, respectively) (Creal, May 1987).

Ground-water monitoring has been conducted at the three on-site wells, shown on Figure 21. Ground-water samples were collected in February and March 1988. The results of these analyses are presented in Table 82. The

concentrations of total PCBs ranged from non-detectable (at a detection limit of 0.025 mg/kg) to 1.4 ug/L with an average concentration of 0.28 ug/L. A filtered ground-water sample from MW-3 contained 0.16 ug/L PCBs, and the unfiltered sample had a PCB concentration of 1.4 ug/L. The prevalent PCB Aroclor used for quantation was Aroclor 1242 (WMES, February 16, February 22, February 29, and March 17, 1988).

In 1987, the MDPH sampled a residential well at 1017 Riverside Avenue, at the corner of St. Joe Avenue. The ground-water sample was analyzed for Scan 1, 2, and 3 parameters, and all parameters were found to be non-detectable (MDPH, July 1987).

An EP Toxicity test was performed on a composite sample of fill material collected from boring B-3/MW-3 and the results are presented in Table 83. The metals concentrations were below the concentrations which define the characteristics of EP Toxicity (40 CFR 261.24).

Table 83 also presents the results of the TCLP (SW-846, Method 1311) and ASTM D3987-85 extractions that were conducted on samples of residuals collected from the Willow Boulevard Site. The results of the TCLP indicated that PCB concentrations ranged from 0.24 to 1.4 ug/L (Aroclor 1242). The ASTM extraction results ranged in PCB concentrations from 0.08 to 0.22 ug/L (Aroclor 1242) (WMES, March 3, 1988).

In February 1990, dioxins (PCDDs) and furans (PCDFs) were analyzed in four residual samples from the western half of the site (near borings 1A, 5A, 7A, and 9A) at a depth of 1.8 to 2 feet. The results are summarized in Table 84. Detected concentrations of 2,3,7,8-TCDD, which is considered

to be the most toxic PCDD/PCDF congener, range from 0.000016 to 0.000117 mg/kg with an average concentration of 0.000061 mg/kg (Sullivan, 1990).

In June 1990, ground-water samples from monitoring wells MW-1 and MW-3 were analyzed for PCDD and PCDF homologues and 2,3,7,8-congeners. The results are summarized in Table 85. All congeners were undetected except for 1,2,3,4,6,7,8-heptachlorodibenzodioxin which was also found in the blank. Total hexachlorodibenzodioxin was reported for MW-3 at a level of 0.000007 ug/L. Total pentachlorodibenzofuran was reported at 0.00002 ug/L in MW-1.

Blood serum from nine worm diggers was analyzed for PCBs by MDPH in July and August 1987. Blood serum concentrations ranged from non-detectable (at a detection limit of 3 ug/L) to 14 ug/L with a median of 5.1 ug/L (Table 86). Eight of the nine samples indicated blood serum concentrations below 9 ug/L, and two of these eight were non-detectable (at a detection limit of 3 ug/L). PCB concentrations in blood serum in Michigan residents range from non-detectable concentrations to 60 ug/L and average 6.6 ug/L (Oudbier, 1987).

5.7.2 Response Actions

PCBs were first detected at the Willow Boulevard Site in 1986. In April 1987, Georgia-Pacific Corporation began implementation of a response program which included:

1. Placing 224 cubic yards of broken concrete on a crushed limestone base, up to 8 feet above river level along 268 feet of the site's northeast edge, to prevent erosion (Figure 21);
2. Covering a number of unvegetated areas with crushed stone to minimize soil erosion;
3. Fencing the site with a 6-foot high chain-link fence, topped with strands of barbed wire; installing lockable gates along the road frontage of the landfill's southern border; removing nearby trees which could be climbed in order to gain entrance; and posting the site with "NO TRESPASSING" signs to restrict public access;
4. Removing fallen trees, believed to have contributed to soil erosion along the riverbank; and
5. Performing additional sampling of the residuals for PCBs (Dell Engineering, February 1988).

In April 1988, Georgia-Pacific submitted a "Report on Management Options" to MDNR, which discussed options for remedial action. The preferred remedy was capping the area with a soil, synthetic membrane, and fabric-formed concrete cap and placement of a riverbank sheet-piling wall (Dell Engineering, April 1988). The MDNR stated that the proposed action was technically feasible, was consistent with Michigan's Surface Water Quality Standards, and with adequate monitoring and maintenance would protect public health and the environment (Zugger, 1989).

In anticipation of the proposed revisions to Act 641 and the newly revised Act 307, Dell Engineering redesigned the cap for Georgia-Pacific in

October 1990. A composite soil/geomembrane cap was designed which would be continuous to a depth below the river level. The portion of the cover in contact with the river or having potential to contact flood waters would be overlain with rip-rap to prevent erosion of the cover system and to protect the barrier layer from burrowing animals (Litteral, 1990). Closure details were outlined in the "Interim Remedial Action Plan" submitted to the MDNR in November 1990 (Dell Engineering, November 1990).

The remedial plan also included other modifications to the present site including: temporary dewatering of the bordering riverbank to install the geomembrane, removal of eroded residuals from the river and placement on site, and extensive regrading of the site to direct storm water to the river (Litteral, 1990). To date, MDNR has not responded to the proposed interim response. Although the cap was proposed as an interim measure, it would have met the requirements of a Type C remediation under Act 307 according to the analysis conducted by Blasland & Bouck Engineers, P.C. (Blasland & Bouck Engineers, P.C., January 1991).

5.8 A-Site

5.8.1 Past Surveys

Surficial soil samples collected in April 1987 from the east end of the A-Site (sample numbers 12, 15, and 16) had concentrations of PCBs ranging from non-detectable (at a detection limit of 1 mg/kg) to 3 mg/kg (SEI, May 1987). The data are presented in Table 87. Sample locations are shown on Figure 23.

Table 88 summarizes the results of the analysis of samples from soil borings drilled at the A-Site during July 1990 (SB-1 through SB-10, MW-4, and MW-5). For all borings, sample PCB concentrations in the top 2 feet were non-detectable at a detection limit of 1 mg/kg. The at-depth (2 to 26 feet) PCB concentrations ranged from non-detectable (at a detection limit of 1 mg/kg) to 15 mg/kg (SEI, October 1990).

Soil samples were collected from 11 locations (A-1, A-3, A-7, A-11, B-8, B-14, C-3, C-5, C-9, C-13, and D-13) in the area east of Davis Creek in July 1990 (Figure 23). At all locations, the top 6 inches of soil was collected, and at five locations (A-3, A-7, A-11, B-14, and C-9) the underlying sand 2 feet below the surface was also sampled. The analyses of these samples, presented in Table 89, indicated PCB concentrations of up to 5 mg/kg (SEI, October 1990). A duplicate analysis of sample B-14 indicated a PCB concentration of 80 mg/kg (MDNR, December 1990).

Ground water was sampled at the A-Site between February 1988 and August 1990 and the results are summarized in Table 90. Ground-water monitoring wells MW-2, MW-3, and MW-5 had non-detectable concentrations of PCBs (at a detection limit of (0.05 ug/L). Monitoring well MW-1, located in the northeast corner of the site, had PCB concentrations ranging from 0.59 to 3.2 ug/L (Anderson, 1988; Dell Engineering, July 1989; SEI, October 1990). The initial sampling of MW-1 exhibited a PCB concentration of 22 ug/L. Georgia-Pacific suspected that the well became contaminated during well installation because the other ground-water samples showed significantly lower concentrations (Anderson, 1988). Indeed, monitoring well

MW-4, which is located near MW-1, had a PCB concentration of 0.2 ug/L when sampled in July 1990.

Split samples of surface water were collected by MDNR and Swanson during April 1987 (Table 91). Ponded water near MW-1 was analyzed and results indicated a PCB concentration of 0.15 ug/L as Aroclor 1248 (Creal, June 24, 1987). Water in Davis Creek and in a ditch between the Willow Boulevard Site and A-Site (former Olmstead Creek) had non-detectable PCB concentrations (detection limit of 1 ug/L, SEI, May 1987; detection limit of 0.02 ug/L, Creal, June 24, 1987).

Worms were collected by William Creal of the MDNR near surficial soil location 12 during May 1987. MDPH analysis of the sample indicated non-detectable concentrations (at a detection limit of 0.1 mg/kg, dry weight) (Creal, May 1987).

5.8.2 Response Actions

The A-Site currently has 6-foot high fencing along a portion of its perimeter with a lockable gate at the entrance off of Willow Boulevard. The dike surrounding most of the landfill is vegetated with trees and shrubs, and prevents erosion of material into the Kalamazoo River.

The eastern part of the A-Site is fully revegetated due to a revegetation program performed by Georgia-Pacific. The west end of the site was also seeded and will be revegetated in the near future.

5.9 King Street Storm Sewer

5.9.1 Past Surveys

In August 1976, effluent from the King Street storm sewer (Figure 19) was analyzed for PCBs as part of a 24-hour wastewater survey of the discharge to the Kalamazoo River. The discharge contained 0.19 ug/L reported as Aroclor 1254. Additional analyses of a tannish colored material present in the discharge prior to the survey period had 240 mg/L BOD_5, 4270 mg/L suspended solids (SS), 3 mg/L phosphorus, 6 mg/L zinc, and 3300 colonies/100 ml coliform. This material was only present for 10 to 15 minutes. A composite sample taken during the survey had non-detectable (detection limit of 5 mg/L) BOD_5, 4 mg/L SS, 0.3 mg/L phosphorus, 0.05 mg/L zinc, and concentrations of nickel, copper, and chromium below the detection limits. At the conclusion of the survey, a weir was removed and the sewer was scoured. A sample of the scouring water contained 200 mg/L oil and grease (Polasek, 1976).

Soil sampling by the MDNR near the storm sewer in July 1986 (KS-1 and KS-2) detected Aroclor 1242 concentrations of 5.1 and 64 mg/kg, as presented on Table 70. The sampling locations were between the King Highway Landfill dike wall and the Kalamazoo River. Methoxychlor, a pesticide, was found in sample KS-2 at a concentration of 11 mg/kg. No other Scan 3 compounds were detected (Creal, 1986).

In April 1987, Georgia-Pacific Corporation conducted a soil survey of the King Highway Landfill. Soil samples collected outside of the landfill berm and near the King Street storm sewer outfall (19, 20, and 22) had

total PCB concentrations between 51 and 99 mg/kg, while samples collected within the bermed area of the landfill (21 and 23 through 27) had PCB levels below 6 mg/kg (Table 71). A soil sample collected from the effluent pipe (sample 18) showed non-detectable (detection limit of 1 mg/kg) concentrations of PCBs (MDNR, April 1987).

In response to the findings of April 1987, MDNR requested additional sampling of the King Street storm sewer (Table 92, Figure 19). In August 1989, eight shallow borings (B-1 through B-8) were completed to a depth of up to 3.5 feet and samples were analyzed for PCBs. The top 6 inches had an average concentration of 25 mg/kg, ranging from 3.6 to 48 mg/kg total PCBs. Samples taken from depths of 1.0 to 3.5 feet ranged in PCB concentration from 0.19 to 40 mg/kg. Aroclors used for quantitation included Aroclor 1016, 1248, and 1254 (ERM, October 1989). The material sampled was described as paper waste residuals-like material (Hester, November 10, 1989).

Terra Environmental Corporation collected soil samples for Georgia-Pacific on October 18, 1988 for use in a demonstration of the Clor-N-Soil PCB Screening Kit. Borings up to 60-inches deep were collected at six different locations (A through F) on the eastern bank of the outfall (Figure 19). The samples were analyzed by KAR Laboratories and the data are presented in Table 93. The results indicated PCB concentrations ranging from non-detectable (detection limit of 0.5 mg/kg) to 44 mg/kg as Aroclors 1248 and 1254 (KAR Laboratories, November 1988).

5.10 Simpson Plainwell Paper Company Mill

5.10.1 Past Surveys

In 1984, residuals from the Simpson Plainwell Mill were sampled by KAR Laboratories and an EP Toxicity test was conducted. None of the samples exhibited the characteristics of EP Toxicity (KAR, November 1984). Similar studies conducted in 1986 and 1989 resulted in the same conclusions (KAR, October 1986, October 1989). The results of these studies are presented in Table 94.

In March 1991, analyses were performed on ASTM and TCLP extracts from the mill residuals. The TCLP extract was analyzed for purgeable halocarbons and purgeable aromatics, and none were detected. The ASTM extract was analyzed for various metals. The results of this analysis are presented in Table 94.

In October 1984, four water samples from each of the mill's outfalls (004 and 005) were analyzed for purgeable halocarbons. These samples had non-detectable concentrations of all MDNR Scan 1 parameters except chloroform and 1,1-dichloroethane. Chloroform was detected in two samples of the process wastewater outfall (005) at a concentration of 0.001 and 1.0 mg/L, and in one sample from Outfall 004 (cooling and storm water) at a concentration of 0.001 mg/L (KAR, December 1984). As a result, Plainwell Paper resampled Outfall 005. The results of this second analysis (Table 95) indicated non-detectable chloroform concentrations at the detection limit of 0.001 mg/L (Lawton, July 1985). Low levels of 1,1-dichloroethane (0.0001 and 0.0002 mg/L) were detected in Outfall 004; however, this

compound was also detected in the intake water at a level of 0.0019 mg/L in a previous MDNR wastewater survey (MDNR 1984d).

Several samples of the mill discharge were collected by the MDNR between 1971 and 1988. A sample collected from the mill discharge in 1971 had no detectable PCB concentrations (at a detection limit of 0.1 ug/L). Two samples collected from the mill discharge in August and September 1985 had non-detectable PCB concentrations (at the detection limit of 0.010 ug/L) and 0.039 ug/L, respectively (MDNR, August-September 1985). The MDNR performed an industrial wastewater survey for various water quality parameters at the mill in January 1985 and April 1988. The results of both surveys found non-detectable PCB concentrations (detection limits of 0.1 and 0.05 ug/L, respectively). These results are presented in Table 96. In the January 1985 survey, samples from Outfalls 004 and 005 were analyzed for MDNR Scan 1 (Purgeable Halocarbons) and Scan 3 (Chlorinated Hydrocarbons, PCBs, and Organochlorine Pesticides) compounds, and no compounds were detected. In the April 1988 survey, Outfall 005 was analyzed for Scan 1, 2 (Purgeable Aromatic Hydrocarbons) and 3 compounds. None of these compounds were detected (MDNR, January 7-8, 1985, April 1988).

The MDNR performed an aquatic toxicity test on Outfall 005 effluent in 1985 and 1988. The results, presented in Table 97, demonstrated that the effluent was not acutely toxic, and satisfied the requirements of the Michigan Water Quality Standards (MDNR, January 9-11, 1985, May 1988).

5.11 12th Street Landfill

5.11.1 Past Surveys

Wastepaper was deinked at the Plainwell Mill between 1910 and 1962. The residuals deposited at the landfill between 1957 and 1962 may have contained PCBs due to the presence of PCB-containing carbonless paper in waste paper during that time.

A surface water quality investigation was conducted during 1973 at the 12th Street Landfill by Williams & Works (1973). The study consisted of the collection and analysis of nine surface water samples from the areas close to the landfill. The samples were analyzed for several water-quality parameters including pH, COD, ammonia nitrogen, organic nitrogen, total phosphorous, specific conductivity, sulfate, zinc, and copper. The study concluded that the presence of the mill residuals produced no obvious harmful ecological effects on the lowlands and Kalamazoo River in the vicinity of the site. Aquatic fauna, zooplankton, and other forms of plankton typical of naturally pooled river waters, were observed in the samples, and terrestrial plants (brush) seemed to thrive on the mill residuals. No obvious harmful ecological effects or significant changes in water quality in the surrounding lowlands and the Kalamazoo River could be attributed to either leachates or surface runoff.

In June 1987, representatives from MDNR and Plainwell Paper took samples of residuals outside the east side of the retaining berm (sample numbers 1 through 3) and one sample of residuals from the mill (sample number 4). PCBs were detected in samples 1, 2, and 3 during this

sampling program, which led to two other sampling events (September 1987 and January 1989) at the locations (1 through 7, and SB1 through SB6) shown on Figure 26. A total of 24 samples were analyzed. In the first sampling event, PCB concentrations ranged from non-detectable (at a detection limit of 0.1 mg/kg) to 39 mg/kg (Table 98). Residuals samples analyzed from the September 1987 sampling event ranged in PCB concentrations from non-detectable (at a detection limit of 0.5 mg/kg) to 21 mg/kg. The third sampling event detected PCB concentrations from 0.16 to 20 mg/kg, with one sample at 120 mg/kg (the 120 mg/kg concentration was detected in boring SB6 located on the west side of the landfill).

5.11.2 Response Actions

On August 27, 1990, the MDNR conducted an electromagnetic survey of the landfill to determine whether buried drums existed there. The results of this survey were sent to Simpson Plainwell on May 16, 1991. August 5, 1991, Simpson Plainwell conducted a follow-up geophysical survey to determine if metallic objects had been deposited in the landfill. Both electromagnetic and magnetometer surveys were performed. Magnetic anomalies were found in several areas in the southern and eastern portions of the site (Geraghty & Miller, 1991).

References

REFERENCES

Adams, Ray, Kalamazoo Nature Center, Personal Communication (April 25, 1991).

Agency for Toxic Substances and Disease Registry (ATSDR), "Toxicology Profile for Selected PCBs (Aroclors 1260, 1254, 1248, 1232, 1221, and 1016)," U.S. Public Health Service, 1989.

ATSDR, Preliminary Health Assessment Allied Paper/Portage Creek/Kalamazoo River, Kalamazoo, Kalamazoo County, Michigan. MID 006007306 (Working Draft). Prepared by Interagency Center on Health and Environmental Quality, Michigan Department of Public Health under cooperative agreement with Office of Health Assessment - Agency for Toxic Substances and Disease Registry, March 7, 1990.

ATSDR, Preliminary Health Assessment Allied Paper, Inc./Portage Creek/Kalamazoo River, Kalamazoo and Allegan Counties, Michigan. MID006007306 (Public Comment Draft). Prepared by Interagency Center on Health and Environmental Quality, Michigan Department of Public Health under cooperative agreement with Division of Health Assessment and Consultation-Agency for Toxic Substances and Disease Registry, February 19, 1991.

Albro, P.W. and C.E. Parker, "Comparison of the Compositions of Aroclor 1242 and Aroclor 1016," Journal of Chromatography, 169: (1979), pp. 161-166.

"Allied Paper Mills, Inc., Stresses Employee Activities," Kalamazoo Gazette, June 24, 1934.

"Allied to Close Mill at Otsego," Kalamazoo Gazette, February 29, 1956.

Amano, M., K. Yagi, H. Nakajima, R. Takehara, H. Sakai, and G. Umeda, "Statistical Observations About the Causes of the Death of Patients with Oil Poisoning," Japan Hygiene, 39(1): (1984), pp. 1-5.

Anderson, Jack A., Georgia-Pacific Corp., Letter to Lynn Spurr, MDNR (April 8, 1988).

Anderson, Jeffrey, GZA-Donohue, Letter to Bill Creal, MDNR (January 26, 1989).

Anderson, Jeffrey, W. Birge, J. Gentile, J. Lake, J. Rodgers, and R. Swartz, "Biological Effects, Bioaccumulation and Ecotoxicology of Sediment-Associated Chemicals," Fate and Effects of Sediment-Bound Chemicals in Aquatic Systems, eds. Dickson et al., Elmsford, New York, Pergamon Books, Inc., 1987, pp. 267-290.

Anderson, Jeffrey and William Creal, "The Distribution of PCB Contaminated Sediment in the Kalamazoo River Valley, Michigan," (Donohue & Associates, Inc., and Michigan Surface Water Quality Division, no date).

Anonymous Summary Table, "Sediment Sampling Results of PCB Concentrations and Total Solids from the Kalamazoo River at Otsego Dam," June 19, 1984.

Anonymous Summary Table, "Sediment Sampling Results of PCB Concentrations and Total Solids from the Kalamazoo River," January 9, 1985.

REFERENCES
(Continued)

Anonymous Summary Table, "Sediment Sampling Results of PCB Concentrations and Total Solids from the Kalamazoo River, Upstream of Allegan City Dam," May 29, 1985.

Anonymous Summary Table, "Sediment Sampling Results of PCB Concentrations and Total Solids from the Kalamazoo River, Trowbridge and Plainwell Impoundments," August 1, 1985.

Austin, Franklin R., Soil Survey of Kalamazoo County, Michigan, USDA Soil Conservation Service in cooperation with Michigan Agricultural Experiment Station, November 1979.

Bacci, E. and C. Gaggi, "Polychlorinated Biphenyls in Plant Foliage: Translocation or Volatilization from Contaminated Soils?" Bull. Environ. Contam. Toxicol. 35: (1985), pp. 673-681.

Bahn, A.K., I. Rosenwaike, N. Herrmann, P. Grover, J. Stellman, and K. O'Leary, "Melanoma After Exposure to PCBs," New Engl. J. Med., 295: (1976), p. 450.

Bahn, A.K., P. Grover, I. Rosenwaike, K. O'Leary, and J. Stellman, Reply to Letter from C. Lawrence entitled, "PCB and Melanoma," New Engl. J. Med., 296: (1977), p. 108.

Baker, E.L., P.J. Landrigan, C.J. Glueck, M.M. Zack, J.A. Liddle, V.W. Burse, W.J. Houseworth, and L.L. Needham, "Metabolic Consequences of Exposure to Polychlorinated Biphenyls (PCBs) in Sewage Sludge," Am. J. Epidem., 112(4): (1980) pp. 553-563.

Baker, J.E., P.D. Capel, and S.J. Eisenreich, "Influence of Colloids on Sediment-Water Partition Coefficients of Polychlorobiphenyl Congeners in Natural Water," Environ. Sci. Technol., 20, No. 11 (1986), pp. 1136-1143.

Beck, M. and S. Buda, "Kalamazoo River Study - Comstock to Plainwell August 16-18, 1976," Pub. No. 4833-6140 (MDNR: April 1978).

Bedard, D.L., M.L. Haberi, R.J. May, and M.J. Brennan, "Extensive Degradation of Aroclors and Environmental Transformed PCBs by Alcaligenes eutrophus H850," Appl. Environ. Microbiol., 53: (1987a), pp. 1094-1102.

Bedard, D.L., M.L. Haberi, R.J. May, and M.J. Brennan, "Evidence for Novel Mechanisms of PCB Metabolism in Alcaligenes eutrophus H850," Appl. Environ. Microbio., 53: (1987b) pp. 1103-1112.

Bertazzi, P.A., L. Riboldi, A. Pesatori, L. Radice, and C. Zacchetti, "Cancer Mortality of Capacitor Manufacturing Workers," Am. J. Ind. Med., 11(2): (1987), pp. 165-176.

Bhaskar, Ravi D. et al. "Distribution of Polychlorinated Biphenyls and Dieldrin in the Kalamazoo River Sediments," Hope College: 87th Annual Meeting of the Michigan Academy of Arts and Sciences, March 25, 1983.

REFERENCES
(Continued)

Blasland & Bouck Engineers, P.C., Risk Assessment for the Willow Boulevard Site, (Syracuse, NY: January 1991).

Blasland & Bouck Engineers, P.C., "Allied Paper, Inc./Portage Creek/Kalamazoo River Superfund Site: Land Use Maps," (Syracuse, NY: October 1991).

Blasland & Bouck Engineers, P.C., Results of Soil Tests - Residential Lots, letter from Mark Brown to Scott Cornelius, MDNR, March 26, 1992.

Bloomer, Art, MDPH, Memorandum, Subject: Kalamazoo River PCB Problem (April 10, 1984).

Blus, L.J., "Further Interpretation of the Relation of Organochlorine Residues in Brown Pelican Eggs to Reproductive Success," Environmental Pollution, 28: (1982), pp. 15-33.

Bohunsky, John M., MDNR, Memorandum to Tom Leep, MDNR, Subject: PCB Clean-up, Allied King Mill Site (July 20, 1988).

Brewer, R., "Amphibians, Reptiles, and Non-game birds and mammals, Kalamazoo - Black - Macatawa - Paw Paw River Basin," Technical Paper No. 5, Western Michigan University, U.S. Department of Agriculture, 1976.

Brink, Irwin J., Untitled, Subject: Distribution of PCBs and Dieldrin in Kalamazoo River Sediments (Hope College: No Date).

Brown, D.P., "Mortality of Workers Exposed to Polychlorinated Biphenyls - An Update," Arch. Environ. Health, 42(6): (1987), pp. 333-339.

Brown, D.P. and M. Jones, "Mortality and Industrial Hygiene Study of Workers Exposed to Polychlorinated Biphenyls," Arch. Environ. Health, 36(3): (1981), pp. 120-129.

Brown, J.F. Jr. and R.E. Wagner. "A Simple Index for Summarizing the Alteration State of Environmental PCBs" (Arlington: SETAC, November 13-16, 1988).

Carr, R.A., R.L. Durfee, and E.G. McKay, "PCBs Involvement in the Pulp and Paper Industry," (Prepared by Versar, Inc., Springfield, Virginia, for USEPA, February 25, 1977).

Chadzynski, Lawrence, MDPH, letter to County Commissioner Mary Powers (November 20, 1987).

Chase, K.H., J. Doull, S. Friess, J.V. Rodericks, and S.H. Safe, "Evaluation of the Toxicology of PCBs," (Texas Eastern Gas Pipeline Company: Houston, Texas, 1989).

Chen, M., C.S. Hong, B. Bush, and G.Y. Rhee, "Anaerobic Biodegradation of Polychlorinated Biphenyl by Bacteria from Hudson River Sediments," Ecotox. Environ. Safety, 16(2): (1988), pp. 95-105.

REFERENCES
(Continued)

City of Plainwell, "Plainwell 2020, A Forward Vision, Final Report to the Community," April 1991.

Coates, H., "WRC Orders Mills End Pollution," Kalamazoo Gazette, October 24, 1951.

Creal, William, MDNR, "A Survey of PCBs in the Kalamazoo River and Portage Creek Sediments, Kalamazoo to Lake Allegan, 1983," (Michigan Surface Water Quality Division, November 1983).

Creal, W., MDNR, Memorandum to Art Bloomer, Michigan Department of Public Health (MDPH), Subject: "Kalamazoo River PCB Problem," (Michigan Surface Water Quality Division, April 10, 1984).

Creal, W., MDNR Laboratory Report, Lab Log. No. 4341, June 19, 1984.

Creal, W., MDNR, Memorandum to Fred Morley, MDNR, Subject: Georgia-Pacific Waste Disposal Ponds (December 4, 1986).

Creal, W., MDNR, Letter to Rich Powers, MDNR, Subject: Georgia-Pacific Worm Collections (May 27, 1987).

Creal, W., MDNR, Letter to Jack A. Anderson, Georgia-Pacific (June 15, 1987).

Creal, W., MDNR, Letter to Linda Koivuniemi, MDNR (June 24, 1987).

Creal, W., MDNR, Memorandum to John Bantjes, MDNR, Subject: Plainwell Paper Soil Sampling Results (September 9, 1987).

Creal, W., MDNR, Letter to Del Rector, MDNR, Subject: Kalamazoo River PCB Update (October 26, 1989).

Creal, W., and J. Wuycheck, MDNR Laboratory Report, Lab Log. No. 4556, August 2, 1984.

Dell Engineering, Inc., Work Plan for an Expanded Investigation of the Willow Boulevard Landfill, (Holland, MI: November 1987).

Dell Engineering, Inc., Site Investigation Report of Willow Boulevard Landfill, (Holland, MI: February 1988).

Dell Engineering, Inc., Report on Management Options at Willow Boulevard for Georgia-Pacific Corporation, (Holland, MI: April 1988).

Dell Engineering, Inc., Preliminary Site Investigation at "A" Landfill Site, (Holland, MI: July 1989).

Dell Engineering, Inc., Interim Remedial Action Plan for the Willow Boulevard Site, (Holland, MI: November 1990).

REFERENCES
(Continued)

DeWeese, L.R., L.C. McEwen, G.L. Hensler, and B.E. Petersen, "Organochlorine Contaminants in Passeriformes and Other Avian Prey of the Peregrine Falcon in the Western United States," Environmental Toxicology and Chemistry, 5: (1986), pp. 675-693.

Dragun, J., The Soil Chemistry of Hazardous Materials, (The Hazardous Materials Control Research Institute, Silver Spring, Maryland, 1989).

Eisler, R., "Polychlorinated Biphenyl Hazards to Fish, Wildlife and Invertebrates: A Synoptic Review," U.S. Fish Wildl. Serv. Biol. Rep. 85(1.7).

Emerson, Frank, "River Quality and Industrial Adjustment: A Case Study," Environmental Affairs, 3, No. 1 (1974), pp. 188-198.

EMS Heritage Laboratories, Inc., Certificates of Analysis, Laboratory Project No. 90WT07 (Darien, IL: May 1990).

Environmental Data, Inc. (EDI), Results of Leachate Analysis for Georgia-Pacific, July 21, 1980.

EDI, Results of EP Toxicity Analysis for Georgia-Pacific, May 1983.

Environmental Research Group, Inc. (ERG), Results of Leachate Analysis for Georgia-Pacific, July 31, 1980.

Environmental Resource Management, Inc. (ERM), Letter Report of Soil Investigation, August 1989, Georgia-Pacific Facility Kalamazoo, Michigan, October 31, 1989.

ERM, Report of Residual Material Sampling at King Highway Landfill, March 22, 1991.

Erickson, Bill, MDNR, Memorandum to Roger Przybysz, Subject: Toxicity Evaluation at Allied Paper Company (November 8, 1982).

Fien, G.G., J.L. Jacobsen, S.W. Jacobsen, P.M. Schwartz, and J.K. Dowler, "Prenatal Exposure to Polychlorinated Biphenyls: Effects on Birth Size and Gestational Age," J. Pediatr., 102: (1984), pp. 315-320.

Fimreite, N., "Mercury Contamination of Aquatic Birds in Northwestern Ontario," J. Wildl. Manage., 38: (1974), pp. 120-131.

Fishbein, L., "Halogenated Polyaromatics," Potential Industrial Carcinogens and Mutagens, EPA 560/5-77-005, NTIS PB 273197 (as cited by Mather, ed.) (1988), pp. 180.

Forney, James, MDNR, Memorandum to John Robinson, Fish Contaminant Advisory Committee, Subject: Organochlorine and mercury levels in fish (MDNR: Toxic Chemical Evaluation Section, August 1, 1983).

REFERENCES
(Continued)

French, William B., Wilkins & Wheaton Testing Laboratory, Inc., Letter to James Akers and Pat Krause, Kalamazoo County Health Department (March 27, 1987).

Fries, G. and G.S. Morrow, "Chlorobiphenyl Movement from Soil to Soybean Plants," J. Agric. Food Chem., 29: (1981), pp. 757-759.

Fries, G. and G.S. Morrow, "Metabolism of Chlorobiphenyl in Soil," Bull. Environ. Contam. Toxicol., 33: (1984), pp. 6-12.

Gaule, Michael D., "A Chemical and Biological Assessment of the Kalamazoo River Between Morrow Dam and D Avenue Immediately Following Tertiary Updgrading at the Kalamazoo Water Reclamation Plant," Western Michigan University, November 1987.

Georgia-Pacific Corp., Report on Further Characterization of Papermill Residue for the King Highway Landfill, (August 3, 1989).

Geraghty & Miller, 12th Street Landfill Geophysical Investigation, Plainwell, Michigan, (October 11, 1991).

Great Lakes Basin Commission (GLBC), Great Lakes Basin Framework Study, Appendix 7, Water Quality (Ann Arbor, Michigan: Public Information Office) (1975) pp. 68.

Green, S., J.V. Carr, K.A. Palmer, and E.J. Oswald, "Lack of Cytogenetic Effects in Bone Marrow and Spermatogonial Cells in Rats Treated with Polychlorinated Biphenyls (Aroclors 1242 and 1254)," Bull. Environ. Contam. Toxicol., 13(1): (1975), pp. 14-22.

GZA-Donohue, Technical memorandum, Subject: Laboratory Data Sediment Cores, Surface Sediment, and River Water, September 1988.

GZA-Donahue, Evaluating Sediment Burial Rates and PCB Partition Coefficients, Kalamazoo River, Michigan, (June 1990).

GZA-Donohue, Interim Remedial Action for Portions of the Kalamazoo River System - Conceptual Design Technical Memorandum, Vols. 1 and 2, (August 1990).

Hager, Dave, "Parties Settle King Mill Suit Out-of-Court," Kalamazoo Gazette, October 16, 1979.

Hankin, L. and B.J. Sawhney, "Microbial Degradation of Polychlorinated Biphenyl in Soil," Soil Science, 137(6): (1984), pp. 401-407.

Hanney, Glen, Kalamazoo County Drain Commission, Personal Communication (October 7, 1991).

Harrington, Hal, MDNR, Letter to Harry Bogorad, Subject: Denial of Hydropower development, (Michigan Department of Natural Resources, DNR File No. 83-12-344, 1984).

REFERENCES
(Continued)

Harrison, Dayle, "Polychlorinated Biphenyls (PCBs) in Fish, Sediments, and Water in the Michigan Department of Public Health Fish Consumption Ban Zone of the Kalamazoo River," Kalamazoo River Preservation Association, 1982.

Harrison and Yerkes, "Laboratory Analysis Report, Job No. 25345," (Environmental Data, Inc.: Kalamazoo River Preservation Association, June 28, 1983).

Harvey, Chester, MWRC, Letter to U.G. Stoeffler, Allied Paper, Inc., (May 25, 1976).

"Hawthorne Paper Mill Specializes in Tough Watermark Jobs", Kalamazoo Gazette, June 24, 1934.

Heddle, J.A. and W.R. Bruce, "Comparison of Tests for Mutagenicity or Carcinogenicity Using Assays for Sperm Abnormalities, Formation of Micronuclei and Mutations in Salmonella," Origins of Human Cancer, H.H. Hiatt et al., Ed. Cold Spring Harbor Conf. Cell Prolif., Cold Spring Harbor Lab., Cold Spring Harbor, NY, 4: (1977), pp. 1549-1557.

Hesse, John L. and Ronald Wilson, "Evaluation of Aquatic Environment of the Kalamazoo River Watershed - Part A, Biological Survey, June-August 1971," (Michigan Water Resources Commission: May 1972).

Hesse, J.L., "Status Report on Polychlorinated Biphenyls in Michigan Waters," (MWRC, 1973).

Hesse, J.L., MDPH, Letter to Mark Brown, Blasland & Bouck Engineers, Subject: Waterfowl Data (January 29, 1992).

Hester, Philip D., Georgia-Pacific Corporation, Letter to Richard Sadowski, MDNR (Kalamazoo, MI: November 3, 1989).

Hester, Philip D., Georgia-Pacific Corporation, Letter to Lynn Spurr, MDNR, (Kalamazoo, MI: November 10, 1989).

Holtz, Robert D. and William D. Kovacs, An Introduction to Geotechnical Engineering, New Jersey: Prentice-Hall, Inc., 1981.

Horvath, F.J., "PCBs in Fish, Sediments and Water of the lower Kalamazoo River and nearby Lake Michigan," MDNR Pub. No. 3730-0043, (January 1984).

Humphrey, H.E.B., "The Human Population - An Ultimate Receptor for Aquatic Contaminants," Hydrobiologia, 149: (1987), pp. 75-80.

IARC, Monographs on the Evaluation of the Carcinogenic Risk of Chemicals to Humans, Suppl. 4, Lyon, France: WHO, 1982.

Ito, N., H. Nagasaki, M. Arai, S. Makiura, S. Sugihara, and K. Hirao, "Histopathologic Studies on Liver Tumorigenesis Induced in Mice by Technical Polychlorinated Biphenyls and its Promoting Effect on Liver Tumors Induced by Benzene Hexachloride," J. Natl. Cancer Inst., 51(5): (1973), pp. 1637-1646.

REFERENCES
(Continued)

Ito, N., H. Nagasaki, S. Makiura, and M. Arai, "Histopathological Studies on Liver Tumorigenesis in Rats Treated with Polychlorinated Biphenyls," Gann., 65: (1974), pp. 545-549.

Iwata, Y. and F.A. Gunther, "Translocation of the Polychlorinated Biphenyl Aroclor 1254 from Soil into Carrots Under Field Conditions," Arch. Environ. Contam., 4: (1976), pp. 44-59.

Jacobson, Joseph L., et al. "Prenatal Exposure to an Environmental Toxin: A Test of the Multiple Effects Model." American Psychological Association, vol. 20 (1984), pp. 523-532.

Jacobson et al., "The Effect of Intrauterine PCB Exposure on Visual Recognition Memory," Child Development, 56: (1985), pp. 853-860.

Jacobson, Joseph L., H.E. Humphrey, S.W. Jacobson, S.L. Schantz, M.D. Mullin, and R. Welch, "Determinants of Polychlorinated Biphenyls (PCBs), Polybrominated Biphenyls (PBBs), and Dichlorodiphenyl Trichloroethane (DDT), Levels in the Sera of Young Children," Am. J. Public Health 79 (10): (1989), pp. 1401-1404.

Jacobson, Joseph L., et al. "Effects of In Utero Exposure to Polychlorinated Biphenyls and Related Contaminants on Cognitive Functioning in Young Children." The Journal of Pediatrics, vol. 116 (1990), pp. 38-45.

Johnson, D., MDNR Fish Manager, Plainwell, Personal Communication (May 1991).

Jones, Al, "Converting Southwest Michigan's Paper Industry Needs Investment to Keep It on a Roll," Kalamazoo Gazette, June 24, 1990.

Kalamazoo City Parks Department, Personal Communication (December 1991).

"Kalamazoo's First Paper Mill Established in 1867," Kalamazoo Gazette, November 16, 1947.

KAR Laboratories, Inc., "EP Toxicity Studies of Waste Materials for Plainwell Paper Co., Inc.," November 6, 1984.

KAR Laboratories, Inc., Analytical Report of eight water samples for purgeable halocarbons, December 13, 1984.

KAR Laboratories, Inc., Laboratory Reports, April 30, 1984, September 25, 1984, December 21, 1984, February 28, 1985, and June 4, 1985.

KAR Laboratories, Inc., "Evaluation of Leachates from Paper Sludge Waste for Georgia-Pacific Corporation - Kalamazoo Paper Division," May 23, 1986.

KAR Laboratories, Inc., "EP Toxicity Evaluation of Waste Materials for Plainwell Paper Company," October 29, 1986.

REFERENCES
(Continued)

KAR Laboratories, Inc., "EP Toxicity Evaluation of One Sample of Georgia-Pacific Residuals," March 12, 1987a.

KAR Laboratories, Inc., "ASTM Leachate Study of One Sample of Georgia-Pacific Residuals," March 12, 1987b.

KAR Laboratories, Inc., Laboratory Report of Water Samples From Allied Paper, May 27, 1988.

KAR Laboratories, Inc., Results of Residual Samples from Georgia-Pacific, September 1988.

KAR Laboratories, Inc., Analtyical Report, "PCB Analysis of Thirteen Soil Samples from Georgia-Pacific Submitted October 21, 1988," November 4, 1988.

KAR Laboratories, Inc., "EP Toxicity Evaluation of Waste Materials for Plainwell Paper Company," October 17, 1989.

KAR Laboratories, Inc., Analytical Report of Well Water Samples From Allied Paper, January 8, 1990.

KAR Laboratories, Inc., Analytical Reports, July 12, 1990 and July 16, 1991.

Katanski, A.V. and K. Gervasi, "Kalamazoo River Inventory Report Prepared for the River Steering Committee of the Forum for Kalamazoo County," December 14, 1990.

Kimbrough, R.D. and R.E. Linder, "Induction of Adenofibrosis and Hepatomas in the Liver of BALB/cJ Mice by Polychlorinated Biphenyls (Aroclor 1254)," J. Natl. Cancer Inst., 53(2): (1974), pp. 547-552.

Kimbrough, R.D., R.A. Squire, R.E. Linder, J.D. Strandberg, R.J. Montali and V.W. Burse, "Induction of Liver Tumors in Sherman Strain Female Rats by Polychlorinated Biphenyl Aroclor 1260," J. Natl. Cancer Inst., 55(6): (1975), pp. 1453-1459.

Kimbrough, R.D., "Human Health Effects of Polychlorinated Biphenyls (PCBs) and Polybrominated Biphenyls (PBBs)," Ann. Rev. Pharmacol. Toxicol., 27: (1987), pp. 87-111.

Kimura, N.T. and T. Baba, "Neoplastic Changes in the Rat Liver Induced by Polychlorinated Biphenyl," Gann., 64: (1973), pp. 105-108.

King, K.A., T.W. Custer, and J.S. Quinn, "Effects of Mercury, Selenium and Organochlorine Contaminants on Reproduction of Forster's Terns and Black Skimmers Nesting in a Contaminated Texas bay," Arch. Environ. Contam. Toxicol., 20: (1991), pp. 32-40.

Knapp, B.D., Soil Survey of Allegan County, Michigan, USDA Soil Conservation Service (SCS) in cooperation with Michigan Agricultural Experiment Station, March 1987.

REFERENCES
(Continued)

Koivuniemi, Linda, MDNR, Letter to Al Campbell, Georgia-Pacific Corp., Subject: PCB Sampling Results at Willow Boulevard Site (November 3, 1987).

Kubiak, T.J., H.J. Harris, L.M. Smith, T.R. Schwartz, D.L. Stalling, J.A. Trick, L. Sileo, D.E. Docherty, and T.C. Erdman, "Microcontaminants and Reproductive Impairment of the Forster's Tern on Green Bay, Lake Michigan - 1983," Arch. Environ. Contam. Toxicol., 18: (1989), pp. 706-727.

Kubiak, T.J. and D.A. Best, "Wildlife Risks Associated with Passage of Contaminated, Anadromous Fish at Federal Energy Regulatory Commission Licensed Dams in Michigan," unpublished report, US FWS Contaminants Program, East Lansing, MI, August 16, 1991.

Kunita, N., et al., "Causal Agents of Yusho," PCB Poisoning in Japan and Taiwan, Kuratsume and Shapiro, eds., Alan R. Lis, Inc., (1984), pp. 45-59.

Lauer, Jon, "Polychlorinated Biphenyl Survey of the Kalamazoo River and Portage Creek in the Vicinity of the City of Kalamazoo, 1972," (Michigan Water Resources Commission (MWRC): January 1973).

Lawton, George W., Plainwell Paper Company, Letter to Fred Morley, MDNR (July 30, 1985).

Lawton, George W., Plainwell Paper Company, "Historical Waste Disposal Practices at Plainwell Paper Company, Inc.," (June 3, 1987).

Lewis, B., "Paper Industry Economic Force Here Since 1867," Kalamazoo Gazette, October 27, 1963.

Limno-Tech, Inc., Recorded Observation of Allied Site Conditions, Allied Subsurface Investigations, June/July 1988.

Limno-Tech, Inc., "Preliminary Risk Assessment Report for Containment and Removal Alternatives," February 1989.

Limno-Tech, Inc., Report on the HM Holdings/Allied Paper, Inc., Investigations of the Historical Residuals Dewatering Lagoons and Seeps 1 and 2 (January 1990a).

Limno-Tech, Inc., Addendum II to the Hydrogeological Investigation for the HM Holdings/Allied Paper, Inc., Sanitary Landfill (January 31, 1990b).

Limno-Tech, Inc., Results of the Stream Diversion Design Studies, Portage Creek in Bryant Mill Pond (February 1990).

Limno-Tech, Inc., Summary of Portage Creek Water Quality Sampling, Allied Paper/H.M. Holdings, Inc. (October 8, 1991).

Litteral, Blaine A., Dell Engineering, Inc., Letter to Mark P. Brown, Blasland & Bouck Engineers, P.C., (October 8, 1990).

REFERENCES
(Continued)

1992 Lockwood-Post's Directory of the Pulp, Paper and Allied Trades, Miller Freeman Publications, 1991.

Loselle, Virginia L., Letter to Terry Hartman, MDNR (May 13, 1982).

Lyman, W.J., W.F. Reehl, and D.H. Rosenblatt (Eds.), Handbook of Chemical Property Estimation Methods, New York: McGraw-Hill Book Co., 1982.

Maas, Peter, "Neighborhood Group Pushes for King Mill Demolition," Kalamazoo Gazette, March 18, 1977.

Marti, Edwin A., "Polychlorinated Biphenyls in Lake Michigan Tributaries", Journal of Great Lakes Research, 16, (1984), pp. 396-405.

Massie, Larry B. and Peter J. Schmitt, "Kalamazoo: the Place Behind the Products," Windsor Publications: 1981.

Mather, P.E., "A Preliminary Assessment of Risk Associated with Land Disposal of Sludge Containing Polychlorinated Biphenyls," (Wisconsin: Madison Metropolitan Sewerage District, 1987).

McMahon, Megan, "Aquatic Toxicity Assessment of Process Effluent from Plainwell Paper Company Outfall 005, Plainwell, Michigan," MDNR-SWQD, May 1988.

Michigan Bureau of Water Management, Pesticide Analyses, January 18, 1973.

MDNR, "Wastewater Survey, Monarch Division, Allied Paper, Inc.," June 1968.

MDNR, "Evaluation of the Aquatic Environment of the Kalamazoo River Watershed-Part A, Biological Survey, June-August 1971," May 1972.

MDNR, "Report of an Industrial Wastewater Survey Conducted at Georgia-Pacific," July 18-19, 1977.

MDNR, "Kalamazoo River - PCB contaminated fish - Allegan to Saugatuck." Interoffice memo from John Wuycheck to Robert Courchaine, August 21, 1978.

MDNR, "Report of a Toxicity Evaluation Conducted on Wastewaters Discharged by Allied Paper Company," March 1979.

MDNR, "Biological Survey of the Kalamazoo River in the Vicinity of the Battle Creek Wastewater Treatment Plant, July 24, 1979," Water Quality Division, 1979.

MDNR, "Mini-Screening Test for Acute Effluent Toxicity, Allied Paper Company," March 1982.

MDNR, "PCBs in Fish, Sediments, and Water of the Lower Kalamazoo River and Nearby Lake Michigan," October 1982a.

MDNR, "Contaminants in Kalamazoo River Fish," October 1982b.

REFERENCES
(Continued)

MDNR, "Macro-Invertebrate and Sediment Chemistry Survey of the Kalamazoo River, Kalamazoo to Allegan, July 22 and October 7, 1982," November 1982.

MDNR, Laboratory Report, Lab Log. No. 4172, May 24, 1984.

MDNR, "A Fisheries Survey of the Kalamazoo River, July and August 1982," Fisheries Technical Report, 84-7, October 1984.

MDNR, Fish Contaminant Monitoring Program Data Sheets, 1984a.

MDNR, "PCB and Mercury Concentrations in Carp (Cyprinus carpio) from the Lower Kalamazoo River, July 1983," Surface Water Quality Division, 1984b.

MDNR, Briefing Memo/Fact Sheet for Allied Paper, Inc. NPDES Permit, 1984c.

MDNR, Briefing Memo/Fact Sheet for Plainwell Paper Co., Inc., 1984d.

MDNR, "Report of an Industrial Wastewater Survey Conducted at Plainwell Paper Company," January 7-8, 1985.

MDNR, "Toxicity Evaluation of Effluent Discharged by Plainwell Paper Company," January 9-11, 1985.

MDNR, Point Source Discharge Sampling Results for PCB, Kalamazoo area, August-September 1985.

MDNR, Fish Contaminant Monitoring Program Data Sheets, 1985.

MDNR, "Physical, Chemical, and Biological Monitoring Results from the Kalamazoo River, Comstock to Plainwell, 1984," (Surface Water Quality Division, February 1986).

MDNR, Permit No. 85-12-412, Lansing, Michigan: Engineering Water Management Division, July 10, 1986a.

MDNR, Fish Contaminant Monitoring Program Data Sheets, 1986b.

MDNR, "Results of PCB Analyses of Mute Swan Eggs Collected from the Allegan State Game Area," (1986c).

MDNR, "Report of an Industrial Wastewater Survey Conducted at Allied Paper Company," January 1987.

MDNR, "Summary Table of Sediment Sampling Results from Georgia-Pacific, Kalamazoo Sludge Disposal Areas," April 21, 1987.

MDNR, "Analysis of PCB Concentrations in a numerically large sample of Carp from Lake Allegan (Kalamazoo), May 1987.

MDNR, "Acute Toxicity Assessment of Treated Process Effluent from Allied Paper Company", June 29, 1987.

REFERENCES
(Continued)

MDNR, "Report of an Industrial Wastewater Survey Conducted at Allied Paper Company," October 20-21, 1987.

MDNR, Survey of Sediment Upstream of Ceresco Dam, October 1987.

MDNR, "Kalamazoo River Remedial Action Plan second draft," December 1987.

MDNR, Fish Contaminant Monitoring Program Data Sheets, 1987a.

MDNR, "Soil PCB Analytical Data Report," Submitted to Surface Water Quality Division (SWQD), Plainwell Office, 1987b.

MDNR, "Report of an Industrial Wastewater Survey Conducted at Simpson Paper Plainwell Division," April 18, 1988.

MDNR, "Aquatic Toxicity Assessment of Process Effluent from Plainwell Paper Company Outfall 005," May 1988.

MDNR, Results of Analysis of Ground-Water Samples from Georgia-Pacific, June 14, 1988.

MDNR, "Kalamazoo River Basin Fisheries Management Plan," July 1988.

MDNR, "Biological Survey of the Kalamazoo River between Comstock and Plainwell, July 1988," SWQD, Staff Report, September 1988.

MDNR, "Acute Toxicity Assessment of Allied Paper Company, Outfall 002 Effluent," October 1988.

MDNR, "Report of an Industrial Wastewater Survey Conducted at Performance Paper Company," April 17, 1989.

MDNR, Laboratory Analysis Report, Work code 89-10-022, October 24, 1989.

MDNR, "A Summary of Bioaccumulation Studies Conducted on Michigan Rivers in 1987," SWQD, November 1989.

MDNR, "Kalamazoo River Basin Fisheries Management Plan," 1989.

MDNR, "Biological Survey of the Kalamazoo River Between Kalamazoo and Allegan, August 1989," SWQD, Staff Report, February 1990.

MDNR, Kalamazoo River Preliminary Health Assessment, Memorandum, S. Luzkow, March 8, 1990.

MDNR, "Draft Plan Type B Cleanup Standards," June 22, 1990.

MDNR, "Portage Creek Caged Fish Study Plan," July 1990.

MDNR, Results of Analysis of Soil Sample, December 20, 1990.

MDNR, "1990 Michigan Fishing Guide," 1990a.

REFERENCES
(Continued)

MDNR, Comments on Draft Description of the Current Situation, May 16, 1991.

MDNR, Communication from Chris Waggoner, MDNR, to Thomas Sullivan, Georgia-Pacific Corporation, 1990b.

MDNR, Summary Tables of Great Lakes Anadromous Trout and Salmon Plantings, Lake Michigan, 1991 Target Stocking Plantings, 1990c.

MDNR, Kalamazoo County Element List, Michigan Natural Features Inventory, 1990d.

MDNR, Michigan Boat Launching Directory, 1989-90, Recreational Division, 1990e.

MDNR, "1991 Michigan Fishing Guide," 1991.

MDNR, Comments on Draft Description of the Current Situation, May 16, 1991.

MDNR, Minutes of meeting with Georgia-Pacific and RMT, June 26, 1991.

MDNR, Results of PCB Analysis of Sediment Sample, October 24, 1991.

MDPH, Fish Consumption Advisory/Kalamazoo River memorandum, Center for Environmental Health Sciences, Lansing, Michigan, 1983.

MDPH, Report of Chemical Analysis of Water Sample, July 20, 1987.

MDPH, Analytical Report of Soil Samples from Lakewood Area, Kalamazoo, September 23, 1987.

MWRC, "Self-Purification Capacities - Kalamazoo River 1956 Survey Comstock to Trowbridge," 1958.

MWRC, "Report of Waste Survey at Allied Paper Corporation (Monarch, Bryant & King Division), Kalamazoo, Michigan," June 1961.

MWRC, "Wastewater Survey, Allied Paper Corporation, Bryant, Monarch & King Divisions," June 1967.

MWRC, "Report of Wastewater Survey, King Division of Allied Mills, Inc., Kalamazoo," July 23, 1968.

MWRC, "Polychlorinated Biphenyl Survey of the Kalamazoo River and Portage Creek in the Vicinity of the City of Kalamazoo," 1972.

MWRC, "Monitoring for Polychlorinated Biphenyls in the Aquatic Environment," May 1973.

Miller, Herbert, Memorandum, Subject: Hydroelectric Impoundments on the Kalamazoo River, (Michigan: Recreation Resource Planning Division, March 22, 1966).

REFERENCES
(Continued)

Miller, T.J., Memorandum, Subject: Sediment samples from proposed Otsego Hydroelectric Reservoir, (US FWS, May 20, 1983).

Miller, T.J., W.S. Creal, and D. Suppnick, "Dissolved Oxygen and Sediment Contamination Consideration in Refurbishment of Defunct Hydropower Site: A Case Study on the Kalamazoo River, Michigan," Symposium on Small Hydropower and Fisheries. Eds.: Forrest W. Olson, Robert G. White and R.H. Hanre. Aurora, Colorado: The American Fisheries Society, (1985) pp. 114-120.

National Cancer Institute (NCI), "Bioassay of Aroclor (trademark) 1254 for Possible Carcinogenicity, CAS No. 27323-18-8", NCI Carcinogenesis Tech. Rep., Ser. No. 38, (1978).

National Dam Safety Program, Inspection Report Plainwell #1 Dam, Report #491, (Allegan County, Michigan, US Army Corps of Engineers, August, 1979).

National Institute for Occupational Safety and Health (NIOSH), Criteria for a Recommended Standard . . . Occupational Exposure to Polychlorinated Biphenyls (PCBs), U.S. DHEW, PHS, CDC, Rockville, Md. Publ. No. 77-225, 1977.

National Oceanic and Atmospheric Administration, Local Climatological Data for 1951 through 1980 - Annual Summary with Comparative Data, Lansing, Michigan, ISSN 0198-2613, 1989.

National Wildlife Federation (NWF) and the Canadian Institute for Environmental Law and Policy, "A Prescription for Healthy Great Lakes -Report of the Program for Zero Discharge," (February 1991).

Newell, A.J., D.W. Johnson, and L.K. Allen, "Niagara River Biota Contamination Project: Fish Flesh Criteria for Piscivorous Wildlife, New York State Department of Environmental Conservation (NYSDEC)," Technical Report 87-3, NYSDEC Division of Fish and Wildlife, Bureau of Environmental Protection, 1987.

Norback, D.H. and R.H. Weltman, "Polychlorinated Biphenyl Induction of Hepatocellular Carcinoma in the Sprague-Dawley Rat," Environ. Health Perspect., 60: (1985), pp. 97-105.

NUS Corporation, Draft Feasibility Study of Alternatives: Kalamazoo River PCB Project, Kalamazoo and Allegan Counties, Michigan (March 1986).

O'Brien & Gere, Conceptual Design: Bryant Mill Pond Site (February 1990).

Oeming, L.F., MWRC, Letter to H.B. Johnson, Allied Paper, Subject: Proposed Treatment Facilities at King Mill (June 18, 1954).

Oeming, L.F., MWRC, Memorandum to files, Subject: Allied Paper Company (September 13, 1965).

REFERENCES
(Continued)

Omernik, J.M., "Ecoregions of the Conterminous United States," (Map) Environmental Research Laboratory, Corvallis, Oregon, 1986.

Ostlund, P. and K. Mottinger, "Report of an Industrial Wastewater Survey Conducted at Allied Paper Corporation," MDNR, June 1980.

Oudbier, Adrian J., MDPH, Letter to Pat Krause, Kalamazoo County Health Department, Subject: Blood Samples from Worm Diggers, (September 2, 1987).

Paustenbach, O.J., H.P. Shu, and F.J. Murray, "A Critical Examination of Assumptions Used in Risk Assessments of Dioxin Contaminated Soil," Reg. Toxicol. Pharmacol., 6: 284-307 (1986).

Peakall, D.B., J.L. Lincer, and S.E. Bloom, "Embryonic Mortality and Chromosomal Alterations Caused by Aroclor 1254 in Ring Doves," Environ. Health Perspect., 1: (1972), pp. 103-104.

Peerless - Midwest, Inc., "Aquifer Performance Analysis, Wells TW1 and TW2, Allied Paper, Inc./H.M. Holdings, Kalamazoo, Michigan," Final Report, November 29, 1989.

Peterson, G.W., Limno-Tech, Inc., Letter on Results of PCB Sampling in Portage Creek for September and October 1990 (November 28, 1990).

Peterson, G.W., Limno-Tech, Inc., Personal Communication (February 15, 1991).

Peterson, G.W., Limno-Tech, Inc., Personal Communication (May 9, 1991).

Peterson, G.W. and R. Betz, Limno-Tech, Inc., Memorandum on "EPA Soil Sampling at the Allied Paper Site - Conducted to Determine the Need for a Fence," (June 13, 1990).

Pignatello, J.J., "Sorption Dynamics of Organic Compounds in Soils and Sediments," in Reactions and Movement of Organic Chemicals in Soils, Soil Science Society of America Special Publ. No. 22, 1989.

Pippen, R.W., "Inventory of Rare, Endangered, Scarce and Other Herbaceous and Shrubby Plant Species, Kalamazoo - Black - Macatawa - Paw Paw River Basin," Technical Paper No. 6., Western Michigan University, U.S. Department of Agriculture, 1976.

Planning Commission Memorandum, Subject: Plainwell Dam Vandalism and Safety Hazards, 1974.

Polasek, Thomas M., MDNR, Memorandum to Chester Harvey and Steve Eldredge, MDNR, Subject: King Street storm sewer (September 27, 1976).

Pope, J.L., MWRC, Memorandum to R.J. Courchaine, MWRC, Subject: Allied Paper Company, King Division - Kalamazoo (April 18, 1969).

REFERENCES
(Continued)

Pope, J.L., MWRC, Memorandum to R.J. Courchaine, MWRC, Subject: Allied Paper Company, King Division Clarifier Effluent (March 25, 1970).

Przybysz, Roger, MWRC, Letter to U.G. Stoeffler, Allied Paper (July 23, 1976).

Quensen, J.F., J.M. Tiedje, and S.A. Boyd, "Reductive Dechlorination of Polychlorinated Biphenyls in Anaerobic Microorganisms from Sediment," Science, 242 (1988), pp. 752-754.

Reggiani, G. and R. Bruppacher, "Symptoms, Signs and Findings in Humans Exposed to PCBs and their Derivatives," Environmental Health Perspectives, 60: (1985), pp. 225-232.

Rheaume, S.J., Geohydrology and Water Quality of Kalamazoo County, Michigan, 1986-1988, (U.S. Geological Survey, 1990).

RMT, Sampling and Analysis Plan, 12th Street Sludge Disposal Area, (Grand Ledge, Michigan: 1990).

Roman, William C., Memorandum to Robert Campeau, Assistant Bureau Chief - Bureau of Resources (Chief Engineer - Engineering Division, MDNR, January 20, 1982).

Schaeffer, E., H. Greim, and W. Goessner, "Pathology of Chronic Polychlorinated Biphenyl (PCB) Feeding in Rats," Toxicol. Appl. Pharm. 75: (1984), pp. 278-288.

Schmidt, Eric, Georgia-Pacific Corporation, Personal Communication (May 10, 1991).

Schoeny, R., "Mutagenicity Testing of Chlorinated Biphenyls and Chlorinated Dibenzofurans," Mutat. Res., 101: (1982), pp. 45-56.

Schoeny, R.S., C.C. Smith, and J.C. Loper, "Non-mutagenicity for Salmonella of the Chlorinated Hydrocarbons Aroclor 1254, 1,2,4-trichlorobenzene, Mirex and Kepone," Mutat. Res., 68: (1979), pp. 125-132.

Schulz, D.E., Pertrick, G., and J.C. Duinker. "Complete Characterization of Polychlorinated Biphenyl Congeners in Commerical Aroclor and Clophen Mixtures by Multidimentional Gas Chromatography - Electron Capture Detection." Environ. Sci. Technol. 23(7): (1989) pp. 852 - 859.

Soil Conservation Service (SCS), Soil Survey of Kalamazoo County, Michigan, (USDA, November 1979).

"St. Regis Mill Here Spans Sixty Years," Kalamazoo Gazette, September 23, 1955.

Strickler, "Year of the Big Cleanup - Allied Paper to Curb Stream Pollution in 1969," Kalamazoo Gazette, January 5, 1969.

REFERENCES
(Continued)

Sullivan, Thomas F., Georgia-Pacific, Letter to Chris Waggoner, MDNR (July 16, 1990).

Suppnick, J. and W. Creal, "Physical, Chemical, and Biological Monitoring Results from the Kalamazoo River, Comstock to Plainwell, 1984," (MDNR: Water Quality Division, 1986).

Swanson Environmental, Inc. (SEI), Site Investigation, Willow Boulevard Landfill, (Farmington Hills, MI: 1987).

Swanson Environmental, Inc., Analytical Report, "Water/Sediment/Soil/Sludge Samples (Georgia-Pacific, Kalamazoo)" May 1, 1987.

Swanson Environmental, Inc., Analytical Report, "Waste Sludge - Georgia-Pacific," July 22, 1987 and July 30, 1987.

Swanson Environmental, Inc., Workplan for A-Site Investigation, (Farmington Hills, MI: May 1990).

Swanson Environmental, Inc., A-Site Investigation, (Farmington Hills, MI: October 1, 1990).

Taylor, P.R., J.M. Stelma, I. Auger, and C. Lawrence, "The Relation of Occupational Polychlorinated Biphenyl Exposure to Cancer and Total Mortality," *Unpublished study funded by the National Cancer Institute*, (1988).

Taylor, P.R., J.M. Stelma, and C.E. Lawrence, "The Relation of Polychlorinated Biphenyls to Birth Weight and Gestational Age in the Offspring of Occupationally Exposed Mothers." Am. J. Epidemiology 129(2): (1989) pp. 395-406.

Thacker, W.E., Simpson Plainwell Paper Co., Personal Communication (February 20, 1991).

Thinnes, Tom, "Ground Broken at Plainwell for Water Treatment Facility," Kalamazoo Gazette, February 23, 1967.

Troyer, Byron, "Kalamazoo Paper Company Pioneered Field Here," Kalamazoo Gazette, October 13, 1957.

Untitled report of water quality investigation of the Kalamazoo River conducted from 1965-1966.

U.S. Department of Agriculture (USDA), "Analysis of Wildlife Habitat, Kalamazoo - Black - Macatawa - Paw Paw River Basin," Technical Paper No. 3, Economic Research Service, 1975.

USDA, "Analysis of Wetlands, Kalamazoo - Black - Macatawa - Paw Paw River Basin," Technical Paper No. 4., USDA, Economic Research Service, 1976.

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REFERENCES
(Continued)

U.S. Department of Health, Education, and Welfare (HEW), Criteria for a Recommended Standard ... Occupational Exposure to Polychlorinated Biphenyls (PCBs), (as cited by Mather), 1977.

USEPA, "Drinking Water Quality Criteria Document for Polychlorinated Biphenyls," USEPA/440/5-80-068, NTIS PB 81-117798, 1980.

USEPA, Drinking Water Criteria Document for Polychlorinated Biphenyls (PCBs), ECA-CIN-414, Environmental Criteria and Assessment office (Cincinnati, OH, 1987).

USEPA, "Drinking Water Criteria Document for Polychlorinated Biphenyls (PCBs)," Prepared by the Office of Health and Environmental Assessment, Environmental Criteria and Assessment Office, Cincinnati, OH for the Office of Drinking Water, Washington, DC, (1988).

USEPA, "Guidance on Remedial Actions for Superfund Sites with PCB Contamination," Prepared by the Office of Emergency and Remedial Response, Washington, DC, EPA/540/G-90/007, (1990).

USEPA, Health Effects Assessment Summary Tables, Third Quarter (OERR 9200.6-303 NTIS PB 90-921103) 1990.

USEPA, "Bioaccumulation of Selected Pollutants in Fish, A National Study, Volume II," EPA 506/6-90/001b, (1991).

U.S. Fish and Wildlife Service (US FWS), "Polychlorinated Biphenyl Hazards to Fish, Wildlife, and Invertebrates: A Synoptic Review," Biological Report 85(1.7), Contaminant Hazard Report No. 7, U.S. Department of the Interior, 1986.

US FWS, Letter from John W. Cooper, March 27, 1991.

USGS 7.5 Minute Series Topographic Map, Galesburg Quadrangle, Michigan-Kalamazoo County, 1961 (photorevised 1985).

USGS 7.5 Minute Series Topographic Map, Kalamazoo Quadrangle, Michigan-Kalamazoo County, 1967a (photorevised 1973).

USGS 7.5 Minute Series Topographic Map, Kalamazoo NE Quadrangle, Michigan - Kalamazoo County, 1967b (photorevised 1973).

USGS 7.5 Minute Series Topographic Map, Otsego Quadrangle, Michigan - Allegan County, 1967c (photorevised 1973).

USGS 7.5 Minute Series Topographic Map, Allegan Quadrangle, Michigan-Allegan County, 1981a.

USGS 7.5 Minute Series Topographic Map, Fennville Quadrangle, Michigan-Allegan County, 1981b.

REFERENCES
(Continued)

USGS 7.5 Minute Series Topographic Map, Hamilton West Quadrangle, Michigan-Allegan County, 1981c.

USGS 7.5 Minute Series Topographic Map, Merson Quadrangle, Michigan - Allegan County, 1981d.

USGS 7.5 Minute Series Topographic Map, Millgrove Quadrangle, Michigan-Allegan County, 1981e.

USGS 7.5 Minute Series Topographic Map, Saugatuck Quadrangle, Michigan-Allegan County, 1981f.

Velz, C.T., "Report on Natural Purification Capacities - Kalamazoo River" (Michigan, National Council for Stream Improvement, 1946).

Waggoner, Chris, MDNR, Letter to Mark Brown, Blasland & Bouck Engineers, Subject: 1990 Fish Contaminant Data (August 26, 1991).

Warshaw, R., A. Fishbein, J. Thornton, A. Miller, and J.J. Selikoff, "Decrease in Vital Capacity in PCB Exposed Workers in a Capacitor Manufacturing Facility," Ann. N.Y. Acad. Sci. 320: (1979) pp. 277-283.

Webber, M.D., H.D. Monteith, and D.G.M. Corneau, "Assessment of Heavy Metals and PCBs at Sludge Application Sites," J. Water Pollut. Control Fed., 55(2): (1983) pp. 187-195.

Weber, J.B. and E. Mrozek, Jr., "Polychlorinated Biphenyls: Phytotoxicity, Absorption and Translocation by Plants and Inactivation by Activated Carbon," Bull. Environ. Contam. Toxicol., 23: (1979) pp. 412-417.

Wegman, D., S. Greenland, T. Smith, A. Salvan, and M. Hallock, A Case-Control Study of Cancer Mortality at the General Electric Pittsfield Facility, Vol. I, University of Lowell, Lowell, Massachusetts, 1990.

Western Michigan Environmental Services (WMES), "Evaluation of Leaching of Paper Mill Sludge for Georgia-Pacific Corporation," July 11, 1980.

WMES, "ASTM Water Leachate Report on B-1 Process Residuals from Georgia-Pacific," January 1988a.

WMES, "Evaluation of Extraction Procedure Toxicity Study of B-1 Process Residuals from Georgia-Pacific," January 1988b.

WMES, Inc., Analysis of Water Samples from Willow Boulevard Landfill, February 16, February 22, February 29, and March 17, 1988.

WMES, Analysis of Waste Samples from Willow Boulevard Site, February 18, 1988.

WMES, ASTM Water Leachate Reports on Composite Fill Material, March 3, 1988.

REFERENCES
(Continued)

WMES, Analysis of Water Samples from King Highway Site, March 17, 1988.

WMES, "Toxicity Characteristic Leaching Procedure Extract Evaluation of Papermill Residuals for Georgia-Pacific," June 21, 1990.

Wiemeyer S.N., T.G. Lamont, C.M. Bunck, C.R. Sindelar, F.J. Gramlich, J.D. Fraser, and M.A. Byrd, "Organochlorine Pesticide, Polychorobiphenyl, and Mercury Residues in Bald Eagle Eggs - 1969-79 - and their Relationships to Shell Thinning and Reproduction," Arch. Environ. Contam. Toxicol., 13: (1984), pp. 529-549.

Wiemeyer, S.N., R.W. Frenzel, R.G. Anthony, B. Riley McClelland, and R.L. Knight, "Environmental Contaminants in Blood of Western Bald Eagles," J. Raptor Res., 23: (1989), pp. 140-146.

Wiemeyer, S.N., "Organochlorines and Mercury Residues in Bald Eagle Eggs, 1968-1984: Trends and Relationships to Productivity and Shell Thickness," Proc. Expert Consultation Meeting on Bald Eagles, International Joint Commission, 1990.

Wilkins & Wheaton Engineering Company, Georgia-Pacific Corporation Kalamazoo Paper Division Residuals Management Plan, (Kalamazoo, MI: January 1981).

Wilkins & Wheaton Testing Laboratory, Inc., Engineering Plan for the Georgia-Pacific Corporation Kalamazoo Paper Division, King Highway Landfill Site, (Kalamazoo, MI: February 1982a).

Wilkins & Wheaton Testing Laboratory, Inc., Environmental Impact Assessment for the Georgia-Pacific Corporation Kalamazoo Paper Division, King Highway Landfill Site, (Kalamazoo, MI: February 1982b).

Wilkins & Wheaton Testing Laboratory, Inc., Hydrogeologic Investigation for the Georgia-Pacific Corporation Kalamazoo Paper Division King Highway Landfill Site, (Kalamazoo, MI: February 1982c).

Wilkins & Wheaton Testing Laboratory, Inc., Closeout Plan, Allied Paper, Inc., Sanitary Landfill; Kalamazoo, Michigan, (Kalamazoo, MI: November 1983).

Wilkins & Wheaton Testing Laboratory, Inc., Short-Term Waste Characterization Study for Allied Paper, Inc., (Kalamazoo, MI: November 1985).

Wilkins & Wheaton Testing Laboratory, Inc., Program for Effective Residuals Management for the Allied Paper, Inc., Solid Waste Disposal Facility for Residuals Disposal, (Kalamazoo, MI: 1986).

Wilkins & Wheaton Environmental Services, Inc., Addendum I to the Hydrogeological Investigation for the Allied Paper, Inc., Sanitary Landfill, (Kalamazoo, MI: 1988).

Williams & Works, Water Quality Investigation at the Sludge Disposal Site for Plainwell Paper Company, (Grand Rapids, MI: 1973).

REFERENCES
(Continued)

Willie, R.J., Memorandum, Subject: Water Quality Before and After Discharge at Monarch Clarifier, (Allied Paper, Inc.: August 8, 1975).

WDNR, "Wisconsin Great Lakes Planting Program," Bureau of Fisheries Management, Michael J. Hansen, Madison, Wisconsin, 1989.

Wood, Robert, Memorandum, Subject: Otsego Dam Site (August 1, 1983).

Wuycheck, J., unpublished data, MDNR, Lansing, 1976.

Wyndham, C., J. Devenish, and S. Safe, "The In Vitro Metabolism, Macromolecular Binding and Bacterial Mutagenicity of 4-chlorobiphenyl, a Model PCB Substrate," Res. Commun. Chem. Pathol. Pharmacol., 15: (1976), pp. 563-570.

Zugger, Paul D., MDNR, letter to Thomas F. Sullivan, Georgia-Pacific Corporation (December 4, 1989).