WARZYN

Report
13076

Alternatives Array Document
Feasibility Study
Wausau Water Supply NPL Site
Wausau, Wisconsin

Prepared for:
U.S. Environmental Protection Agency
Region V
Chicago, Illinois

Prepared by:
Warzyn Engineering Inc.
Madison, Wisconsin

April 1989

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Engineers & Scientists
Environmental Services
Waste Management
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April 26, 1989
13076.15

Ms. Margaret Guerriero
Wausau Project Officer
U.S. EPA Region V
5-HS-11
230 South Dearborn Street
Chicago, IL 60604

Re: Alternatives Array Document
Wausau Water Supply NPL Site

Dear Ms. Guerriero:

Enclosed are twenty copies of the Alternatives Array Document for the Wausau Water Supply NPL Site Feasibility Study. Please distribute the document for federal and state agency review and identification of applicable or relevant and appropriate requirements (ARARs) for the identified alternatives. Considering the aggressive project schedule, it is important agency responses be received by Warzyn by May 24 to maintain our schedule goals. If you have any questions regarding the Alternative Array document please call us.

Sincerely,

WARZYN ENGINEERING INC.

Robert L. Mumford

Robert L. Mumford
Project Environmental Engineer

Richard K Hosfeld

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RKH/dlk/DWH
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Wausau, Wisconsin

April 1989

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WAUSAU, WISCONSIN

1.0 INTRODUCTION

1.1 Authorization, Purpose and Scope

The Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA), has established a fund for the investigation and clean up associated with uncontrolled hazardous waste sites. CERCLA requires the United States Environmental Protection Agency (U.S. EPA) to evaluate remedial activities, to determine the appropriate extent of the activities, and to determine that remedial measures are cost effective. Such remedial measures must, to the extent practicable, be in accordance with the National Oil and Hazardous Substances Pollution Contingency Plan (NCP).

The U.S. EPA has authority and responsibility for carrying out these requirements under CERCLA as amended by the Superfund Amendments and Reauthorization Act of 1986 (SARA). The provisions for enacting the requirements of CERCLA appear in the NCP (40 CFR 300).

After discovery of a possible uncontrolled site, a preliminary determination is made as to whether the site presents or may present a threat to the public health or the environment. If additional action is determined to be warranted, the U.S. EPA may place the site on the National Priority List (NPL) of hazardous waste sites. Additional work may then be undertaken to better define potential problems, to develop and evaluate possible solutions (remedies) and to select an action based on the study results. This process for selection of remedial measures consists of the following three major elements:

- Remedial Investigation (RI) - During the RI, data is collected to define site conditions, including the extent of releases from the site and the character of source materials. Data on releases are evaluated to assess the potential effects of releases on public health and the environment.

- Feasibility Study (FS) - In the FS, a number of potential remedial alternatives are developed, evaluated against a range of factors and compared against one another.

- Selection of Remedy - The Agency indicates a preference for a particular remedial alternative, and prepares a Proposed Plan for the site. This Plan, together with the RI and FS reports, are placed in the administrative record for review and comment by the public. The Agency makes a final selection of the remedy for the site after the comments are reviewed, considered and addressed.

The Wausau Water Supply NPL Site consists of the City of Wausau well fields located east and west of the Wisconsin River (see Figure 1). Contamination of the East and West Well Fields with volatile organic compounds (VOCs) was discovered in 1982. VOC stripping towers were installed in late 1984 for treating water from Production Wells CW3 and CW4. The City made provisions for treating water from City Well CW6 for VOC removal, and placed the well back in service in July 1988. Local hydrologic and hydrogeologic conditions changed as a result of the well being placed back in service. A need to begin a remedial response on the west side of the river was identified. Therefore, a PFS was authorized to develop and evaluate alternatives for an operable unit response for the well field and contaminant source area located on the west side of the Wisconsin River.

An operable unit response is being undertaken at the site. An extraction well is to be installed near the west side source area. Groundwater will be extracted and treated using a passive volatilization system prior to discharge to the Wisconsin River.

The FS is being conducted by Warzyn Engineering Inc. (Warzyn) of Madison, Wisconsin under contract with the U.S. EPA to perform RI/FS activities for the Wausau Water Supply NPL Site. The study is being conducted to develop and evaluate alternative remedial actions to address remaining problems at the site.

This report is an Alternatives Array Document. The document has been prepared to provide a summary of site conditions based on information collected during the RI, to describe the remedial alternatives developed to date, and to request the identification by concerned Federal and State agencies of potentially applicable or relevant and appropriate requirements (ARARs) for the contaminants, the site and the remedial actions being considered.

1.2 Report Organization.

In this report, the site background and the nature and extent of the problem are discussed first. A summary of identified risks is presented, and objectives for the remedial actions are identified. General response actions to address site problems are presented, remedial action technologies are identified and screened, and a limited number of remedial action alternatives are then developed and described.

2.0 BACKGROUND INFORMATION

2.1 Site Location and Physiography

The City of Wausau is located along the Wisconsin River in north central Wisconsin in Marathon County. The City currently operates six groundwater production wells, which provide water for approximately 33,000 residents. Five of the production wells are located on the north side of the City. Production Well CW8 is located adjacent to the Wausau Municipal Airport, on the south side of the City. The water from Production Well CW8 contains high iron concentrations and is used only during peak demand periods. Production Wells CW6, CW7 and CW9 are located west of the Wisconsin River and are collectively referred to as the West Well Field. The West Well Field is located in a predominantly residential area, although a few industrial facilities are located in this area. Production Wells CW3 and CW4 are located on the east side of the Wisconsin River and are referred to as the East Well Field. The East Well Field is located in a predominantly industrial section of the City. Refer to Figure 2 for the location of the northern municipal production wells and area businesses.

The six production wells are screened in an aquifer of glacial outwash and alluvial sand and gravel deposits which underlie and are adjacent to the Wisconsin River. This unconfined aquifer supplies nearly all potable, irrigation and industrial water to residents and industries located in Wausau and the surrounding areas. The aquifer formed when the ancestral Wisconsin River eroded a deep valley into the Precambrian aged igneous bedrock. The valley was widened by continental glaciation during the Pleistocene glacial epoch. When the glaciers retreated from north central Wisconsin, coarse outwash sand and gravel sediments were deposited within the valley. Continued erosion of the igneous bedrock upland areas resulted in the deposition of additional fluvial sediments. Within the study area, the alluvial aquifer ranges from 0 to 160 feet thick, and has an irregular base and lateral boundaries.

2.2 Water Utility

2.2.1 Historical Summary of the Wausau Water Supply

The Wausau Water Works was established during the early 1880's for the purpose of providing a municipal water source for City residents. The Wausau Water Works was a predecessor company to the present Wausau Water Utility. The utility was reportedly established in response to population expansion and increased fire hazard associated with low precipitation during the early 1880's (Kendy, 1986). The Wausau Water Works began supplying groundwater in 1885. The water was produced from a large diameter dug well located at the present site of the City water treatment plant. This well was reportedly capable of supplying yields of 2100 gpm (Kendy, 1986).

In 1904 the water utility attempted to supplement the water supply by the addition of a surface water intake crib in the Wisconsin River. However, the usage of the surface water intake was reportedly short-lived due to problems with intake of silt and organic debris. The water utility installed two production wells shortly after 1910. Production Well CW1 was located in the vicinity of the City water treatment plant. Production Well CW2 was reportedly located in the vicinity of River Road and Wausau Avenue. Production Wells CW3 (former), CW4 (former) and CW5 were reportedly added to the supply system during the 1940's. The original Production Well CW3 was located immediately adjacent to its present location near the intersection of Third Street and East Union Avenue. Production Well CW4 was originally located near the intersection of Winton and Third Street. Production Well CW5 was installed near the intersection of West Street and 17th Ave, on the west side of the Wisconsin River. Available pumping history records do not indicate the use of Production Well CW5 for water supply.

The production well records indicate that Production Wells CW1 and CW2 were removed from service during the early 1950's, after installation of Production Wells CW6 and CW7 on the west side of the Wisconsin River. Following the shut down of Production Wells CW1 and CW2, water demand was met by Production Wells CW3 (former), CW4 (former), CW6 and CW7. Production Well CW8 was installed near the Wausau Airport in the mid 1950s. Production Well CW9 was added to the system in 1961 in order to meet increasing water demands. Production Wells CW3 and CW4 were replaced during the 1960's due to excessive wear of inferior materials used in well construction during World War II. The replacement well CW4 was relocated adjacent to the River at the City water treatment plant. The City production system has remained relatively unchanged between 1966 and 1988, with respect to the installation of new water supply wells. However, Test Well CW10 was installed in early 1986, and was pump tested for more than a year. Construction of Production Well CW10 has been completed at the test well location.

Groundwater production records have been kept by the water utility for approximately the past 40 years. The pumpage records indicate extreme seasonal fluctuations in the water demand over the 40-year period. The average water demand remained fairly constant at approximately 110 million gallons per month during the 1950's. Water demand increased throughout the 1960's and early 1970's. By the late 1970's, the average water demand had risen to approximately 140 million gallons per month. Water demand has increased slightly over the past 10 years and currently averages approximately 155 million gallons per month.

2.2.2 Water Supply System

The water utility provides potable water to the City of Wausau and some adjacent areas. There are currently seven production wells available for use or potential use (see Table 1). The water treatment plant was originally designed for iron and manganese removal, disinfection and fluoridation. VOC removal capabilities for up to 3,500 gpm (4.9 MGD, design flow) are now provided by two packed tower VOC stripping towers located at the water treatment plant. The towers were placed in service in response to the VOC contamination problem under a U.S. EPA-sponsored technology demonstration program (Hand, et al., 1986). The plant has historically produced an average of approximately 5 MGD of potable water (Syftestad, 1985).

Both Production Wells CW3 and CW4 can be pumped to either stripper. Production Wells CW7 and CW9 can be pumped to a newly constructed raw water supply main that crosses the river and conveys water from those wells to the treatment plant. Under the former system, no VOC removal was possible for Production Well CW6 water; it could only be blended with water from Production Wells CW7 and CW9. Production Well CW6 is now pumped to the old raw water supply main which crosses the Wisconsin River. As a result of recent piping modifications, contaminated water from Production Well CW6 is pumped directly to either stripping tower for VOC removal prior to blending with other raw water. The City has used Production Well CW6 as a barrier well to stop the migration of contaminants toward Production Wells CW7 and CW9. The discharge of untreated purge water from Production Well CW6 to a storm sewer, which discharges into Bos Creek near the intersection with Burns Street, has been halted.

The water utility currently uses Production Well CW4 as infrequently as possible. When Production Well CW4 is brought into service, the following problems are reported:

- Increased chlorine demand;
- Increased trihalomethane (THM) formation; and
- Decreased treatment efficiency in terms of iron and manganese removal.

Because of these problems, the City has indicated a desire to reduce their reliance on Production Well CW4 as a supply well, perhaps removing it from service altogether. This makes available adequate VOC removal capacity for Production Well CW6 water.

A new westside Production Well CW10 has been constructed, and replaces the supply capacity lost due to abandonment or infrequent use of Well CW4. Production Wells CW3, CW4, CW6, CW7, CW8, CW9 and CW10 are currently in service. Production Well CW4 will presumably be used as a backup.

2.2.3 Distribution System Monitoring

VOC concentrations in the influent and effluent of the strippers were monitored during the period after startup for purposes of technology evaluation by Michigan Technological University. The utility has collected stripping tower influent and effluent samples to monitor VOC removal efficiency, partly as a result of recent concern over possible VOC concentration increases at Production Well CW3. The water utility uses a five-week monitoring cycle for treated water sampling and analysis for tetrachloroethene, trichloroethene, 1,2-dichloroethene and vinyl chloride. Four sampling locations are used: three in the distribution system and one at the water treatment plant. The monitoring schedule and locations being used in November 1987 were as follows:

Week	Day	Location
1	Friday	Plant effluent
2	Wednesday	Green Bay Packaging
3	Monday	Airport
4	Thursday	Plant effluent
5	Tuesday	Holiday Inn

2.3 Hydrogeology

The City production wells are located within glacial outwash and alluvial sediments underlying and adjacent to the Wisconsin River. The aquifer is located within a bedrock valley which is underlain and laterally bounded by relatively impermeable igneous bedrock. The shape of the aquifer and its water yielding properties are strongly controlled by pre-glacial topography on the bedrock surface. In general, the maximum groundwater yields are obtained from areas where the aquifer width has been extended by outwash filled tributary valleys merging with the main valley (i.e., the West Well Field). However, sizeable production well yields are also obtained from municipal wells located closer to the Wisconsin River. These wells induce recharge of surface water into the aquifer, resulting in higher aquifer yields. The groundwater flow in the vicinity of the City well fields is strongly influenced by the following factors:

- Production well pumpage rate and duration;
- Bedrock topography;
- Soil heterogeneities;
- Fluctuations of river and stream elevations;
- Hydraulic resistance of stream and river beds; and
- Rate and distribution of rainfall percolation recharging the aquifer.

A detailed description of the role that each of these factors plays in groundwater flow and contaminant migration is presented in the RI report.

Groundwater flow within the unconfined glacial aquifer has been changed by the installation of City production wells. Under non-pumping conditions, groundwater flows toward the Wisconsin River and, in places, toward its tributaries (e.g., Bos Creek). Groundwater naturally discharges to the Wisconsin River, however, under pumping conditions, groundwater flows toward the production wells. The natural groundwater flow directions are frequently reversed due to City well pumping which induces recharge of surface water into the aquifer. Under certain conditions the zone of capture appears to extend beneath the Wisconsin River and to induce flow to a well from the opposite side of the river.

The horizontal flow in the vicinity of the well field in January 1988 is indicated by the potentiometric contours shown in Figure 3. The potentiometric map indicates pronounced cones of depression around the five active City production wells. The combined cone of depression of the West Well Field extends asymmetrically away from the pumping wells. Based on water levels recorded during January 1988, the southern extent of the cone of depression at the water table appears to be limited by Bos Creek, which acts as a recharge boundary. Bos Creek received approximately 1000 gpm of discharge water from Production Well CW6 pumping to waste. The effectiveness of this recharge boundary is evident in potentiometric Cross Section BB' (see Figure 4). The potentiometric section shows the divide extends through the fine to coarse sand and into the underlying fine sand. This section indicates there may be continuity of flow from south of Bos Creek to Production Well CW6 within the basal gravel deposit. The recharge boundary effect at Bos Creek may be more pronounced since early 1986, when Production Well CW6 began regularly discharging to the creek, substantially increasing the flow. Prior to 1986, the groundwater divide may have been located further south of its present location due to higher pumpage at Production Well CW6 and lack of well discharge into Bos Creek.

The potentiometric surface map also indicates that the cone of depression from the East Well Field appears to affect groundwater flow below and to the west of the Wisconsin River. This is shown by the continuity in gradient from the west to the east side monitoring wells. The effect of the East Well Field production well pumpage is shown by potentiometric Cross Section AA' (see Figure 5). The potentiometric contours on Section AA' indicate a relatively strong component of vertical flow (recharge) adjacent to the bedrock valley slopes, especially on the west end of Section AA'. This recharge may be the result of inflow of groundwater from bedrock fractures, but more likely is caused by infiltration of surface or near surface water runoff from the bedrock uplands. The potentiometric contours become increasingly vertical toward the east, indicating a higher component of horizontal groundwater flow. Monitoring well nests located at Marathon Electric indicate very slight downward gradients adjacent to the Wisconsin River. Below the Wisconsin River, the East Well Field production well pumpage has induced surface water recharge of the aquifer, causing flow downward through the river bed and toward Production Well CW3. Deep groundwater flow remains predominantly eastward (horizontal) as indicated by the almost vertical equipotential lines. Potentiometric contours of the aquifer below the East Well Field indicate groundwater flow converging at Production Well CW3. Groundwater flowing at the base of the aquifer flows upward into the pumping well and shallow groundwater flows downward to reach the screened section of the production well.

Single well aquifer hydraulic conductivity tests performed during the Phase I investigation indicate hydraulic conductivity values ranging from 1.7×10^{-4} cm/sec at Monitoring Well C4D to 8.1×10^{-2} cm/sec at Monitoring Well E22. The overall average hydraulic conductivity of the outwash aquifer is approximately 2.2×10^{-2} cm/sec, based on the analysis of baildown test data from tests at monitoring wells. In general, the bedrock valley underlying the present Wisconsin River tends to widen toward the south. This bedrock valley widening may have resulted in decreased flow velocities during deposition, resulting in finer sediments being deposited in the southern portion of the well field and coarser sediments being deposited in the northern portion of the well field. This depositional scheme may result in reduced hydraulic conductivity toward the south. However, hydraulic conductivity tests results do not confirm such a relationship.

3.0 NATURE AND EXTENT OF THE PROBLEM

3.1 Groundwater Quality

Groundwater quality sampling conducted during the Phase I investigation has identified a vertical and lateral distribution of Total Chlorinated Ethenes which suggest that a minimum of three sources are affecting the City well fields. The estimated areal distribution of Total Chlorinated Ethenes is shown on Figure 6. The distribution is based on a combination of data obtained from contract laboratory VOC analyses of Round 1 groundwater samples (October 1987) and field GC analyses of groundwater samples collected during drilling (October and November 1987).

West side Monitoring Wells W52, W54, W55, C4D, R2D and R4D appear to delineate a deep (greater than 100 foot) north-south trending TCE plume. Based on the vertical distribution of TCE throughout the aquifer in the vicinity of Monitoring Wells W53 and W54 and the presence of TCE in unsaturated zone soils at Boring W54, a potential source was identified within the northern portion of the former City (of Wausau) Landfill. Additional supporting information was obtained from results of a test pit excavation and soil boring program in the former City Landfill area. The plume appears to have migrated northward, under the influence of pumpage from Production Well CW6. The highest TCE concentration (4200 ug/L) within this plume was detected at Monitoring Well W55, which is located approximately 550 ft south of Production Well CW6. The magnitude of the TCE concentrations detected at Well W55 and the distance from the suspected source area suggest that the contaminant release rate was previously much greater. TCE concentrations in the vicinity of the landfill are currently generally less than 3000 ug/L.

TCE concentrations within the deep aquifer plume appear to abruptly decrease in the vicinity of Bos Creek as indicated by the relatively low concentrations at Monitoring Well R3D. This may be due to a genuine separation of the plume into two sections. Alternatively, the concentration decrease may be only an apparent decrease, due in part to the cross-section line deviating from the actual plume centerline. Refer to isoconcentration profile BB', presented in

Figure 7. TCE concentrations at Monitoring Wells R2D and W52 indicate substantial decreases. TCE levels at Monitoring Well R2D decreased from 1020 ug/L in October 1987, to approximately 400 ug/L in December 1987. The TCE concentrations at Monitoring Well W52 decreased from approximately 650 ug/L to 180 ug/L over a similar time period. The decreasing concentrations in this area appear to have resulted from the development of a recharge boundary in the vicinity of Bos Creek. The recharge boundary became apparently more pronounced as a result of Production Well CW6 pumpage rate being decreased, with the well discharge pumped to waste into Bos Creek creating additional flow within the creek and additional recharge to the groundwater from the ponded areas north of Randolf St. Production Well CW6 was pumped to waste nearly continuously between February 1986 and June 1988.

TCE was observed in the shallow aquifer at Monitoring Wells R3S, R2S, W55A, W56A and MW4B. This plume is shown on Figure 6 by the lightly screened contours between Bos Creek and Production Well CW6. The shallow aquifer TCE contamination appears to result from the induced infiltration of surface water from Bos Creek, which has been contaminated by the discharge of Production Well CW6 to Bos Creek. The induced surface water recharge of the aquifer is evident from the downward vertical gradients at Monitoring Well Nests R2 and R3. The TCE levels within the creek have exhibited wide fluctuation. Based on Contract Lab analysis of samples collected during October 1987, TCE concentrations adjacent to the CW6 discharge to Bos Creek (at Burns St.) were above 100 ug/L. TCE concentrations at the ponded area northwest of Randolph Street were approximately 70 ug/L. Surface water samples collected from the ponded area during December 1987 indicate TCE concentrations of approximately 36 ug/L. However, the lower TCE concentrations observed during the December 1987 sampling are probably the result of substantial dilution resulting from precipitation during the sampling period. TCE was not detected in surface water samples collected upstream of the CW6 discharge.

The distribution of TCE in Monitoring Wells E21, E27, E30, E31, W53, W54, C4D and Production Well CW3 suggests eastward migration of a deep TCE plume below the Wisconsin River from the vicinity of the former City Landfill (refer to Figure 6). TCE appears to be vertically distributed throughout the aquifer in the vicinity of Monitoring Wells W53 and W54, indicating close proximity to the source area. Slight vertical downward gradients were observed in the area surrounding these wells. The highest concentrations of TCE were detected at a depth of approximately 115 feet (1105 feet MSL). After moving into the deeper portion of the aquifer, a portion of the plume appears to migrate eastward under the influence of pumpage from Production Well CW3 (refer to Figure 3). Analytical results for samples from monitoring wells WSWS, WSWD (shallow and deep wells near the west shore, adjacent to the former City Landfill), IWS, IWM and IWD (shallow, intermediate and deep wells located on the island near the east shore) confirm the presence of TCE near the top of bedrock beneath the Wisconsin River. These five monitoring wells were recently installed by the City, and are not shown on Figure 3. As previously stated, a part of the plume has also been captured by the pumpage from Production Well CW6 and appears to migrate northward under the influence of this well. Due to the strong induced recharge from the Wisconsin River, the eastern portion of the plume is forced to flow along the base of the aquifer where it is detected by Monitoring Wells E27, E21, E30, E31, IWD and WSWD. As the plume approaches Production Well CW3, the groundwater flow converges, causing the contaminated groundwater to ascend to the screened interval.

The resulting TCE concentrations in Production Wells CW3 and CW6 are significantly less than the highest observed TCE concentrations in the surrounding aquifer due to dilution across the screened interval. The TCE-contaminated portion of the aquifer appears to be less than 20 feet thick and is laterally restricted to a relatively narrow flow path into the well. It is reasonable to expect that Production Well CW6 produces water nearly equally from all sides of the 50-foot screened interval, resulting in a dilution factor that appears to range from 15 to 25. Thus, concentrations observed at the supply well are likely to be 15 to 25 times less than actual in-plume concentrations.

Elevated concentrations of tetrachloroethene (PCE) and other volatile compounds have also been identified within the shallow aquifer in the vicinity of the East Well Field (CW3 and CW4). Based on VOC analyses of groundwater samples collected at monitoring well nests in the vicinity of Wausau Chemical (WC3, W3A, W3B, W3C, WC5 and WC5A), VOC occurrence (primarily PCE) appears to be restricted to shallow depths within the aquifer. However, previous investigations have indicated substantial VOC concentrations at piezometers WC3A and WC6 (Twin City Testing, 1986). Generally, the highest VOC concentrations have been observed in the vicinity of the former bulk solvent storage area near the southern end of the building.

VOC analytical results from a Boring B23 groundwater sample indicate substantial (low ppm level) VOC concentrations in shallow groundwater south of the former bulk storage area, just north of the water utility building. This may indicate that high levels of contaminants such as those encountered during foundation excavation for a 1975 water plant addition are still present in the immediate area, possibly extending under the water plant building. Compounds detected included PCE, TCE, DCE, toluene, xylenes and 1,1,1-trichloroethane. VOC data for shallow groundwater samples suggest eastward migration of chlorinated VOCs onto the Marathon Box (Well E24A) and Wausau Energy (Well E22A) properties. It appears the area of influence of the Wausau Chemical extraction system, located at the former bulk storage area, is fairly limited, and substantial off-site contaminant migration is occurring.

Michelle said yes

Analyses of shallow groundwater samples collected from screened auger Borings B17, B18 and B19 indicate PCE concentrations ranging from 200 ug/L to 1600 ug/L near the north end of the building and in the vicinity of the northwest loading dock.

VOCs detected in groundwater samples in the vicinity of Wausau Energy include light aromatic hydrocarbons and 2-carbon chlorinated alkyl hydrocarbons. Data from Well FVD7, located at the northern end of the property, indicate the presence of chlorinated compounds, but not aromatics. Data from water table wells at the southern end of the property indicate the aromatic and chlorinated compounds are both present. Data from a water table sample collected at Boring B29 (east-central portion of the property), show the presence of PCE and several monoaromatic hydrocarbons (BETX group).

3.2 Source Conditions

The former City Landfill occupies a sand and gravel pit located on the west bank of the Wisconsin River. The landfill covered approximately 4.5 acres, underlying the southeastern portion of Marathon Electric property. The landfill operated from approximately 1948 to 1955 and was reportedly the only landfill operating within the City at that time. During its period of operation, almost all commercial, industrial and residential waste generated within the City was disposed at the site. Prior to landfilling, the waste was generally burned in order to reduce volume. Ash and cinders are reportedly disposed throughout the landfill. Observations made during test pit excavations are consistent with these reports. Former landfill employees indicated that waste burning often could not keep pace with the amount of waste received in a day. In such instances, waste was generally filled directly into the western part of the former sand and gravel pit at the landfill site. The former employees also indicated that bulk liquids contained in 55-gallon drums were frequently emptied directly into the landfill.

The majority of the landfill site is currently covered by a bituminous pavement parking lot. The southern portion of the site is vegetated. An electric utility substation is located over the south central portion of the landfill. The Marathon Electric Company reportedly encountered drummed waste materials during foundation excavations beneath the east side of the plant foundry (see Figure 2).

The predominant source of TCE contamination to Production Wells CW3 and CW6 appears to be the Marathon Electric/Former City Landfill area. Elevated concentrations of TCE were detected in groundwater, soil and soil gas samples obtained both within and beyond the apparent limits of the fill area.

Soil gas samples were collected during a shallow soil gas (2.5 ft) survey, and while drilling Phase II borings (up to 20 ft). Soil samples were collected from testpits within the landfill and from borings within the landfill and at various locations around the Marathon Electric assembly plant. Soil gas VOC data indicate VOCs distributed in the northeastern half of the old landfill, beyond the fill to the north, and to the south and east of the Marathon Electric assembly plant. The highest concentrations were observed at and near the northeast corner of the fill area. Results of laboratory VOC analyses of soil samples generally confirm these findings.

Non-VOC contaminants identified in landfill soil/waste samples included primarily polycyclic aromatic hydrocarbons (PAH) and metals. PAHs were found throughout the fill, but highest concentrations were observed near the center of the fill area. Heavy metals were distributed ununiformly throughout the fill. Chromium, zinc and nickel were detected in groundwater samples from beneath the fill. Metals do not appear to be migrating from the old City Landfill source area in groundwater.

Solvents released from the Wausau Chemical Co. source are primarily responsible for the shallow groundwater contamination in the East Well Field area. Soil gas data reflecting the distribution of VOCs in unsaturated soils were collected during a shallow (2.5 ft) soil gas survey, and while drilling Phase II borings. Shallow soil gas survey data show VOCs in unsaturated soils at highest concentrations near the southern end of the site, with decreasing concentrations within an elongated contaminant zone trending toward the east-northeast. Data from soil sample analysis generally confirm this, but elevated VOC concentrations were also found in unsaturated soils near the northeast loading dock and along the east side of the building. It should be noted that approximately 1000 CY of soils were removed from the former bulk storage area in 1984. The highest VOC concentrations reported for soil samples in the current study were 3 mg/kg, for a sample collected near the water table southwest of the former bulk storage area (B24), and 5.3 mg/kg, for a shallow sample (2.5 ft) collected near the northwest loading dock area. Observations reported during the excavation of soils from the former bulk storage area indicate the likely presence of VOC contamination beneath the southern end of the Wausau Chemical bulding. As indicated previously, VOC contamination beneath the City Water Treatment Plant is suspected.

Wausau Energy was the other east side source area identified. The property functioned as a petroleum bulk storage and distribution center until 1983. Soil gas surveys and unsaturated soil sampling have been conducted at the property. The data indicate hydrocarbons (including light aromatics) are present in unsaturated soils on the southern portion of the site. The maximum VOC concentration reported for a soil sample was 23.9 mg/kg. PCE was reported in samples collected at the northern end of the site in a previous investigation. The maximum PCE concentration reported was 8.6 mg/kg. Only a shallow surface soil was collected from the northern end of the building as part of the current study. No PCE was detected in Wausau energy soil samples in the current study.

3.3 Water Supply Contamination

In early 1982, the City discovered that Production Wells CW3, CW4 and CW6 were contaminated by two-carbon volatile halogenated hydrocarbon compounds (VHH). Toluene, ethylbenzene and xylenes were also detected at Production Well CW4 (Hand, et al., 1986). Trihalomethanes (THMs) were detected in the distribution system, but were attributed to chlorination in the water treatment process. TCE is the predominant volatile organic compound detected at Production Well CW6, although below method detection limit (BMDL) concentrations of PCE and DCE have also been previously reported (Weston, 1975). Since the contamination was first detected in early 1982, TCE concentrations from Production Well CW6 have ranged from 70 ug/L to 260 ug/L. Results from the March 1988 sampling indicate TCE concentrations of approximately 160 ug/L. Sample results from the East Well Field (Production Wells CW3 and CW4) have indicated considerable PCE, TCE and DCE impact at both wells. Production Well CW4 has generally indicated steadily decreasing concentrations of the three constituents since February 1984. Production Well CW3 has indicated decreasing PCE and DCE concentrations since the problem was discovered in early 1982. However, TCE concentrations at Production Well CW3 have remained relatively constant at concentrations ranging between 80 ug/L and 210 ug/L.

To reduce VOC concentrations, the City originally instituted a program where uncontaminated water from Production Wells CW9 and CW7 was blended with water from Production Wells CW3, CW4 and CW6 to dilute the VOC concentrations. However, increasing VOC concentrations in groundwater caused this method to be ineffective, and resulted in regulatory limits being exceeded.

In 1983, the U.S. EPA awarded the City of Wausau a Federal grant to help fund the design and installation of a packed tower VOC stripper in order to provide sufficient water of acceptable quality to City residents. As an interim measure in May 1984, the U.S. EPA installed a granular activated carbon (GAC) treatment system on Production Well CW6. VOC stripping towers were installed in the Summer and Fall of 1984 at the City water treatment plant to treat water from CW3 and CW4. Subsequently, the GAC system was removed from service in October 1984. The City has been blending water treated for VOC removal with water from uncontaminated supply sources (Production Wells CW7 and CW9) to reduce VOCs concentrations in the water supply distribution system.

Data indicate that prior to installation of treatment units (pre-July 1984), drinking water samples taken from various taps in the City of Wausau consistently contained TCE with concentrations ranging from detectable levels (> 1 ug/L) to 80 ug/L. Lower levels of PCE and DCE were identified shortly after discovery of the contamination, probably before blending had reduced the levels of VOCs.

Following installation of the packed tower VOC strippers, the water supply distribution system has had relatively low levels of VOCs (generally below detection limits of 0.5 to 1.0 ug/L). These levels are dependent on continued effective operation of the treatment system for Production Wells CW3, CW4, and CW6, the influent VOCs concentration for each well, and continued use of the two uncontaminated wells (Production Wells CW7 and CW9).

As indicated in Section 2.2.2, the City has brought Production Well CW6 back on line as a supply well. This involves conveying water from Production Well CW6 across the Wisconsin River via a dedicated pipeline to the water treatment plant. Bringing this well back on line caused a change in source water quality relative to previously existing conditions, because water produced by Production Well CW6 is contaminated with TCE. Because of this change, and because uncertainties exist regarding possible increases in contaminant concentrations, an analysis of VOC stripping tower performance was completed to determine whether the existing towers would be capable of reducing VOC concentrations to acceptable levels under a range of water flow rate and raw water TCE concentration assumptions. The analysis is described in Appendix A. Under the new conditions, the two stripping towers could potentially be used to treat water from three wells. Various combinations of wells and pumping rates could potentially be used. The following flow rates were used in the analysis and are considered to represent a reasonable range of operating conditions for the two towers:

Water Flow	8 ft. tower	600 to 2100 gpm
	9 ft. tower	900 to 2400 gpm
Air Flow	8 ft. tower	6000 to 12000 cfm
	9 ft. tower	8000 to 16000 cfm

Results of the analysis for TCE and PCE (the major contaminants at Wells CW3, CW4 and CW6) are presented in Table 2. Predicted contaminant removal efficiencies are given for each tower under various combinations of air and water flow rates. Also shown are the corresponding estimated maximum raw water contaminant concentrations that could be treated, while still meeting drinking water standards in the stripper effluent. The values for TCE were calculated using the Federal Maximum Contaminant Level (MCL) of 5 ug/L as the effluent goal. The values for PCE were calculated using 5 ug/L (reportedly under consideration as a Federal MCL) and 10 ug/L (used by the WDNR as an advisory level for PCE in public water supplies). The analysis indicates that drinking water standards can be met over a range of operating conditions using the existing stripping towers.

It should be recognized that water from the strippers is normally blended with water from uncontaminated Production Wells CW7 and CW9. Thus, the contaminant concentrations in the distribution system have been lower than drinking water standards and generally less than analytical method detection limits of 0.5

ug/L or 1.0 ug/L, depending on the compound and laboratory conducting the analysis. Results of distribution system monitoring data submitted to the WDNR by the City are summarized in Table 3.

3.4 Summary of Health Risk Assessment

The purpose of the health risk assessment is to characterize the nature and estimate the magnitude of potential risks to public health and the environment caused by the contaminants identified at the site. Assessment of risks from environmental contaminants involves identification of contaminants of most concern, routes of contaminant migration and populations potentially exposed to the contaminants. This information is then integrated to estimate contaminant intake for a given population, which in turn, can be compared to chemical toxicity information to arrive at an estimation of health risk.

3.4.1 Contaminants of Concern (Indicator Chemicals)

More than 50 Target Compound List chemicals were detected in various environmental media during the remedial investigation of the site (Table 4). The large number of chemical contaminants detected prohibits consideration of each one for the assessment of risks. Therefore, a subset of the total number of compounds identified (indicator chemicals) was selected for further risk characterization. The objective in selecting indicator chemicals was to choose those which pose the greatest human health and/or environmental threat. Factors used to select indicator chemicals include: the concentration, location and frequency of detection of the chemical at the site, the inherent toxicity of the chemical, and physical/chemical properties of the chemicals (e.g., aqueous solubility, vapor pressure) used as indices of their environmental mobility and persistence. Only compounds present at current points of exposure and those that may migrate to exposure points in the future were considered as indicator chemicals.

The following indicator chemicals were considered to be representative of site contamination and to pose the greatest potential health risk.

- Tetrachloroethene (PCE)
- Trichloroethene (TCE)
- 1,2-Dichloroethenes (DCE)

3.4.2 Toxicity Assessment

The health risk assessment evaluates potential risk to two general types of adverse health effects caused by chemical exposure, cancer and non-cancer effects. The types of toxic effects caused by PCE, TCE and DCE are, in general, similar and are briefly described below.

Non-Cancer Effects

The predominant effect from short-term inhalation exposure to the chlorinated ethenes is depression of the central nervous system, with sufficiently high exposure producing anesthesia. Other symptoms of short-term exposure include eye irritation, lung irritation and gastrointestinal disturbance. Prolonged exposure to these compounds has been observed to cause changes in liver and kidney weight in laboratory animal species.

Cancer Potential

Based on toxicological studies performed in laboratory animals, both PCE and TCE have been classified as Group B2, or probable, human carcinogens. Scientific data collected to date is not sufficient to classify DCE as to its carcinogenic potential.

Because different chemicals that produce similar toxicities usually do so at different concentrations (i.e., have different toxic potencies), information on the toxic potencies of the indicator chemicals must be incorporated into the evaluation of health risks. This factor is addressed in the risk assessment by considering "critical toxicity values" developed by the U.S. EPA. These critical toxicity values (i.e., cancer potency factors and reference doses) were compared to contaminant intakes estimated for exposed populations to arrive at an estimate of health risk.

3.4.3 Exposure Assessment

The purpose of the exposure assessment is to develop an estimate of the magnitude of contaminant intake by exposed populations. This estimation integrates information on pathways of contaminant migration within the environment, concentrations of contaminants at points of contact with receptors, and estimations of the degree of receptor contact with the contaminated media. This assessment was performed using assumptions of current population activities and current conditions at the site. In addition, potential future exposures were considered by evaluating assumptions of future activities or events. The contaminant intake, and thus, risk, an individual would likely incur from exposure to a chemical was estimated for the exposure pathway of concern by incorporating standard exposure assumptions (e.g., a 70 kg man ingests 2 L of water per day).

The possible exposure pathways at the site and those pathways considered to be most important are illustrated in Figure 8 and summarized in Table 6. Potential health risks were evaluated for:

- Residents using municipal water assuming they are exposed to contaminant concentrations equal to the laboratory detection limits (described below).
- Hypothetical users of private well water assuming a private well is installed within the contaminated aquifer in the future.
- Residents and company employees, exposed via inhalation, in the vicinity of the sources of air contaminant emissions.

The City water distribution system supplies potable water, derived exclusively from the Wausau groundwater source aquifer, to approximately 33,000 residents. During the period of 1982 through mid-1984, prior to pumping Production Well CW6 to waste and the installation of the VOC strippers, levels of TCE sampled at various drinking water taps throughout the water distribution system ranged from approximately 10 to 100 ug/L. PCE and DCE were periodically detected, but usually below minimum detectable limits (Weston, 1985). Recently, the City has been monitoring levels of PCE, TCE, and DCE weekly at selected points in the distribution system. Results of these analyses show undetectable levels of these VOCs (PCE and TCE detection limit, 0.5 ug/L; DCE, 1.0 ug/L). Thus, exposure to these compounds via the groundwater is below measurable limits under the existing water distribution practices.

Records of private well installations were obtained from the Wisconsin Department of Natural Resources and the Wisconsin State Board of Health. No residential private wells were identified as installed and drawing from the contaminated aquifer. The records indicated that the nearest private residential well to the zone of contamination is located approximately 1500 feet north west of the contaminant plume impacting the west well field. In addition, a City of Wausau ordinance requires that Wausau residents utilize the municipal water supply for domestic purposes. Thus, based on City regulations, the potential for current and future use of untreated groundwater is very low.

In the absences of these institutional controls, however, it is conceivable that a private well could be installed within the zone of groundwater contamination in the future.

Stripping tower treatment of contaminated groundwater is currently occurring at the City Water Treatment Plant and at the Wausau Chemical Company. In addition, the effluent from the extraction well proposed for the West Well Field will likely be treated. Indicator contaminants dispersed into the atmosphere from groundwater treatment pose a potential contaminant exposure pathway to employees of companies and residents near the sources of air emissions.

3.4.4 Summary of Potential Health Risks

Under current water use conditions a potential carcinogenic risk of approximately 1.0×10^{-6} was calculated for users of municipal water for the combined effects of PCE and TCE. Health risk to the noncarcinogenic effects of the indicator contaminants appears very low. The U.S. EPA has set a Maximum Contaminant Level (MCL) of 5 ug/L for TCE in drinking water. An MCL of 5 ug/L for PCE is reportedly under consideration for proposal in the near future. MCLs are enforceable standards promulgated under the Safe Drinking Water Act. The levels reflect consideration of a range of factors, including not only health risks, but also treatment technology capabilities, analytical methods capabilities and costs. Thus, some level of risk to health may still exist when treated water meets MCLs. Because PCE and TCE are carcinogenic and are not considered to be without hazard below a given threshold, the U.S. EPA has set a non-enforceable Maximum Contaminant Level Goal (MCLG) of zero for TCE in drinking water and is reportedly considering the same MCLG for PCE. Because it is not possible to measure accurately levels of these compounds below the minimum detectable limit, a future health hazard may exist to individuals consuming water over a prolonged period of time in which PCE and TCE are present, but below detectable limits.

Calculated potential carcinogenic risks for individuals consuming private well water were approximately 100 times higher than those calculated for users of municipal water, assuming they are exposed to average contaminant concentrations identified in groundwater at the site. In addition, exposure to these higher concentrations of the chlorinated ethenes may produce adverse non-cancer health effects.

The potential cancer risk to individuals inhaling contaminated air emanating from the stripping towers was estimated from contaminant concentrations calculated by applying simple dispersion equations to source air emissions. The estimated cancer risks ranged from 1.0×10^{-6} to 1.0×10^{-5} at various distances from the sources. Calculations of these risks however, employed conservative assumptions (e.g., continual operation of stripping towers with Production Wells CW3 and CW6 on line) and thus, the actual risk is likely lower.

4.0 PHASE I REMEDIAL ACTION

4.1 Background, Scope and Response Actions

An operable unit response is to be conducted as the first phase of the overall site remedy. Major issues considered in assessing the West Well Field problems and the desirability of a phased response can be summarized as follows:

- Contaminants are being drawn toward the West Well Field from an apparent source area located to the south on or near Marathon Electric property.
- Trichloroethene (TCE) is the major contaminant observed in the West Well Field contaminant plume.
- Production Well CW6 has been pumped to waste, with a discharge to Bos Creek.
- Production Well CW6 acts as an interceptor well, capturing contaminants that would migrate further north to clean wells CW7 and CW9, if CW6 was not being pumped.
- The discharge of Production Well CW6 to Bos Creek resulted in a groundwater mound between the source area and CW6. The influence of the groundwater mound may not have fully penetrated the glacial outwash aquifer, but data suggest the mound may have served effectively to divide the West Well Field contaminant plume into northern and southern portions, indicating that contaminant migration from the source area may have been slowed. However, discharging untreated water from Production Well CW6 into Bos Creek apparently caused induced recharge of contaminated surface water from Bos Creek to the upper portions of the aquifer, resulting in a northward-moving, shallow, low-concentration TCE plume.
- Production Well CW6 has been placed back in service. The pumping rate of CW6 was increased, and the discharge to Bos Creek was discontinued. These two factors will both tend to increase the rate of migration from the source area toward CW6. The probable source of the shallow aquifer contaminants will be removed, however.
- Water from Production Well CW6 is treated for VOC removal using one of the existing stripping towers at the water utility. Based on stripping tower operating experience, water meeting drinking water standards for TCE can be produced using CW6 as a source well.
- TCE is considered to be a carcinogen by the U.S. EPA, and it is assumed there is no concentration at which health risks no longer exist. Therefore, long term exposure to trace levels in drinking water may still present a health risk.

- If no further action is taken, Production Well CW6 will continue to serve as an interceptor well, providing the sole protection for the remaining wells in the West Well Field. Contaminant migration from the apparent source area would likely continue.

Based on this information, it was determined that the long-term solution to the West Well Field TCE contamination problem would involve groundwater controls. Further, it was determined that reducing the period during which Production Well CW6 draws in contaminated water would reduce the period during which drinking water consumers were exposed to TCE at trace (less than detectable) concentrations. An expedited response was therefore considered desirable.

A Phased FS was conducted to develop and evaluate alternatives for addressing the west well field contamination. The major response objectives developed were:

- implement migration control measures to reduce the time during which Production Well CW6 draws in contaminants, and to reduce the potential for contaminant migration further north to uncontaminated supply wells, and

- implement source area groundwater control measures to reduce migration of contaminants away from the apparent source area to the west and east Well Fields.

Viable response actions identified for the Phase 1 remedy included groundwater extraction, treatment and discharge. Each of the alternatives developed incorporated treatment, as a result of Best Available Technology (BAT) requirements. VOC stripping using a packed tower was evaluated as the most cost-effective treatment technology that would likely meet the most stringent BAT requirements for a surface water discharge.

4.2 Phase I Remedial Action Alternatives

Four alternatives were developed and evaluated. They were:

Alternative 1 - No Action.

Alternative 2 - A northern groundwater extraction, treatment and discharge system, located north of Bos Creek.

Alternative 3 - A southern groundwater extraction, treatment and discharge system, located south of Bos Creek near the apparent contaminant source area.

Alternative 4 - A combination of Alternatives 2 and 3.

Alternative 1 is the No Action alternative. Under this alternative, contaminants would continue to be drawn from the west side source area to Production Well CW6. Water from the well would be treated for VOC removal at the City water treatment plant. Pumping by Production Well CW6 would be the only means by which contaminants would be removed from the aquifer on the west side of the Wisconsin River. No additional aquifer remediation would be used to reduce the time to purge the aquifer of contaminants. This would be the lowest cost alternative and would result in the slowest aquifer cleanup, thereby maximizing the period during which water consumers would be exposed to trace levels of contaminants remaining after treatment of water from the west side wells.

Alternative 2 incorporates a groundwater extraction well, treatment using packed tower stripping, and discharge to the Wisconsin River via a municipal storm sewer. Technology-based effluent limits for discharge can be met. The system would be located north of Bos Creek. The influence of the extraction well would extend to the north between Randolph and Burek Streets. Under this scenario, Production Well CW6 would draw in contaminants in the plume that are located north of this area. The extraction system would greatly reduce the period during which Production Well CW6 draws in contaminants, and therefore the time during which water consumers would be exposed to trace contaminants in treated water. The northern extraction well would be relatively ineffective in source area groundwater control. Contaminants would be drawn away from the west side source area prior to being captured by the extraction well. Source area contaminants could potentially migrate to the East Well Field under this alternative if high east well field pumping rates were used. This alternative is comparable in cost to Alternative 3, and would result in relatively rapid protection of Production Well CW6 compared to Alternatives 1 and 3, but relatively less effective source area groundwater control and longer west side aquifer cleanup than Alternatives 3 and 4.

Alternative 3 also incorporates a groundwater extraction well, treatment with packed tower stripping and discharge to the Wisconsin River via a municipal storm sewer. Technology-based effluent limits can be met. The system would be located on Marathon Electric property east and near the southern end of the manufacturing building. The influence of the extraction well would extend north approximately to Randolph Street. Compared to Alternative 1, this would greatly reduce the time during which Production Well CW6 draws in contaminants. Alternative 3 would be somewhat less effective than Alternative 2 in this regard, but would effect better control of source area groundwater than would Alternative 2. This would reduce the potential for migration of contaminants to the east under the influence of East Well Field pumping. Alternative 3 is comparable in cost to Alternative 2, would result in somewhat less rapid protection of Production Well CW6, would achieve better control of source area groundwater and would likely result in more rapid west side aquifer cleanup.

Alternative 4 essentially combines the Alternative 2 and 3 systems. As a result, it would achieve relatively rapid protection of Production Well CW6 (as in Alternative 2) and control of source area groundwater (as in Alternative 3). This alternative would provide the most rapid cleanup of the west side aquifer, but at roughly twice the cost of either Alternative 2 or 3.

The major differences among alternatives, as discussed above, are in short-term effectiveness and cost. None of the alternatives achieves a reduction in toxicity, mobility or volume. Technology-based effluent limits for discharge can be met. Each of the action alternatives is technically and administratively feasible, and required services and materials are considered to be available. With the exception of the No Action alternative, the alternatives can comply with identified ARARs. The action alternatives differ in overall protection of human health and the environment, because of their differences in short term effectiveness (time to achieve long-term protection), but each (including No Action) would result in similar residual public health risks in the long term.

4.3 Selection of Phase 1 Remedy

The U.S. EPA distributed a proposed plan for the operable unit response prior to a public meeting, which was held on October 17, 1988. The 30-day public comment period started on October 3, 1988, when the proposed plan was placed in the administrative record. The plan indicated the Agency's preference for Alternative 3. Following the close of the public comment period, the Agency prepared a Record of Decision (ROD) including a Responsiveness Summary.

Based on the evaluation and comparison of alternatives using nine evaluation criteria developed by the U.S. EPA, Alternative 3 was selected for the operable unit response. The WDNR concurred with the decision.

Implementation of the Phase I remedy represents a change in baseline conditions under the No Action scenario for the remainder of the FS. It is estimated that implementation can be accomplished during the 1989 construction season.

The major components of the Phase I remedy are:

- a groundwater extraction well located near the former City Landfill on Marathon Electric Co. property,
- an active or passive VOC stripping system, and
- discharge to the Wisconsin River.

5.0 REMEDIAL ACTION ALTERNATIVES

5.1 Remedial Action Objectives

Considering the overall long-term goals of protecting public health and the environment, and the primary site specific goals of remediating the water supply aquifer, a number of remedial action objectives were developed as follows:

(1) Attain maximum excess cancer risk within the 1 in 10,000 (1.0×10^{-4}) to 1 in 10,000,000 (1.0×10^{-7}) range, with a target level of less than 1 in 1,000,000 (1.0×10^{-6}), for identified exposure pathways and contaminants, primarily TCE and PCE,

(2) Attain Federal MCLs for the drinking water sources,

(3) Attain State groundwater quality standards at points of standard application,.

(4) Reduce the potential for contaminant release from source area materials remaining in place via leaching and gas phase migration to air, soils and groundwater,

(5) Reduce the potential for exposure to source area materials remaining in place,

(6) Reduce the potential for exposure to contaminants in groundwater, and

(7) Attain compliance with all identified Federal and State ARARs.

5.2 General Constraints on the Development of Alternatives

Alternatives must be formulated to address the specific circumstances of the source areas, contaminant releases, contaminant types, distribution, transformation, and migration, and both current and potential exposure pathways. Considering physical site conditions and public health, environmental and administrative needs, constraints that affect configuration of the alternatives have been identified. The major constraints are:

- Baseline conditions include the implementation of the west side source area extraction well and passive volatilization treatment system. Its estimated effects on groundwater flow within the local aquifer and a public health and the environment must be taken into account,

- Treatment for the reduction in toxicity, mobility or volume of identified contaminants or contaminated media must be considered,
- Disruption of the water utility's operation should be avoided or minimized.

5.3 General Response Actions

Attaining the response objectives will require the use of groundwater control and source area control measures. Aquifer remediation goals can be achieved using aquifer purging and/or in-situ restoration methods. Where groundwater pumping is used, treatment, discharge, and management of treatment residuals are required. Contaminant migration control may involve some type of hydraulic gradient control using groundwater extraction, recharge, physical barriers, or some combination of these. Source control objectives may be met using removal, treatment, disposal, isolation and/or closure measures. The major strategies would include removal and disposal of contaminated materials (with or without treatment), removal and/or destruction of contaminants using in-situ methods, or isolation of the areas and limiting infiltration using barriers such as caps. Institutional measures including restrictions on groundwater and/or land use, and providing an alternate water supply may also be appropriate.

General response actions and associated technology groups identified for consideration are:

Response Actions	Technology Group
Groundwater Controls	Barriers Injection Extraction Extraction/Injection
Groundwater Treatment (above-ground and in-situ)	Physical Chemical Biological
Discharge	Groundwater Surface Water

Soil/Waste Removal	Excavation
Soil/Waste Treatment (above-ground and in-situ)	Physical Chemical Biological
Disposal	On-site Off-site
Containment	Capping Barriers
Institutional Measures	Deed Restrictions Groundwater Use Restrictions Alternate Water Supply Monitoring

5.4 Identification and Screening of Technologies

In the following sections, specific technologies corresponding to the general response actions and technology groups presented in Section 5.3 are identified and discussed. A decision is made whether to retain a given technology for use in developing alternatives or to eliminate it from further consideration. The purpose of the screening is to select a limited number of promising technologies for consideration in developing alternative remedial actions.

The general criteria used in screening technologies are effectiveness, implementability and cost. Effectiveness is evaluated considering end results; i.e., whether the technology can be used to attain a desired cleanup level or other effects within the desired time. Implementability is evaluated considering a range of factors relevant to obtaining, installing and using particular technologies. Some remedial technologies are proven and readily available, while others are in research and development stages. Insufficiently developed technologies are generally screened out.

In general, technologies are considered insufficiently developed if there is not sufficient information from experience or testing to indicate clearly their potential feasibility or effectiveness. This criterion may include cases where only preliminary or unconfirmed testing results are available, where performance claims are not substantiated, or where a technology's capabilities have not been demonstrated at a scale relevant to its application at the site.

Site conditions must be compatible with the feasible range of a given technology's capability, considering, for example, aquifer characteristics, depth to bedrock, depth to groundwater, space requirements, contaminant types and concentrations. At this site, the existence of commercial/industrial and residential development in the area of concern favors the use of technologies whose construction and operation is relatively non-disruptive. Certain institutional issues were considered at this stage, as appropriate. Once the technologies have been screened for basic application at the site, relative cost may be used for further screening. Both capital and annual operation and maintenance (O&M) costs are considered when costs are used in technology screening.

5.4.1 Groundwater Controls

Groundwater control methods fall into two categories: physical barriers and hydraulic gradient control. Physical barriers can be effective in controlling the movement of groundwater and its associated contaminants by placement of low permeability barriers to reduce flow from one area to another. Hydraulic gradient control is used to modify local groundwater flow patterns. This is accomplished using water injection, groundwater extraction, or a combination of the two. The screening of groundwater control technologies is summarized in Table 7.

Barriers

Physical barriers can be effective in preventing contaminant migration. At this site, barriers would be used to limit the migration of contaminants from the source areas to wells. This would be best accomplished by placement around the source areas, creating partial (e.g., on downgradient sides) or full circumferential barriers.

The depth to bedrock in the primary source areas makes the use of full containment barriers impractical. Barriers at the old City Landfill would not provide additional protection against contaminant migration. The best application at this site would be the installation of shallow barriers near the Wausau Chemical property source areas, to control the migration of contaminants in shallow groundwater. Shallow barriers would not, however, provide reliable containment, and groundwater extraction would need to be used for active remediation. Because of the contaminant distribution, barriers would need to be constructed in areas containing railroad tracks, raw and potable water supply lines and sewer lines. Materials storage areas at both Wausau Chemical and Marathon Box would be disrupted. Considering effectiveness concerns related to the limited benefits of only partial and temporary gradient control together with the implementation problems arising ✓ from physical site limitations, physical barriers are eliminated from further consideration.

Injection

Injection could be used to develop a hydraulic barrier by creating a mound in the water table. Water could be injected into the aquifer using wells, trenches or seepage basins. Seepage basins would require too large an area for this site. Trenches may not have a hydraulic influence that fully penetrates the aquifer, although a partially penetrating mound would be acceptable for the shallow contamination. Injection wells would be the most promising technology for this action. Three potential sources of water for injection are:

Treated City Water -	Injection would be a waste of an already limited supply of potable water.
River Water -	Pretreatment would be necessary, and THM production at the water plant would likely increase as injected water is drawn in by supply wells.
Groundwater -	Direct use of clean groundwater as a potable water source would be more efficient.

Injection alone is not considered viable, because no adequate source of injection water is available, and injection wells are generally not allowed by ✓ the WDNR. This technology is therefore eliminated from further consideration due to technical and administrative feasibility limitations.

Extraction

Groundwater extraction is the most promising method of controlling groundwater movement, while removing contaminants. Wells and trenches are most commonly used to collect groundwater. In this application, wells would be favored over trenches, for extraction of contaminants from relatively deep to intermediate zones in the sand and gravel aquifer. Trenches could be used to intercept relatively shallow contaminant plumes. Some of the site limitations discussed for subsurface barriers also apply to construction of trenches for groundwater collection. A wellpoint and header system could potentially be used. This would provide flexibility in operation of a multiwell system while limiting maintenance on pumps. The effective depth of such a system may limit its viability at this site. The most generally applicable groundwater extraction technology is the deep well. Deep wells will be retained for alternatives development, because they are the most generally effective and readily implemented groundwater extraction devices at this site.

Extraction/Injection

A combination of groundwater extraction and injection could be used to control local hydraulic gradients. The vertical influence of trenches may be limited, but this may be acceptable for shallow groundwater control. Wells are favored over trenches where control of deep groundwater potentiometric gradients is desired. Extraction and reinjection are judged to be technically feasible. Water would be recharged to the aquifer to (1) dispose of treated water, (2) create a water table mound and resultant hydraulic barrier, (3) manage flow within a certain portion of the aquifer (recirculating extraction/injection system), or (4) to introduce substances and effect desired chemical, biological or physical changes. Discharge to the Wisconsin River would be the most straight forward disposal option, because injection wells are typically not allowed in Wisconsin, and it is doubtful that a waiver from this restriction would be granted when there are other viable options. Creating a water table mound may enable effective control over shallow groundwater flow. At this site, substances could potentially be introduced into the aquifer to enhance biological activity, to promote bioreclamation of the aquifer. As discussed above, administrative difficulties associated with injections may be serious. Considering the potential effectiveness and implementability of extraction/injection systems at this site, they are retained for use in developing alternatives.

5.4.2 Groundwater Treatment

Some level of treatment will be required prior to any surface water discharge, because of technology-based effluent limits. Substances contained in water recharged to the aquifer are also regulated. Water will therefore be treated prior to discharge. Treatment methods can be divided into three categories: physical, chemical and biological. The screening of groundwater treatment technologies is summarized in Table 8.

Physical Methods

Conventional physical treatment methods such as screening, filtration or settling would not treat VOCs and are therefore not considered viable. Ion exchange is applicable only for removal of charged ions or complexes in solution, and is therefore inappropriate for removal of uncharged dissolved VOCs. Potentially applicable physical treatment technologies include stripping, adsorption and reverse osmosis (hyperfiltration).

VOCs are conventionally stripped from water using air or steam in a packed column. Water is pumped to the top of a tower packed with a high surface area, high void volume, inert material. Water trickles over the packing and is discharged at the bottom of the tower. The stripping gas is typically introduced at the bottom of the tower, flows upward through the packing void spaces and is discharged at the top of the tower. Volatile contaminants are transferred from the water to the stripping gas. For solutes as volatile and readily strippable as the VOCs detected at the site, at the concentrations anticipated (< 1 mg/L), ambient temperature stripping with air is generally used. Air pollution controls may be required. The effectiveness of this technology has been well demonstrated at the water utility and at numerous other sites, and the technology is therefore retained.

Passive VOC stripping is also a viable option for treatment at this site. This could be accomplished using a modified discharge structure to create turbulence in the water and enhance air-water contact prior to discharge to the receiving stream. A smooth or riprap-lined channel constructed on the river bank could serve this purpose. It would be relatively simple to construct at relatively low cost and operating costs would be minimal. This technology is retained due primarily to its potentially acceptable effectiveness and low cost.

Activated carbon adsorption is also commonly used to remove VOCs. Most frequently, granular activated carbon beds are used. Contaminated water flows through the carbon bed and contaminants are adsorbed on the carbon. The process is capable of reducing contaminants to less than detectable levels. When the capacity of the carbon is exhausted, the bed is taken out of service. The spent carbon is usually either regenerated, disposed in a landfill or incinerated. The choice of carbon handling methods depends largely on the contaminants, concentrations and economics of regeneration versus disposal or destruction. The effectiveness of this technology for VOC removal has been demonstrated at several sites, and the technology is retained.

Reverse osmosis (hyperfiltration) is potentially applicable for the removal of VOCs. A semi-permeable membrane is used to effect a separation of solvent (water, in this case) and solute (e.g., TCE or benzene, in this case). The pore size in the membrane is such that water passes through more readily than the contaminant. Contaminated water is pumped under high pressure to membrane-holding cartridges. Water with low contaminant levels passes through the membrane (permeate stream) and a concentrated aqueous VOC solution (concentrate stream) remains on the pressurized side of the membrane. A concentrated reject stream must therefore be managed. The relative proportions of permeate and concentrate depend on solute properties, membrane properties, flow rates, operating pressures and the configuration and number of units used in the process. No reports of full scale use of membrane separation for VOC removal have been identified. A major unknown is membrane material compatibility with the contaminants. Laboratory and pilot scale testing to determine feasibility and design parameters would be required. The energy needed to operate a high pressure system and the need for permeate treatment would likely make this a costly process. This technology is not considered to be adequately demonstrated at full scale and is therefore not retained.

Chemical Methods

Conventional chemical treatment methods such as coagulation or precipitation would not be effective in TCE removal. Chemical oxidation may be applicable, providing contaminant destruction. The most promising technology is oxidation using ozone and/or hydrogen peroxide.

In this process, ozone and hydrogen peroxide are contacted with contaminated water in a reactor. Ozone is fed to the reactor using fine bubble diffusers and hydrogen peroxide is fed as a concentrated liquid solution. Ozone decomposes in water to form hydroxyl radicals which react with chlorinated ethenes. The addition of hydrogen peroxide accelerates the process, because a hydrogen peroxide decomposition product (hydroperoxide ion) accelerates the decomposition of ozone (Glaze and Kang, 1988). Chemical doses and overall reaction rates must be determined experimentally for a particular water, because of competing oxidation and free radical reactions. This technology is retained due to its demonstrated effectiveness in contaminant destruction.

Biological Methods

Aerobic biological degradation is potentially applicable to treatment of 1- and 2-carbon chlorinated hydrocarbons such as those found at this site. Aerobic degradation of TCE, cis- and trans-1,2-DCE, 1,1-DCE and vinyl chloride by methanotrophic bacteria has been demonstrated [Wilson and Wilson (1985), Fogel et al. (1986), Moore et al. (1989)]. Microbially-mediated degradation of the same compounds has also been demonstrated under anaerobic conditions [Bouwer et al. (1981), Bouwer and McCarty (1983), Parsons et al. (1984), Kloepfer et al. (1985), Vogel and McCarty (1985), and Boyer et al. (1987)]. PCE is degradable anaerobically, but was not degraded under aerobic conditions by methanotrophs (Fogel et al. 1986). The degradation of petroleum-type hydrocarbons such as those found at Wausau Energy has been demonstrated in conventional wastewater treatment systems and in petroleum waste land treatment systems.

Methane mono-oxygenase appears to be the enzyme responsible for the aerobic transformation of chlorinated alkenes by methanotrophs. Methane and nutrients would need to be fed to an aerobic biological reactor. The mechanism for anaerobic transformation of these compounds is not well understood. Studies where transformation and degradation has been demonstrated all were conducted under conditions where another carbon and energy source was available: (e.g., ethanol, acetate or naturally-occurring sediment organic matter). Therefore, a carbon/energy source and nutrients would have to be provided.

Reaction rates and microbial growth kinetics have not been well defined for these processes. Reactor configurations are being developed and assessed, including a fixed-film gas-permeable membrane system (Woods, Williamson and Strand, 1989), a concurrent flow, packed bed, gas-phase continuous reactor (Huffman et al., 1989), and a center downflow, annular space upflow column (Pritchard, 1989). Groundwater would be pumped to a biological reactor for treatment. Laboratory and pilot scale studies would have to be conducted to determine removal rates, biological growth kinetics and nutrient requirements. Although this technology holds some promise, it has not been demonstrated in an application like this, even at the pilot scale. Considering the potential benefit of contaminant destruction, it is retained for alternatives development based on potential effectiveness.

5.4.4. In-Situ Treatment Methods

In-place treatment of contaminants is potentially viable for the physical conditions and contaminants identified at the Wausau site. As with above-ground processes, the technologies can be categorized as physical, chemical or biological methods. The screening of in-situ treatment methods is summarized in Table 8.

Physical In-Situ Methods

The only viable physical in-situ treatment method is a vertical permeable treatment bed. In this system, a trench is excavated to a depth sufficient to enable capture of the contaminant plume, and is backfilled with an adsorbent material, such as granular activated carbon. Slurry trench construction methods would be used, and the implementation problems associated with trench construction in this area would apply to this technology. The trench width would be limited to perhaps three feet. In principle, groundwater would flow through the trench and contaminants would be removed by adsorption to the carbon. A major problem with this system is that there is no provision for replacing the adsorbent, and contaminants would break through when the bed capacity is exhausted. This technology would ultimately only slow, not prevent, migration of contaminants toward production wells. This technology is eliminated from further consideration because of its limited effectiveness and implementability limitations.

Chemical In-Situ Methods

The most promising in-situ chemical treatment method is oxidation. As discussed earlier, ozone and hydrogen peroxide can be used to chemically destroy VOCs in water in a reaction vessel. In principle, these chmicals could be injected into the aquifer to effect TCE destruction. Because the desired reactions would take place in the porous medium of the aquifer instead of in a tank, many other competing reactions could be anticipated. The system would involve feeding chemicals in agueous solution into water from groundwater extraction wells, and reinjecting the water into the aquifer. Materials of construction (pumps, piping, wells, etc.) must be resistant to the oxidants used. No reports of chemical oxidation of the contaminants of concern in an aquifer or in soils have been identified, so this technology would require extensive testing. Obtaining approvals for injection into the aquifer would likely be time-consuming, at the very least. This technology is not considered adequately developed for use at the site, and is therefore eliminated from consideration due to effectiveness and implementability concerns.

Biological In-Situ Methods

According to available information, the biological degradation of most one- and two-carbon chlorinated aliphatics occurs either aerobically or anaerobically. PCE is apparently a notable exception. Physically, an in-situ bioreclamation system would be similar to the extraction and injection system discussed above for in-situ chemical treatment. Nutrients, an organic substrate, and possibly a terminal electron acceptor would be fed into the reinjection stream instead of chemical oxidants. The goal of this system would be to maintain suitable environmental conditions throughout the aquifer section of interest to support the growth of desired microorganisms to enhance aerobic or anaerobic degradation of contaminants. Different environments may need to be maintained for transformation of different contaminants (e.g., PCE may not be transformed aerobically). The major difficulty associated with this treatment is that in some cases, neither the mechanisms responsible for specific compound degradation nor optimum growth conditions have been identified. Therefore, the ability to maintain suitable conditions is difficult to assess at this stage. Again, obtaining approval for a system incorporating injection of chemicals into an aquifer near a public water source may be difficult. In spite of potentially serious limitations, the site conditions, contaminant types and concentrations appear to favor use of this technology. Testing will be required. In-situ bioreclamation of the local aquifer has the potential to provide a relatively rapid cleanup while achieving contaminant destruction, and is therefore retained for development of alternatives based on promising effectiveness and implementability, and on the potential long term cost savings associated with in-place contaminant destruction.

5.4.5 Discharge Options

Groundwater

As discussed above under injection and extraction/injection, a groundwater discharge may be desirable to enhance local hydraulic gradient control. This technology is retained based on effectiveness.

Surface Water

Two options are available for discharge of groundwater to surface water:

1) Conventional pipeline and outfall, and
2) Publicly-owned treatment works (POTW).

A conventional discharge to surface water is appropriate for consideration. This could include construction of a new discharge pipeline, or use of an existing storm sewer. This option is retained.

Discharge to the POTW would result in an increase in hydraulic loading on the plant. Volatilization would be the major fate of VOCs at the POTW, and substantial removal efficiencies may be obtained, even though the plant was not specifically designed for VOC removal. Because treatment at the POTW should only be incidental, it is not considered suitable as the principal treatment of contaminated groundwater. If groundwater were pretreated, then this would likely meet BAT requirements for direct discharge, so a POTW discharge would not be necessary. In any case, POTW performance would likely be adversely affected due to the increased hydraulic loading. This discharge option is therefore eliminated from consideration. A summary of discharge options screening is provided in Table 9.

5.4.6 Soil/Waste Removal

Removal of contaminated materials at the source areas would be a technically feasible means of minimizing the additional release of contaminants to groundwater, soil and air. Options for managing these materials include treatment (on-site or off-site) and disposal (on-site or off-site).

Candidate areas for removal include contaminated fill in the old City Landfill, contaminated soils at and near the Wausau Chemical property and contaminated soils at Wausau Energy. The major problems associated with these source areas are VOC residuals. Preliminary estimates indicate the volume and soils with VOC concentrations greater than 1 mg/kg is on the order to 5,000 to 10,000 cy at the north end of the old landfill. Corresponding quantities for the east side source (Wausau Chemical) are difficult to obtain, because there were only two soil samples with VOC concentrations greater than 1 mg/kg: one near the north loading dock and one east of the former tank farm area. Highly contaminated soils in the former tank farm area were removed in 1984. Low level VOC contamination of soils exists over much of the site, making excavation impractical. The volume of contaminated soils at Wausau Energy is difficult to assess, but may be less than 1000 CY. Excavation of materials at the north end of the old City Landfill and possibly Wausau Energy is retained for alternatives development due to its potential effectiveness and implementability.

5.4.7 Above-Ground Treatment

Treatment processes applicable to VOC-contaminated material include:

- Thermal treatment
- Solidification
- Stabilization
- Volatilization
- Bioreclamation
- Soil washing

The screening of above ground treatment technologies is summarized in Table 10. The only methods considered available for off-site treatment are thermal treatment (incineration) and solidification/stabilization. Off-site incineration of solids is normally prohibitively expensive, with quoted costs on the order of $1/lb treated for drummed soil. This is normally best applied to very limited quantities of highly contaminated material, and is not considered appropriate for the quantities or VOC concentrations of this waste. Off-site stabilization/solidification services are available though they are best suited for treating metals-bearing wastes. The suitability of stabilization treatment for VOC contaminated solids is questionable, because the volatile organics are not immobilized in the treated waste. Solidification may have some benefit, because the treatment can produce a low permeability product. In the long term, however, VOCs can be released by leaching and/or volatilization. Off-site treatment is therefore eliminated from further consideration due principally to effectiveness and/or cost considerations.

Options for on-site treatment also include incineration and stabilization/solidification. Comments made above regarding stabilization and solidification also apply to on-site use of those technologies. With regard to incineration or similar high temperature thermal treatment methods, the major issue for an application like the one at this site is the cost of mobilization, permitting and processing versus the quantity of material to be treated. High unit costs, on the order of several hundred dollars per ton, are typically associated with thermal treatment of small quantities (5,000 to 10,000 cy range). On-site high temperature thermal processing is not considered practical for this application because of waste quantities and treatment costs.

Enhanced volatilization may be applicable to this material. Two general types of approaches to above-ground enhanced volatilization are employed: elevated temperature methods and mechanical methods. Elevated temperature methods include use of such devices as a rotary drum dryer, or other mixer with air or steam injection. Off-gases are either vented or collected (condensed in the case of steam) and treated. The equipment is less complex than that required for high temperature thermal treatment, and mobilization costs are therefore lower. Mechanical methods can include a variety of methods in which granular solids are mixed to expose VOC contaminated surfaces to air, thereby enhancing VOC removal by volatilization. Contaminants are released to air. A common method of accomplishing this is spreading material in a shallow layer and periodically tilling using conventional equipment. A major site limitation is the lack of adequate space to accomplish this (10,000 cy of soil spread to a depth of 12 inches requires an area of 6.2 acres). After a certain amount of processing (size classification and/or reduction), the contaminated fill material could be treated using enhanced volatilization. This technology (using some mixing device) is retained for use in developing alternatives, because of effectiveness and implementability considerations.

Bioreclamation is potentially applicable to soils treatment. As discussed previously under groundwater treatment technologies, degradation of most of the chlorinated compounds can be accomplished either aerobically or anaerobically. Considering the volatile nature of the contaminants of primary concern and the lack of space for land farming, biological treatment would be best accomplished in a gas-solid contactor, perhaps a moving bed or rotary drum. No applications of this sort have been identified for soils with relatively low-level VOC contamination. Slurry-type reactors could be used, but this would produce an aqueous waste stream requiring treatment and disposal. Pilot testing would be required. This technology is not considered adequately demonstrated and is not retained for alternatives development due to implementability concerns.

Soil washing can be used to remove organics from soils. For sparingly soluble VOCs, surfactants may enhance removal. A dilute aqueous stream containing VOCs and possibly surfactants would result from this process and require additional treatment. Considering the contaminant concentrations, the need to treat the waste stream, and the fact that volatilization is a much more straightforward treatment for this material, the effectiveness (particularly in relation to other technologies) is questionable. This technology is not retained for further consideration.

5.4.8 In-Situ Treatment

A variety of options exist for treating the VOC contaminated soils in-situ. They can be classified as physical, chemical and biological.

Physical Treatment

Physical treatment methods include vitrification, vapor extraction, steam heating/extraction, and flushing.

In-situ vitrification is accomplished by installing electrodes vertically in boreholes around an area, applying a high voltage and heating the soil/waste mass as a result of the electrical resistance of the mass. Soils are melted at the high temperatures developed. A hood is erected over the area to be treated, to collect off-gases. The off-gases are treated. Vitrification results in high temperature organic contaminant destruction and melting of the heated mass, which then cools to a glassy solid, immobilizing residual contaminants. This technology is best applied where very high temperatures are required for contaminant destruction, and where the glassy solid product is beneficial in immobilizing inorganic contaminants that are not destroyed during processing. The process is relatively expensive and energy intensive. The unique capabilities of this technology (high temperature contaminant destruction and immobilization of residual contaminants) would not be appropriately applied to the types of waste/soil at this site. The presence of buildings in very close proximity to contaminant areas presents serious obstacles to implementation, therefore, vitrification is not retained.

Steam-heating and extraction is essentially a high-temperature version of vapor extraction, where steam serves as a hot carrier gas, with the additional benefit of effective physical cleaning of soils. Steam is injected into unsaturated soils, and causes vaporization of volatile contaminants as it moves through contaminated areas. The steam is removed by applying a vacuum at collection points. The steam and contaminants are then condensed above ground, and the condensate can be treated. The highly volatile contaminants at this site can be removed at ambient temperatures, without expending additional energy on steam production. This technology is not retained because it would not be well-applied at this site.

Flushing is used to remove contaminants and transfer them to a liquid medium - most commonly water - where they are then collected and treated. A flushing solution is prepared. In this case, water or an aqueous surfactant solution would be suitable. The solution is applied in some manner above the contaminated unsaturated soils. The solution then trickles down through the contaminated soils and is collected using some groundwater extraction system. Normally, either a shallow trench or spray system is used to distribute the flushing solution and shallow wells or trenches are used to collect the solution along with groundwater. This is a fairly inefficient means of collecting sparingly soluble VOCs from shallow soils. Control of flushing effectiveness would be difficult at the City Landfill source, because of heterogeneities in contaminated unsaturated fill and soils. The area involved at the Wausau Chemical source area would be too extensive for this method to be practical, particularly considering the land use. This technology is not retained, largely because of implementability questions.

Vapor extraction at ambient temperatures is the most practical means of addressing the VOC contamination at both the old City Landfill and Wausau Chemical source areas. A vacuum is applied at some collection point or series of collection points, which may be either wells or perforated pipe laid in trenches. Soil gases and contaminant vapors migrate toward the collection points. The gases may require treatment prior to discharge. This is typically accomplished using an adsorbent bed, a catalytic combustion device or a fume incinerator. With well-placed extraction wells and/or trenches and by controlling pressure within the unsaturated zone, contaminant vaporization can be controlled to effect contaminant removal from extensive areas and from under structures. Unsaturated soil heterogeneities can present difficulties in control and effectiveness. The basic feasibility of vapor extraction at this site was demonstrated by a field vapor extraction test. During vapor extraction testing at the old City Landfill and at Wausau Chemical source areas, contaminant removal rates on the order of 0.5 to 1 lb VOCs/day were obtained. A summary of the testing, including procedures, field data, analytical results and analysis, will be provided in the FS report. This technology is retained for use in developing alternatives based on implementability and effectiveness considerations.

Chemical Treatment

Available chemical treatment methods for in-situ treatment of chlorinated VOCs in unsaturated soils are limited. The de-halogenation/oxygenation reactions obtained using hydrogen peroxide and ozone for water treatment may be achievable, but aqueous feed of these chemicals over the desired areas would be difficult (as discussed above for flushing). Treatment would therefore be limited to areas where effective solution distribution could be achieved. The ability to obtain and control the desired reaction in a soil matrix would have to be demonstrated. The implementability limitations and uncertainties regarding effectiveness of this technology are fairly serious, therefore, the technology is not retained.

Biological Treatment

Bioreclamation of unsaturated soils is potentially feasible. As indicated in previous discussions, nutrients and an external carbon source would need to be introduced. The limitations associated with the introduction and distribution of aqueous solutions therefore apply to this technology: (1) unsaturated zone heterogeneities at the old City Landfill will likely limit effectiveness, and (2) application over relatively large areas at Wausau Chemical is not practical. This technology is therefore not retained for alternatives development.

5.4.9 Disposal

The only materials (apart from possible treatment process residuals) that may require disposal are the fill and soils that could be removed from the north end of the old City Landfill. On-site disposal after treatment would be preferred. If off-site disposal is deemed necessary, a suitable facility in compliance with its operating permit would be used.

5.4.10 Containment

The old City Landfill is largely filled with ash, cinders, foundry waste, demolition debris, metal scrap and other non-combustibles. Infiltrating precipitation can carry contaminants to the water table. Because organic waste was apparently burned in the fill area, high-strength leachate generation is not a concern at this site. The northern part of the landfill area is currently covered by a bituminous pavement parking lot for Marathon Electric Company. The parking lot does not cover all contaminated areas, and cracks allow some infiltration. Capping of the landfill may be required, to minimize infiltration through waste left in place. A variety of capping methods are available, and will be considered as appropriate.

Capping may be provided at the old City Landfill (and possibly other areas) based on ARARs or health risks, or to meet other response objectives.

5.4.11 Institutional Measures

A variety of institutional measures may be taken as part of an overall site remedy. These include:

- Deed Restrictions
- Groundwater Use Restrictions
- Alternate Water Supply
- Monitoring

Deed restrictions would be appropriate for properties where contaminated materials remain in place. The feasibility of this depends on whether the State/City has this authority and is willing to impose restrictions. Groundwater use restrictions are reportedly already in place within the City of Wausau, such that municipally-supplied water is to be used as a potable supply.

Providing an alternate water supply for the City must be considered. The only viable source identified is the Wisconsin River. An adequate quantity appears to be available from the river. The quality may not be suitable for use without modification of the water treatment plant physical facilities and/or operations. The plant reportedly has a river water intake. This option will be evaluated further.

Monitoring will be necessary to assess remediation effectiveness and maintain an understanding of contaminant distributions in relation to water supply wells.

5.5 Technologies Passing Technology Screening

Considering the site and contaminant characteristics, response objectives and identified constraints on the response, the following technologies were retained for consideration in developing alternatives.

Response Action	Technology
Groundwater Controls	Extraction Wells Extraction/Injection
Groundwater Treatment (above ground)	Ambient Temperature Stripping Carbon Adsorption Chemical Oxidation
Groundwater Treatment (in-situ)	Bioreclamation
Discharge	Pipeline or Cascade Discharge to Surface Water Groundwater
Soil/Waste Treatment (above ground)	Enhanced Volatilization
Soil/Waste Treatment (in-situ)	Vapor Extraction
Disposal	Off-site On-site
Containment	Capping
Institutional Measures	Deed Restrictions Alternate Water Supply Monitoring

6.0 REMEDIAL ACTION ALTERNATIVES

A limited number of remedial action alternatives were developed. The No Action alternative is included to provide an assessment of the consequences of taking no response action at this time.

Phase I
ARARS

6.1 Alternative 1 - No Action

The No Action alternative is evaluated as required by the NCP. Under this scenario, no additional action would be taken beyond the Phase I remedy. Minimal actions such as additional monitoring may be undertaken.

Air 400-499
144.436
144.444
500-520

6.2 Alternative 2 - Active Source Control

Under this alternative, source area remediation would take place, to reduce the potential for future contaminant releases to groundwater. Two options would be considered for the west side source area: (1) excavation with above ground treatment using enhanced volatilization, with redisposal on-site of treated material, and (2) in-situ vapor extraction. In-situ vapor extraction will be evaluated for the Wausau Chemical and Wausau Energy source areas. The need for off-gas treatment will be assessed in each case.

Air Management Reg's

6.3 Alternative 3 - Groundwater Extraction/Above-Ground Treatment

Under this alternative, source area control would be minimal. Groundwater remedial action would consist of extraction and treatment, with either discharge to the Wisconsin River, or recharge of treated water to groundwater for enhanced hydraulic gradient control. These groundwater response actions will be directed toward the east side and the shallow west side contaminant plumes.

NR 112
140
200
214
219
147
102
104
200
219
217
506.08
507.0
504.0
400-499
108
181

6.4 Alternative 4 - Groundwater Extraction/Above-Ground Treatment/and Active Source Control

Under this alternative, active source control measures would be implemented as described under Alternative 2. These active control measures would be intended to minimize releases to groundwater. Active groundwater extraction and treatment would be implemented as described under Alternative 3.

Combine 2+3

6.5 Alternative 5 - In-Situ Bioreclamation

Alternative 5 is similar to Alternative 3 in terms of source control actions. Groundwater controls are primarily oriented toward aquifer restoration using bioreclamation in-situ. This provides the potential for a relatively rapid restoration of the aquifer, while limiting costs associated with source control.

gw

NR
112
140
200
214
219
147
102
104
200
219
217

6.6 Alternative 6 - In-Situ Bioreclamation/Active Source Control

This alternative is similar to Alternative 4 in terms of source control actions. Groundwater controls are primarily oriented toward aquifer restoration using bioreclamation. In-situ bioreclamation provides the potential for relatively rapid aquifer restoration, while the active source control measures serve to minimize additional contaminant releases.

Combine 5 + 2

6.7 Alternative 7 - Alternative Water Supply

Under this alternative, use of the Wisconsin River as a raw water source will be evaluated. Source control and groundwater restoration efforts will be minimized.

NR 111
112
108
109

7.0 REQUEST FOR ARARs IDENTIFICATION

Under the authority of CERCLA, as amended, the U.S. EPA has authorized Warzyn to conduct a Feasibility Study to identify and evaluate alternative remedial actions to address problems identified at the Wausau Water Supply NPL Site. Section 121 of CERCLA requires that remedial actions comply with Federal and more stringent State requirements, although certain requirements may be waived, as appropriate. Accordingly, Federal and State agencies are requested to identify ARARs for the contaminants under consideration, and to notify the U.S. EPA of these requirements.

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TABLE 1
SUMMARY OF CITY WELL LOCATION AND USE
FEASIBILITY STUDY
WAUSAU WATER SUPPLY NPL SITE
WAUSAU, WISCONSIN

Well	Approximate Location	Approx.* Capacity	Comments
CW3	East Study Area between Third St., RR Tracks, E. Wausau Ave. and Devoe St.	1600 gpm	Contaminated with VOCs; water pumped to stripping tower.
CW4	East Study Area, S. of water treatment plant	1400 gpm	Contaminated with VOCs; high Fe, Mn, H_2S odor; THM production up when #4 is on line; water pumped to stripping tower.
CW6	West Study Area, E. side of Pearson St., just S. of Crocker St.	1050 gpm	Reportedly reliable in terms in terms of volume and inorganic water quality; low Fe, Mn; Contaminated with VOCs; currently pumped to waste; water normally would feed into line that crosses river to treatment plant.
CW7	West Study Area, E. side of Marten St., between Crocker St. and Bugbee Ave.	1000 gpm	Reportedly not contaminated with VOCs; water pumped into line that crosses river to treatment plant.
CW8	South of study areas, near airport	** gpm	Reportedly not contaminated with VOCs; high Fe, Mn; used infrequently; pumped directly into distribution system; addition of disinfectant and iron sequestering agents.
CW9	West Study Area, N. side of Bugbee Ave., near Pearson St. intersection.	800 gpm	Reportedly not contaminated with VOCs; heavily used; water pumped into line that crosses river to treatment plant.
CW10	West Study Area, N.E. corner of Bugbee Ave. and Tierney	** gpm	Reportedly not contaminated with VOCs; a test well; new production well is not yet on line

* Typical pumping rates, based on recent pumping records.

** Pumping rates not available.

13076.15
RLM/kjw/DLI
[wpmisc-400-69]

TABLE 2
ESTIMATED VOC STRIPPER PERFORMANCE AND MAXIMUM INFLUENT CONCENTRATIONS FOR MEETING PERFORMANCE LEVELS
WAUSAU WATER SUPPLY NPL SITE
WAUSAU, WISCONSIN

			8 ft Tower Trichloroethene		8 ft Tower Tetrachloroethene			9 ft Tower Trichloroethene		9 ft Tower Tetrachloroethene		
Water Flow gpm	Air Flow cfm	A:W Ratio v/v	Pred. Removal Eff. %	Max. Infl. Conc. for Effl. of 5 ug/L	Pred. Removal Eff. %	Maximum Influent Concentration for Effluent of: 5 ug/L	Maximum Influent Concentration for Effluent of: 10 ug/L	Pred. Removal Eff. %	Max. Infl. Conc. for Effl. of 5 ug/L	Pred. Removal Eff. %	Maximum Influent to meet Effluent of: 5 ug/L	Maximum Influent to meet Effluent of: 10 ug/L
600	6000	74.8	99.29	705	99.25	666	1332	*	*	*	*	*
900	6000	49.9	98.63	364	98.63	365	730	*	*	*	*	*
1200	6000	37.4	97.83	230	97.93	241	483	*	*	*	*	*
1500	6000	29.9	96.93	163	97.17	176	353	*	*	*	*	*
1800	6000	24.9	95.94	123	96.36	137	274	*	*	*	*	*
2100	6000	21.4	94.89	98	95.51	111	223	*	*	*	*	*
600	8000	99.7	99.39	820	99.33	741	1483	*	*	*	*	*
900	8000	66.5	98.84	432	98.79	413	827	99.33	743	99.30	713	1426
1200	8000	49.9	98.20	278	98.20	277	554	98.90	454	98.90	455	911
1500	8000	39.9	97.49	199	97.56	205	410	98.40	312	98.46	324	649
1800	8000	33.2	96.72	153	96.89	161	322	97.83	230	97.97	247	494
2100	8000	28.5	95.91	122	96.20	131	263	97.21	179	97.46	197	393
2400	8000	24.9	*	*	*	*	*	96.54	144	96.91	162	324
600	10000	124.7	99.45	903	99.37	795	1589	*	*	*	*	*
900	10000	83.1	98.97	484	98.88	448	896	99.41	847	99.36	783	1566
1200	10000	62.3	98.41	315	98.35	303	608	99.05	524	99.01	506	1011
1500	10000	49.9	97.81	228	97.78	226	451	98.63	364	98.62	363	726
1800	10000	41.6	97.15	176	97.19	178	356	98.16	272	98.20	279	557
2100	10000	35.6	96.47	141	96.59	146	293	97.65	213	97.76	223	447
2400	10000	31.2	*	*	*	*	*	97.11	173	97.30	185	370
600	12000	149.6	99.48	968	99.40	834	1668	*	*	*	*	*
900	12000	99.7	99.05	524	98.95	474	948	99.46	930	99.40	837	1673
1200	12000	74.8	98.55	344	98.45	323	645	99.14	581	99.08	544	1088
1500	12000	59.8	98.00	251	97.93	242	483	98.77	407	98.73	393	787
1800	12000	49.9	97.43	194	97.39	192	383	98.36	306	98.35	303	607
2100	12000	42.7	96.82	157	96.84	158	316	97.92	241	97.95	244	489
2400	12000	37.4	*	*	*	*	*	97.45	196	97.54	203	407
900	14000	116.4	*	*	*	*	*	99.50	997	99.43	879	1758
1200	14000	87.3	*	*	*	*	*	99.20	627	99.13	575	1150
1500	14000	69.8	*	*	*	*	*	98.87	442	98.80	417	835
1800	14000	58.2	*	*	*	*	*	98.50	334	98.45	323	647
2100	14000	49.9	*	*	*	*	*	98.11	264	98.09	262	523
2400	14000	43.6	*	*	*	*	*	97.69	217	97.71	218	436
900	16000	133.0	*	*	*	*	*	99.52	1052	99.45	913	1826
1200	16000	99.7	*	*	*	*	*	99.25	666	99.17	600	1200
1500	16000	79.8	*	*	*	*	*	98.94	472	98.86	437	875
1800	16000	66.5	*	*	*	*	*	98.60	358	98.53	340	680
2100	16000	57.0	*	*	*	*	*	98.24	285	98.19	276	551
2400	16000	49.9	*	*	*	*	*	97.86	234	97.83	231	461

* Not evaluated for the flow rates indicated.

TABLE 3
SUMMARY OF WAUSAU WATER DISTRIBUTION SYSTEM AND WELL CW3 (UNTREATED) MONITORING RESULTS*
FEASIBILITY STUDY
WAUSAU WATER SUPPLY NPL SITE
WAUSAU, WISCONSIN

SAMPLE LOCATION	DATE	VC*	DCE*	TCE*	PCE*
		ug/L			
Holiday Inn	1/15/88	<2.0	<1.0	<0.5	<0.5
Water Plant	2/05/88	<2.0	<1.0	<0.5	<0.5
Green Bay Packaging	2/10/88	<2.0	<1.0	<0.5	<0.5
Wausau Airport	2/17/88	<2.0	<1.0	<0.5	<0.5
Water Plant	2/24/88	<2.0	<1.0	<0.5	<0.5
Water Plant	3/09/88	<2.0	<1.0	<0.5	<0.5
Holiday Inn	3/13/88	<2.0	<1.0	<0.5	<0.5
Water Plant	3/24/88	<2.0	<1.0	<0.5	<0.5
Green Bay Packaging	3/30/88	<2.0	<1.0	<0.5	<0.5
Wausau Airport	4/06/88	<2.0	<1.0	<0.5	<0.5
Water Plant	4/21/88	<2.0	<1.0	<0.5	<0.5
Holiday Inn	4/28/88	<2.0	<1.0	<0.5	<0.5
Green Bay Packaging	5/06/88	<2.0	<1.0	<0.5	<0.5
Wausau Airport	2/17/88	<2.0	<1.0	<0.5	<0.5
Well CW3	2/17/88	<2.0	8.9	74.2	14.1
Well CW3	2/24/88	<2.0	8.0	69.5	13.0
Well CW3	3/02/88	<2.0	9.8	73.8	14.9
Stripper #2 Effluent	3/02/88	<2.0	<1.0	0.5	<0.5
Well CW3	3/09/88	<2.0	8.4	69.5	13.1
Well CW3	3/15/88	<2.0	9.7	69.9	12.2
Well CW3	3/24/88	<2.0	4.2	71.3	10.4
Well CW3	3/30/88	<2.0	9.0	76.3	14.0
Well CW3	4/06/88	<2.0	8.5	67.1	11.0
Well CW3	4/21/88	<2.0	18.3	115	11.5
Well CW3	4/28/88	<2.0	17.2	115	9.8
Well CW3	5/06/88	<2.0	16.8	102	8.6
Well CW3	5/11/88	<2.0	17.8	101	10.2

* Monitoring Data Reported by the Wausau Water and Sewerage Utilities to the WDNR on May 12, 1988 and June 16, 1988. Samples were analyzed for: Vinyl Chloride (VC), 1,2-Dichloroethenes (DCE), Trichloroethene (TCE) and Tetrachloroethene (PCE).

13076.96
RLM/skb/DLI/DWH
[sss-600-23b]

TABLE 4

TARGET COMPOUND LIST CHEMICALS DETECTED[a]
FEASIBILITY STUDY
WAUSAU WATER SUPPLY NPL SITE
WAUSAU, WISCONSIN

		Chemical Concentration			Number Locations Sampled for Analysis	
Medium	Chemical	Minimum	Maximum	Geometric Mean	Total	Positive Detection
GROUNDWATER						
All Locations	Volatile	ug/L	ug/L	ug/L	134	
	Chloromethane	4	7	5		2
	Vinyl chloride	3	6	4		4
	Methylene chloride	1	190	8		8
	Acetone	2	3070	11		11
	1,1-Dichloroethene	--	2	--		1
	1,1-Dichloroethane	--	3	--		1
	1,2-Dichloroethene (total)	1	1300	20		48
	Chloroform	2	44	11		6
	2-Butanone	--	5	--		1
	1,1,1-Trichloroethane	1	53	3		16
	Carbon tetrachloride	2	69	19		3
	Trichlorethene	1	4200	29		68
	1,1,2-Trichloroethane	2	4	2		5
	Benzene	18	310	125		5
	4-Methyl-2-pentanone	--	2	--		1
	Tetrachloroethene	1	2440	45		53
	Toluene	2	890	46		5
	Chlorobenzene	2	54	7		6
	Ethyl benzene	3	440	53		4
	Xylenes (total)	16	2000	428		6
	Semivolatile	ug/L	ug/L	ug/L	31	
	Phenol	--	2	--		1
	Naphthalene	--	22	--		1
	2-Methylnaphthalene	--	23	--		1
	Fluorene	--	4	--		1
	Pentachlorophenol	--	6	--		1
	Phenanthrene	--	4	--		1
	Bis(2-ethylhexyl)phthalate	3	19	8		5
	Pesticide/PCB				31	
	None Detected					
	Metal/CN[b]	ug/L	ug/L	ug/L	32	
	Barium	206	325	259		3
	Chromium	28	594	77		3
	Iron	169	18100	1800		17
	Manganese	69	6100	937		25
	Zinc	2750	2860	2800		2
Production Wells CW3, CW4, CW6	Volatile	ug/L	ug/L	ug/L	3	
	Acetone	--	16	--		1
	1,2-Dichloroethene (total)	1	20	9		2
	Trichloroethene	53	150	100		3
	Tetrachloroethene	7	14	13		2
	Chlorobenzene	--	15	--		1
	Semivolatile				3	
	None Detected					
	Pesticide/PCB				3	
	None Detected					

Table 4
(Continued)

		Chemical Concentration			Number Locations Sampled for Analysis	
Medium	**Chemical**	**Minimum**	**Maximum**	**Geometric Mean**	**Total**	**Positive Detection**
	Metal/CN[b]	ug/L	ug/L	ug/L	3	
	Iron	957	5300	2110		3
	Manganese	1610	2920	2110		3
SURFACE SOILS	Volatile	ug/kg	ug/kg	ug/kg	8	
	Methylene chloride	64	190	110		2
	1,1,1-Trichloroethane	--	3	--		1
	Tetrachloroethene	--	3	--		1
	Xylenes (total)	--	4	--		1
	Semivolatile	ug/kg	ug/kg	ug/kg	8	
	Phenol	89	93	90		2
	4-Methylphenol	--	200	--		1
	Benzoic acid	--	160	--		1
	Naphthalene	37	720	192		3
	2-Methylnaphthalene	32	770	264		4
	Acenaphthylene	2	110	22		4
	Acenaphthene	51	69	59		2
	Dibenzofuran	38	180	82		2
	Fluorene	100	120	109		2
	Phenanthrene	200	2500	651		5
	Anthracene	32	480	155		3
	Flouranthene	200	6600	1300		5
	Pyrene	150	2900	910		5
	Butylbenzylphthalate	59	390	150		3
	Benzo(a)anthracene	110	2400	749		3
	Bis(2-ethylhexyl)phthalate	150	1600	489		2
	Chrysene	390	3200	861		4
	Di-n-octylphthalate	--	380	--		1
	Benzo(b)fluoranthene	250	5400	1380		3
	Benzo(k)fluoranthene	--	1600	--		1
	Benzo(a)pyrene	100	2700	604		4
	Indeno(1,2,3-cd)pyrene	210	1200	614		3
	Dibenz(a,h)anthracene	--	390	--		1
	Benzo(g,h,i)perylene	230	1400	655		3
	Pesticide/PCB					
	Not Analyzed					
	Metal/CN					
	Not Analyzed					
SURFACE WATER						
Bos Creek	Volatile	ug/L	ug/L	ug/L	12	
	1,2 Dichloroethene (total)	1	1	1		2
	Trichloroethene	1	110	41		10
	Tetrachloroethene	1	3	2		2
	Semivolatile					
	Not analyzed					
	Pesticide/PCB					
	Not Analyzed					
	Metal/CN					
	Not Analyzed					

Table 4
(Continued)

		Chemical Concentration			Number Locations Sampled for Analysis	
Medium	Chemical	Minimum	Maximum	Geometric Mean	Total	Positive Detection
Wisconsin River	Volatile	ug/L	ug/L	ug/L	4	
	1,2-Dichloroethene (total)	--	1	--		1
	Chloroform	1	4	2		3
	Tetrachloroethene	--	6	--		1
	Semivolatile					
	Not Analyzed					
	Pesticide/PCB					
	Not Analyzed					
	Metal/CN					
	Not Analyzed					
SEDIMENT						
Bos Creek	Volatile	ug/kg	ug/kg	ug/kg	11	
	Acetone	18	190	58		3
	1,2-Dichloroethene (total)	6	200	51		3
	Trichloroethene	6	17	59		5
	Toluene	--	7	--		1
	Semivolatile	ug/kg	ug/kg	ug/kg	3	
	None Detected					
	Pesticide/PCB				3	
	None Detected					
	Metals					
	Not Analyzed					
SUBSURFACE SOILS						
	Volatile	ug/kg	ug/kg	ug/kg	29	
	Methylene chloride	1	2000	43		5
	Trichloroethene	4	10	6		3
	Tetrachloroethene	1	3500	77		12
	Toluene	1	46	5		9
	Ethylbenzene	4	2900	37		3
	Xylenes (total)	2	21000	22		7
	Semivolatile	ug/kg	ug/kg	ug/kg	29	
	Phenol	--	320	--		1
	Naphthalene	--	4900	--		1
	2-Methylnaphtalene	--	16000	--		1
	Dimethylphthalate	110	140	120		2
	Fluorene	63	1600	320		2
	Phenanthrene	63	2600	260		11
	Anthracene	48	120	85		6
	Di-n-butylphthalate	58	76	66		2
	Flouranthene	30	1400	220		15
	Pyrene	31	1300	210		12
	Benzo(a)anthracene	98	660	250		6
	Chrysene	130	750	290		6
	Bis(2-ethylhexyl)phthalate	45	84	60		5

Table 4
(Continued)

Medium	Chemical	Chemical Concentration			Number Locations Sampled for Analysis	
		Minimum	Maximum	Geometric Mean	Total	Positive Detection
	Benzo(b)fluoranthene	110	680	220		10
	Benzo(k)fluoranthene	100	760	210		9
	Benzo(a)pyrene	120	750	250		8
	Indeno(1,2,3-cd)pyrene	130	680	220		6
	Dibenz(a,h)anthracene	--	74	--		1
	Benzo(g,h,i)perylene	130	800	270		5
	Pesticide/PCB					
	Not Analyzed					
	Metal/CN[c]	mg/kg	mg/kg	mg/kg	16	
	Copper	--	107	--		1
LANDFILL REFUSE	**Volatile**	ug/kg	ug/kg	ug/kg	15	
	Methylene chloride	9	1900	70		3
	Acetone	71	160	100		3
	1,2-Dichloroethene (total)	21	220	67		4
	Trichloroethene	36	160000	680		9
	Toluene	3	750	60		9
	Ethyl benzene	2	4	3		3
	Xylenes (total)	4	24	13		5
	Semivolatile	ug/kg	ug/kg	ug/kg	15	
	Phenol	--	2200			1
	2-Chlorophenol	--	2200	--		1
	1,2-Dichlorobenzene	--	210	--		1
	2-Methylphenol	--	75	--		1
	4-Methylphenol	--	830	--		1
	Isophorone	--	130	--		1
	1,2,4-Trichlorobenzene	--	1200	--		1
	Naphthalene	49	1300	150		7
	4-Chloro-3-methylphenol	--	2300	--		1
	2-Methylnaphthalene	65	890	150		7
	2-Chloronaphthalene	--	170	--		1
	Acenaphthylene	--	130	--		1
	Acenaphthene	45	730	180		3
	Dibenzofuran	19	330	63		7
	Fluorene	82	500	186		5
	Pentachlorophenol	820	32000	2900		5
	Phenanthrene	170	15000	1100		11
	Anthracene	19	2200	250		10
	Fluoranthene	60	45000	1600		12
	Pyrene	63	49000	1700		12
	Butylbenzylphthalate	130	2300	500		3
	Benzo(a)anthracene	420	24000	1400		10
	Bis(2-ethylhexyl)phthalate	110	54000	860		10
	Chrysene	54	25000	970		12
	Benzo(b)fluoranthene	410	25000	1700		10
	Benzo(k)fluoranthene	430	25000	1400		10
	Benzo(a)pyrene	480	25000	1200		9
	Indeno(1,2,3-cd)pyrene	640	31000	940		7
	Dibenz(a,h)anthracene	280	1200	490		4
	Benzo(g,h,i)perylene	560	14000	1600		7
	Pesticide/PCB	ug/kg	ug/kg	ug/kg	6	
	Arochlor 1260	850	2300	1400		2

Table 4
(Continued)

		Chemical Concentration			Number Locations Sampled for Analysis	
Medium	Chemical	Minimum	Maximum	Geometric Mean	Total	Positive Detection
	Metal/CN[c]	mg/kg	mg/kg	mg/kg	14	
	Arsenic	--	76	--		1
	Chromium	--	1130	--		1
	Copper	107	1410	383		8
	Mercury	0.5	1.9	1.2		9
	Zinc	323	3260	2160		8

[a] Refer to Section 9.3 for data sources and criteria for site contamination characterization. Also, refer to appropriate Appendices to determine total chemicals included in each analysis.

[b] Substances considered as positive detections for groundwater samples exceeded available State of Wisconsin Groundwater Standards, Preventive Action Limits as described in Chapter NR 140 of the Wisconsin Administrative Code (Table 5).

[c] Substances considered as positive detections in subsurface soils and landfill refuse exceeded the upper limit of the common concentration range for soils as described by Lindsay, 1979 (see Table 5).

TABLE 5

STATE GROUNDWATER STANDARDS AND COMMON CONCENTRATIONS IN SOIL FOR SELECTED SUBSTANCES
FEASIBILITY STUDY
WAUSAU WATER SUPPLY NPL SITE
WASAU, WISCONSIN

	Groundwater[a] (ug/L)	Soils[b] (mg/kg)
ALUMINUM	--	300,000
ANTIMONY	--	--
ARSENIC	5	50
BARIUM	200	3,000
BERYLLIUM	--	40
CADMIUM	1	0.70
CALCIUM	--	500,000
CHROMIUM	5	1,000
COBALT	--	40
COPPER	500	100
IRON	150	550,000
LEAD	5	200
MAGNESIUM	--	6,000
MANGANESE	25	3,000
MERCURY	0.2	0.3
NICKEL	--	500
POTASSIUM	--	30,000
SELENIUM	1	2
SILVER	10	5
SODIUM	--	7,500
THALLIUM	--	--
VANADIUM	--	500
ZINC	2,500	300
CYANIDE	92	--

[a] Values are Preventive Action Limits from Wisconsin Groundwater Standards, Chapter NR 140, of the Wisconsin Administrative Code.

[b] Values are the upper limit of the common range of elemental concentrations in soil from Lindsay, W.L. Chemical Equilibria in Soils, John Wiley & Sons, New York, pp6-8; 1979.

(--) Not available.

TABLE 6
POTENTIAL EXPOSURE PATHWAYS
FEASIBILITY STUDY
WAUSAU WATER SUPPLY NPL SITE
WAUSAU, WISCONSIN

Environmental Medium	Exposure Point	Exposed Receptors	Routes Exposure	Pathway Complete?	Exposure Potential	Risk Quantified?
Groundwater	Municipal water supply	Wausau residents	Ingestion, inhalation, dermal absorption	Yes	Very low; air stripping has reduced contaminant concentrations to below detection limits	Yes
	Private well water	Wausau residents with private wells	Ingestion, inhalation, dermal absorption	No; currently no private wells in contaminated aquifer. However potential for future private wells exists	None; currently. Moderate; future private well users could be exposed to untreated water	Yes
Surface soils	Direct contact	Wausau residents	Dermal absorption, incidental ingestion	Not determined	Very low; not considered to be above background	No
Surface water and sediments, Bos Creek and Wisconsin River	Direct contact	Children playing in creek or river	Dermal absorption, incidental ingestion	No, contaminated water no longer discharged to Bos Creek	None	No
		Aquatic organisms, terrestrial wildlife	Bioconcentration, bioaccumulation	No, contaminated water no longer discharged to Bos Creek	None	No
Subsurface soils and landfill refuse	None; subsurface location minimizes contact potential	Wausau residents	Dermal absorption, incidental ingestion	No	None	No
	Direct contact	Remediation workers	Dermal absorption, incidental ingestion	Not determined	Very low, workers assumed to be utilizing protective gear	No
Air	Direct contact, volatilization from soils or landfill refuse	Wausau residents, company employees	Inhalation	No, significant volatilization not occurring	None	No
	Direct contact, emissions from air strippers	Wausau residents, company employees	Inhalation	Yes	Moderate dispersion of VOC emissions may expose Wausau residents and employees of companies near the sources	Yes

TABLE 7
SUMMARY OF TECHNOLOGY SCREENING
GROUNDWATER CONTROLS
FEASIBILITY STUDY
WAUSAU WATER SUPPLY NPL SITE
WAUSAU, WISCONSIN

Technology Group	Technology	Retain	Comment
Barriers	Soil-Bentonite Slurry Wall	No	Deep bariers would be required. Depth to bedrock is over 100 ft. over much of the area, and bedrock surface is irregular, making an effective key into bedrock difficult. Shallow barriers would not be effective for long term containment. Trenching, driving beams, injecting grout, and placing a membrane are not practical at this site. Construction would cause substantial disruption of area residents and businesses.
	Cement-Bentonite Slurry Wall	No	
	Steel Sheet-Pile Wall	No	
	Grout Curtain Wall	No	
	Synthetic Membrane Wall	No	
	Vibrating Beam Slurry Wall	No	
Injection	Wells	No	Acceptable for disposal of water suitable as potable water supply, to maintain a potentially fully penetrating hydraulic barrier. Possible sources include: City Water: This would be a waste of potable water. River Water: Pretreatment would be necessary, and THM production at the water plant would likely increase. Groundwater: From a well located in an uncontaminated area. This water could be acceptably clean, but clean water would be more efficiently used as a water source, not to protect the source. This action would have to continue indefinitely, until the threat of well field contamination is removed.
	Trenches	No	Vertical influence of shallow trenches would be limited. Deep trench construction in this developed area is not considered feasible.
	Basins	No	Vertical influence of basins may be limited. Land required for basins would be too large for this area.
Extraction	Wells	[✓ Yes]	Demonstrated effectiveness in achieving fairly extensive areas of influence locally in the aquifer. Compared to other extraction methods, well construction would be the least disruptive of area residents and businesses.
	Trenches	No	Shallow trenches would not achieve the desired influence throughout the depth of the aquifer. Construction of deep trenches that would achieve the desired effect is not considered feasible in this area.

//

TABLE 7 (cont)
SUMMARY OF TECHNOLOGY SCREENING
GROUNDWATER CONTROLS
FEASIBILITY STUDY
WAUSAU WATER SUPPLY NPL SITE
WAUSAU, WISCONSIN

Technology Group	Technology	Retain	Comment
Extraction/ Injection	Wells	Yes	Most effective for gradient control at depth within aquifer. More easily constructed where desired than trenches.
	Wells/Trenches	Yes	May be more effective at shallower depths. May be more readily permitted than wells.

RLM/jlv/DLI
[jlv-400-30]

TABLE 8
SUMMARY OF TECHNOLOGY SCREENING
GROUNDWATER TREATMENT
FEASIBILITY STUDY
WAUSAU WATER SUPPLY NPL SITE
WAUSAU, WISCONSIN

Technology Group	Technology	Retain	Comment
Physical	Filtration	No	Water quality does not warrant use.
	Settling	No	Water quality does not warrant use.
	Stripping	Yes	Demonstrated effectiveness in VOC removal.
	Adsorption	Yes	Demonstrated effectiveness in VOC removal.
	Ion Exchange	No	Water quality does not warrant use.
	Reverse Osmosis	No	Promising for removal of low concentrations of VOCs.
Chemical	Neutralization	No	Water quality does not warrant use.
	Coagulation/Precipitation	No	Water quality does not warrant use.
	Oxidation	Yes	VOC removal may be required. Contaminant destruction.
	Reduction	No	Not demonstrated for contaminants of concern.
Biological	Aerobic Processes	Yes	Effective contaminant degradation has been consistently reported. Not demonstrated at full scale.
	Anaerobic Processes	Yes	Anaerobic degradation of chlorinated VOCs has been consistently reported, but maintaining a population of slow-growing anaerobes may be difficult.
In-Situ Physical	Fixation	No	Plume area is too large. Long term immobilization of VOCs has not been demonstrated.
	Adsorbent Trenches	No	Difficulties with trench construction as mentioned previously. Contaminants would not be permanently immobilized.
In-Situ Chemical	Oxidation	No	Technology is not adequately demonstrated in this type of application. Long lead time required for studies.
	Reduction	No	Technology is not adequately demonstrated in this type of application. Long lead time required for studies.
In-Situ Biological	Anaerobic	Yes	Technology is not demonstrated in this type of application. Long lead time required for studies. Potential benefits outweigh limitations.
	Aerobic	Yes	Technology is not demonstrated in this type of application. Long lead fine required for studies and permitting. Potential benefits outweigh limitations.

RLM/jlv/DLI
[jpl-400-30]

TABLE 9
SUMMARY OF TECHNOLOGY SCREENING
DISCHARGE OPTIONS
FEASIBILITY STUDY
WAUSAU WATER SUPPLY NPL SITE
WAUSAU, WISCONSIN

Technology Group	Technology	Retain	Comment
Groundwater	Wells	Yes	A groundwater discharge may be desirable to enhance local hydraulic gradient control.
	Trenches	Yes	
	Basins	No	
Surface Water	Pipeline	Yes	A conventional pipeline may be at least partially submerged for part of the year. A cascade-type structure would provide the additional benefit of partial VOC removal. This may be acceptable as the sole treatment if discharge limits on VOCs are not very stringent.
	Publically-Owned Treatment Works (POTW)	No	Flow rates required for groundwater will be too high to make discharge to the POTW a viable option.

RLM/jlv/DLI
[jlv-400-30]

TABLE 10

SUMMARY OF TECHNOLOGY SCREENING
SOIL/WASTE MANAGEMENT
FEASIBILITY STUDY
WAUSAU WATER SUPPLY NPL SITE
WAUSAU, WISCONSIN

Technology Group	Technology	Retain	Comment
Removal	Excavation	Yes	Conventional excavation equipment. Retain for North end of old City Landfill only.
Treatment (above ground)	High Temperature Thermal	No	Off-site incineration would be very costly. On-site incineration would be costly due to limited qualities involved.
	Solidification	No	Does not prevent leaching of VOCs in the long term.
	Stabilization	No	Does not immobilize VOCs
	Enhanced Volatilization	Yes	Effective removal of VOCs at elevated temperature. Control of off-gases is possible.
	Bioreclamation	No	Insufficient space for land farming. Use of above-ground gas solid reactors is not demonstrated for contaminants of concern.
	Soil Washing	No	Extraction of sparingly soluble VOCs with solvent, which requires further management. Less straightforward than volatilization.

TABLE 10
(Continued)

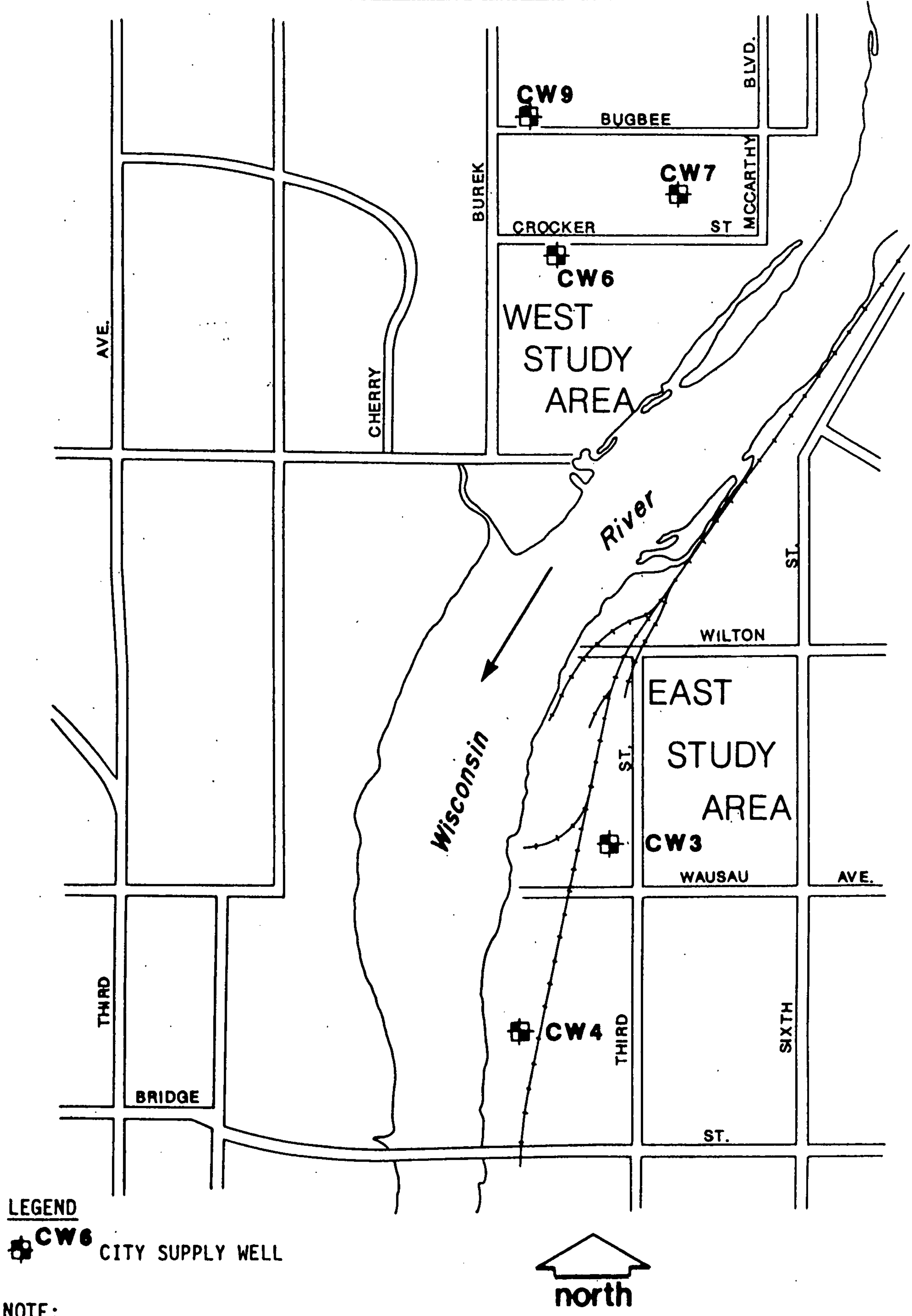
SUMMARY OF TECHNOLOGY SCREENING
SOIL/WASTE MANAGEMENT
FEASIBILITY STUDY
WAUSAU WATER SUPPLY NPL SITE
WAUSAU, WISCONSIN

Technology Group	Technology	Retain	Comment
Treatment (in-situ)	Vitrification	No	Not appropriate for contaminant types.
	Steam Heating/ Extraction	No	Energy intensive, not required for highly volatile compounds at the site.
	Flushing	No	Difficult to control in heterogeneous fill/soil on west side. Area is too extensive for practical complication on east side.
	Vapor Extraction	Yes	Appropriate for volatile compounds present. Flexible with regard to area treated and soil types. Demonstrated in field test at the site.
Treatment (in-situ)	Chemical	No	Desired reactions have not been demonstrated in soil matrix.
	Bioreclamation	No	Limitations associated with flushing also affect this technology.
Disposal	On-Site	Yes	Preferred method for treated waste.
	Off-Site	Yes	At suitable facility, in compliance with its permit.
Containment	Capping	Yes	Trafficable surface that limits infiltration is desirable for old City Landfill.

TABLE 11
SUMMARY OF TECHNOLOGY SCREENING
INSTITUTIONAL MEASURES
FEASIBILITY STUDY
WAUSAU WATER SUPPLY NPL SITE
WAUSAU, WISCONSIN

Technology Group	Technology	Retain	Comment
Institutional Controls	Deed Restrictions	Yes	Appropriate where contaminants remain in place. Local governmental authority is required.
	Groundwater Use Restrictions	Yes	Reportedly already in place.
	Alternate Water Supply	Yes	Only viable alternative is the Wisconsin River. This option will be evaluated further.
	Monitoring	Yes	Tracking contaminant distribution and remediation progress is necessary.

RLM/kjw/MSR
[jlv-400-29]



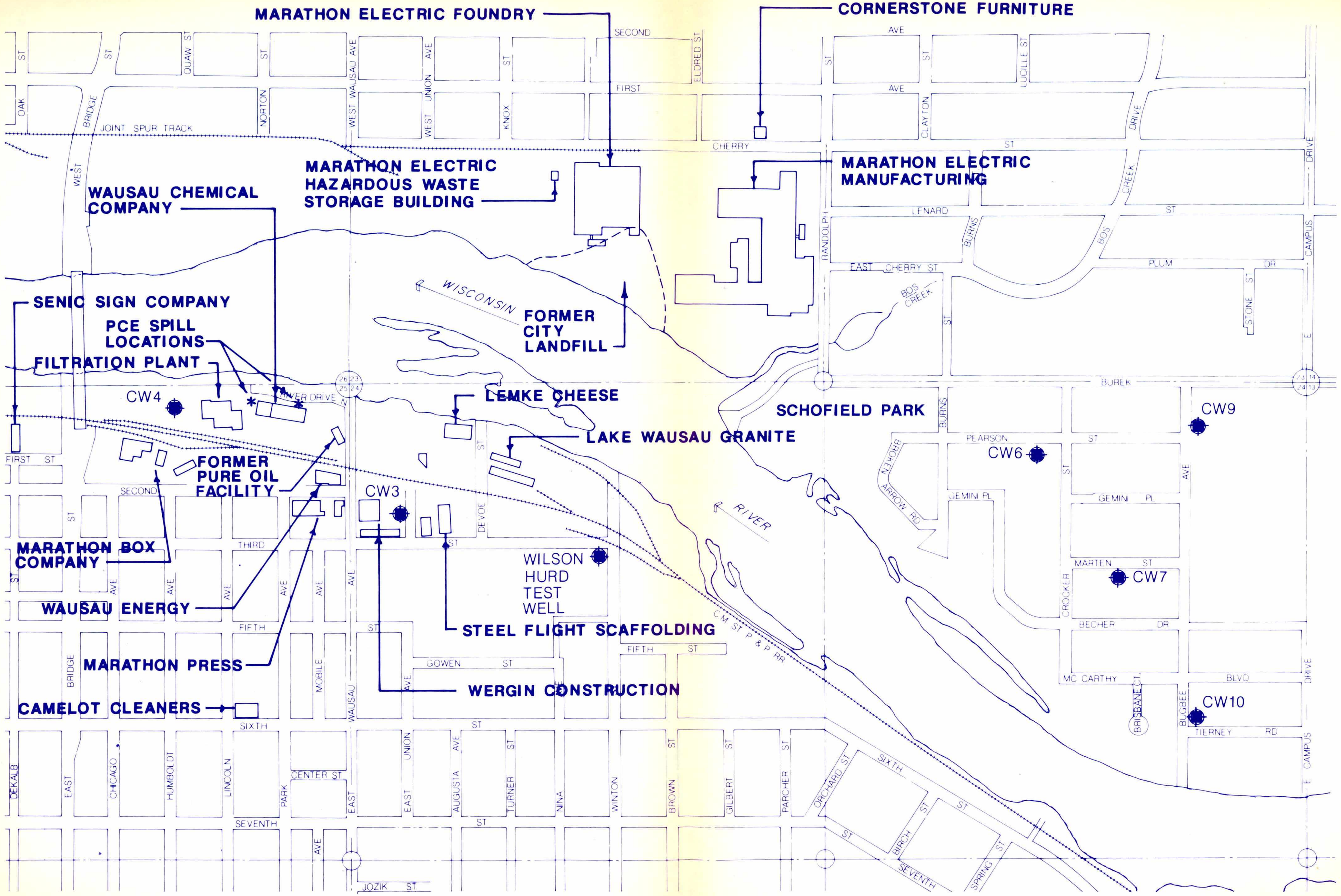
SCALE: 1" = 1000'

NOTE:

BASE MAP DEVELOPED FROM U.S.G.S. 15 MIN. QUADRANGLE MAPS WAUSAU EAST & WAUSAU WEST DATED 1963, PHOTOREVISED 1978.

FIGURE 1

DWN JC	APP'D DW	DATE 8/31/88	13076	A28	WARZYN ENGINEERING INC	SITE LOCATION MAP FEASIBILITY STUDY WAUSAU WATER SUPPLY NPL SITE WAUSAU, WISCONSIN.



north

LEGEND

▭	EXISTING STRUCTURE
● CW9	PUMPING MUNICIPAL WELL
⊕ 26 23 / 25 24	SECTION CORNER AND NUMBERS
⊕	QUARTER SECTION MARKER
═══	EDGE OF WATER
···—···	CREEK/INTERMITTENT STREAM
++++++++	RAILROAD TRACKS
- - - - -	APPROXIMATE BOUNDARY OF FORMER CITY LANDFILL

NOTES

1. THE BASE MAP WAS DEVELOPED FROM THE CITY OF WAUSAU PLAT MAP, REPORTED SCALE: 1" = 1000', DATED MARCH, 1987.
2. REVIEW OF AERO-METRIC ORTHOPHOTOGRAPHIC MAPS DATED APRIL 26, 1974 INDICATE THAT THE CITY OF WAUSAU PLAT MAP EXHIBITS SCALE INCONSISTANCIES.
3. BUILDING LOCATIONS TRANSFERRED FROM AERIAL PHOTOGRAPHS DATED APRIL 23, 1986.
4. TETRACHLOROETHENE (PCE) SPILL LOCATIONS AT WAUSAU CHEMICAL CO. BASED ON INFORMATION OBTAINED DURING THE INDUSTRIAL SURVEY.
5. APPROXIMATE EXTENT OF FORMER CITY LANDFILL BASED ON INTERVIEW OF FORMER CITY EMPLOYEES.

LOCATION OF MUNICIPAL WELLS & INDUSTRIAL SURVEY BUSINESSES

FEASIBILITY STUDY
WAUSAU WATER SUPPLY NPL SITE
WAUSAU, WISCONSIN.

APR 2 1 1989

Project Number 13076 B37

WARZYN

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Minneapolis · Chicago
Detroit

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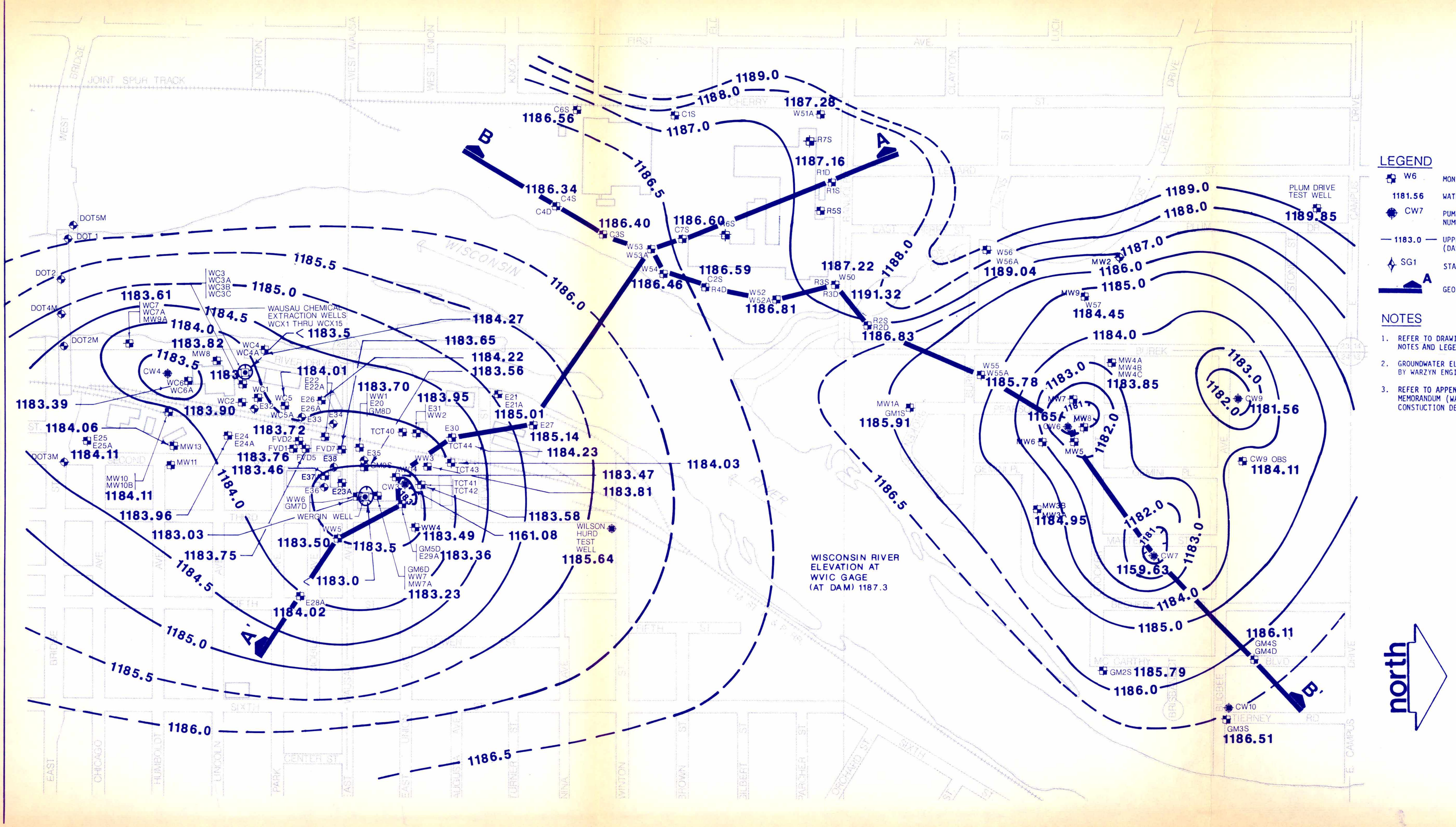
Drawn By S.P.
Checked By DLI
Approved By Robert L Munford
Date 7/6/88
Scale 1" = 500'(APPROXIMATE)
Reference

FIGURE 2



LEGEND

W6	MONITORING WELL LOCATION AND NUMBER
1181.56	WATER TABLE ELEVATION
CW7	PUMPING MUNICIPAL WELL LOCATION AND NUMBER
— 1183.0 —	UPPER AQUIFER POTENTIOMETRIC CONTOUR (DASHED WHERE INFERRED)
SG1	STAFF GAGE LOCATION AND NUMBER
A	GEOLOGIC CROSS SECTION AND NUMBER

NOTES

1. REFER TO DRAWING 13076-B37 (FIGURE 2) FOR NOTES AND LEGEND.
2. GROUNDWATER ELEVATIONS NOTED ARE BASED ON MEASUREMENTS TAKEN BY WARZYN ENGINEERING INC. ON JANUARY 7 AND 8, 1988.
3. REFER TO APPENDIX H PHASE I REMEDIAL INVESTIGATION TECHNICAL MEMORANDUM (WARZYN, APRIL 1988), FOR SUMMARY OF MONITORING WELL CONSTUCTION DETAILS AND OBSERVED GROUNDWATER ELEVATIONS.

FIGURE 3

POTENTIOMETRIC SURFACE (1/7-8/88) AND CROSS SECTION LOCATION MAP

FEASIBILITY STUDY
WAUSAU WATER SUPPLY NPL SITE
WAUSAU, WISCONSIN

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Project Number 13076 B38

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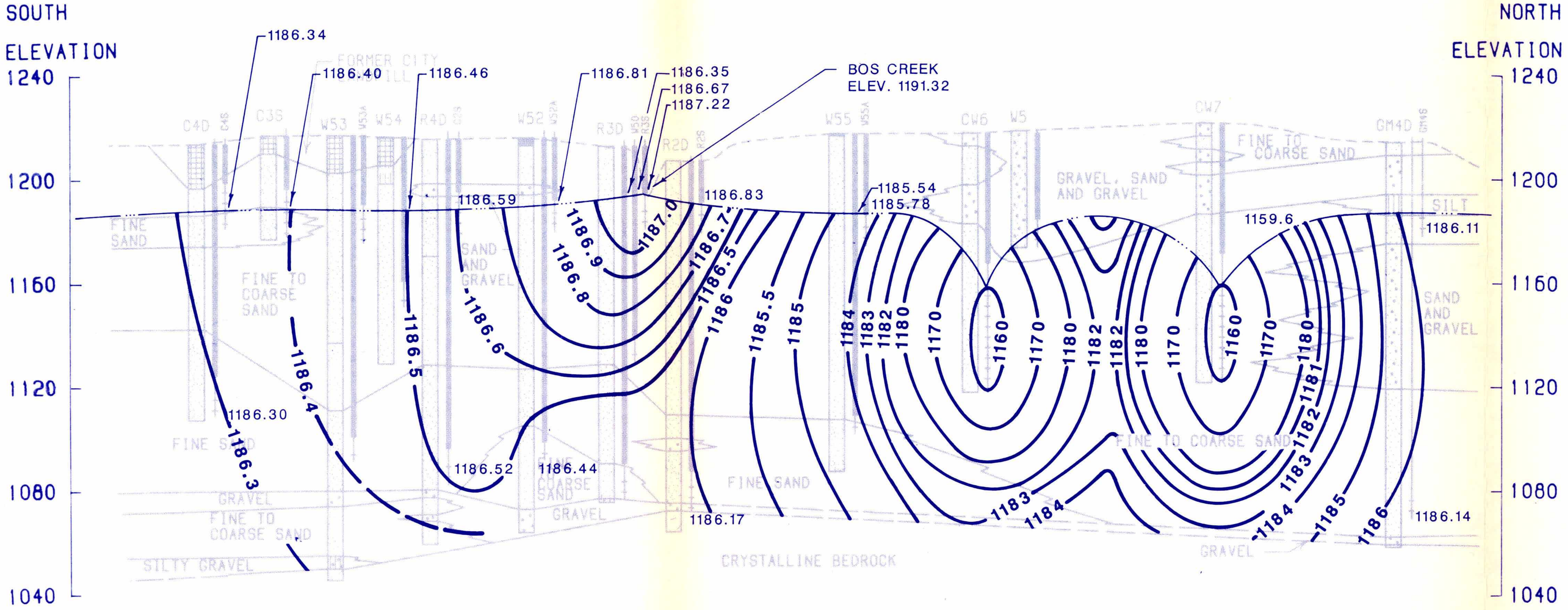

SECTION B-B'

HORIZONTAL SCALE: 1" = 400' (APPROXIMATE)
VERTICAL SCALE: 1" = 40'

NOTES

1. THE STRATUM LINES ARE BASED ON INTERPOLATION BETWEEN BORINGS AND MAY NOT REPRESENT ACTUAL SUBSURFACE CONDITIONS.
2. CROSS SECTION LOCATIONS ARE SHOWN ON DRAWING 13076-B38 (FIGURE 3)
3. FOR THE PURPOSE OF ILLUSTRATING SUBSOIL CONDITIONS ON THE CROSS SECTIONS, SOME OF THE BORING LOGS HAVE BEEN SIMPLIFIED. FOR A DETAILED DESCRIPTION OF SUBSURFACE CONDITIONS AT INDIVIDUAL BORINGS, REFER TO SOIL BORING LOGS, APPENDIX B OF RI TECHNICAL MEMORANDUM (WARZYN, 1988).
4. FOR COMPLETE MONITORING WELL INSTALLATION DETAILS, REFER TO APPENDIX C OF RI TECHNICAL MEMORANDUM (WARZYN,1988).
5. CROSS SECTIONS HAVE BEEN EXAGGERATED TEN (10) TIMES.
6. HORIZONTAL DISTANCES ARE MEASURED WITH RESPECT TO THE CENTER OF EACH SOIL BORING LOCATION.
7. ELEVATIONS ARE SHOWN IN U.S.G.S. DATUM.
8. DASHED GEOLOGIC CONTACT LINES ARE INFERRED.
9. GROUNDWATER EQUIPOTENTIAL CONTOURS BASED ON GROUNDWATER LEVELS MEASURED BY WARZYN ENGINEERING INC., JANUARY 7 AND 8, 1988.
10. REFER TO APPENDIX H PHASE I REMEDIAL INVESTIGATION TECHNICAL MEMORANDUM (WARZYN, APRIL 1988), FOR SUMMARY OF MONITORING WELL CONSTRUCTION DETAILS AND OBSERVED GROUNDWATER ELEVATIONS.

FIGURE 4

POTENTIOMETRIC SECTION BB'

FEASIBILITY STUDY
WAUSAU WATER SUPPLY NPL SITE
WAUSAU, WISCONSIN

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Date 7/6/88
Scale AS SHOWN
Reference

APR 21 1989

Project Number
13076 B39

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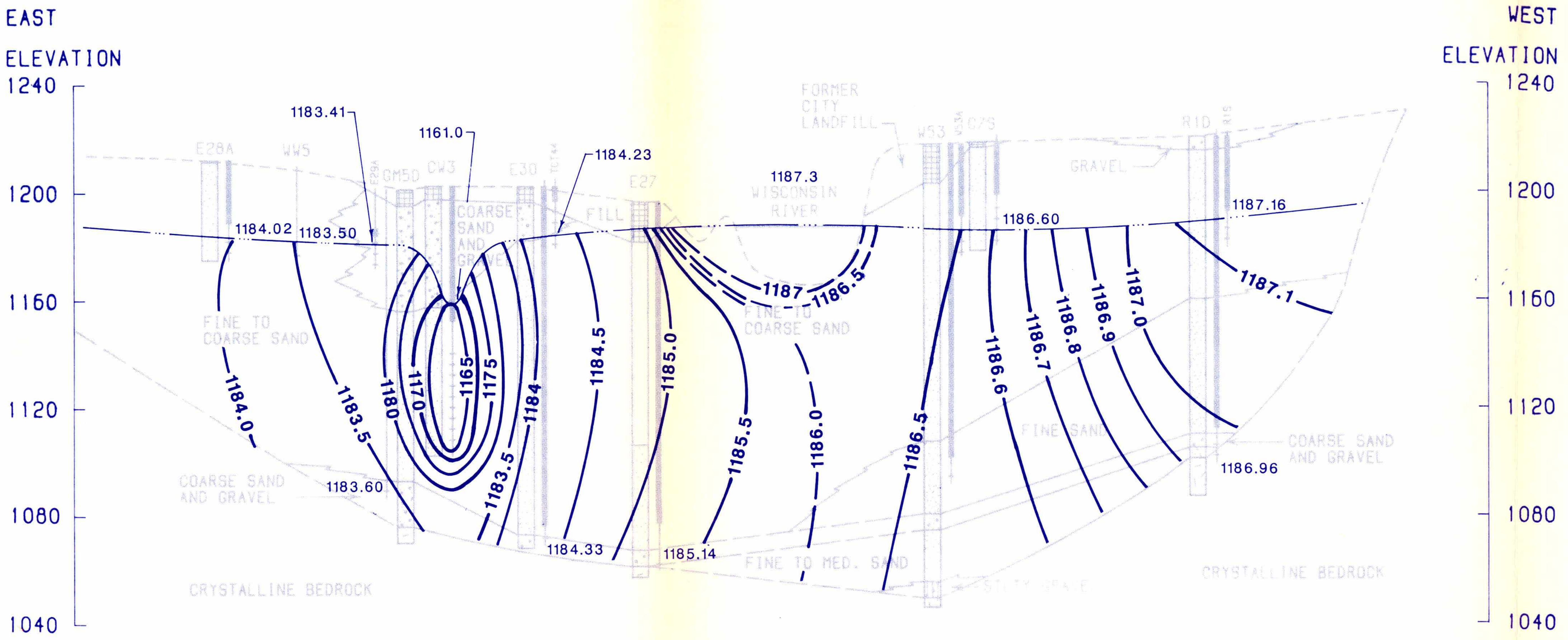

SECTION A-A'

HORIZONTAL SCALE: 1" = 400' (APPROXIMATE)
VERTICAL SCALE: 1" = 40'

NOTES

1. REFER TO DRAWING NO. 13076-B39 (FIGURE 4) AND LEGEND.
2. GROUNDWATER EQUIPOTENTIAL CONTOURS BASED ON GROUNDWATER LEVELS MEASURED BY WARZYN ENGINEERING INC., JANUARY 7 AND 8, 1988.
3. REFER TO APPENDIX H PHASE I REMEDIAL INVESTIGATION TECHNICAL MEMORANDUM (WARZYN, APRIL 1988), FOR SUMMARY OF MONITORING WELL CONSTUCTION DETAILS AND OBSERVED GROUNDWATER ELEVATIONS.
4. REFER TO DRAWING 13076-B38 FOR CROSS SECTION LOCATION.

FIGURE 5

POTENTIOMETRIC SECTION AA'

FEASIBILITY STUDY
WAUSAU WATER SUPPLY NPL SITE
WAUSAU, WISCONSIN

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APR 21 1989

Project Number
13076 B40

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LEGEND

E27	MONITORING WELL LOCATION AND NUMBER
CW4	PUMPING MUNICIPAL WELL LOCATION AND NUMBER
E34	SOIL BORING LOCATION AND NUMBER
532.2	TOTAL CHLORINATED ETHENES CONCENTRATION(ug/L)
BMDL	TOTAL CHLORINATED ETHENES DETECTED BUT BELOW MINIMUM REPORTABLE LIMITS
— 10.0 —	CONTOUR OF EQUAL CONCENTRATION OF TOTAL CHLORINATED ETHENES(PREDOMINANTLY TCE) AT GROUNDWATER SURFACE
— 500 —	CONTOUR OF EQUAL CONCENTRATION OF TOTAL CHLORINATED ETHENES(PREDOMINANTLY TCE) NEAR BASE OF AQUIFER
·— 50 —·	CONTOUR OF EQUAL CONCENTRATION OF TOTAL CHLORINATED ETHENES(PREDOMINANTLY PCE) AT GROUNDWATER SURFACE
*	TOTAL CHLORINATED ETHENES CONCENTRATION DETERMINED FROM ON SITE ANALYSIS OF GROUNDWATER SAMPLES COLLECTED DURING DRILLING
+	TOTAL CHLORINATED ETHENES CONCENTRATION DETERMINED FROM ROUND 1 SAMPLING OF PRE-EXISTING WELLS

NOTES

1. REFER TO DRAWING 13076-B37 (FIGURE 2) FOR BASE MAP LEGEND AND NOTES.
2. PRE-EXISTING MONITORING WELLS WERE SAMPLED BY WARZYN ENGINEERING INC., SEPTEMBER 29 TO OCTOBER 7, 1987.
3. GROUNDWATER SAMPLES WERE COLLECTED AND ANALYZED BY WARZYN ENGINEERING INC. USING AN ON-SITE GAS CHROMATOGRAPH (GC), OCTOBER 12 TO DECEMBER 12, 1987.
4. REFER TO APPENDICES F AND G OF RI TECHNICAL MEMORANDUM (WARZYN, 1988). GROUNDWATER ANALYSIS AND RESULTS OF GROUNDWATER SAMPLING WHILE DRILLING, RESPECTIVELY.

PRELIMINARY ESTIMATE OF TOTAL CHLORINATED ETHENES OCCURRENCE IN THE AQUIFER

FEASIBILITY STUDY
WAUSAU WATER SUPPLY NPL SITE
WAUSAU, WISCONSIN

APR 21 1989

Project Number
13076 **B41**

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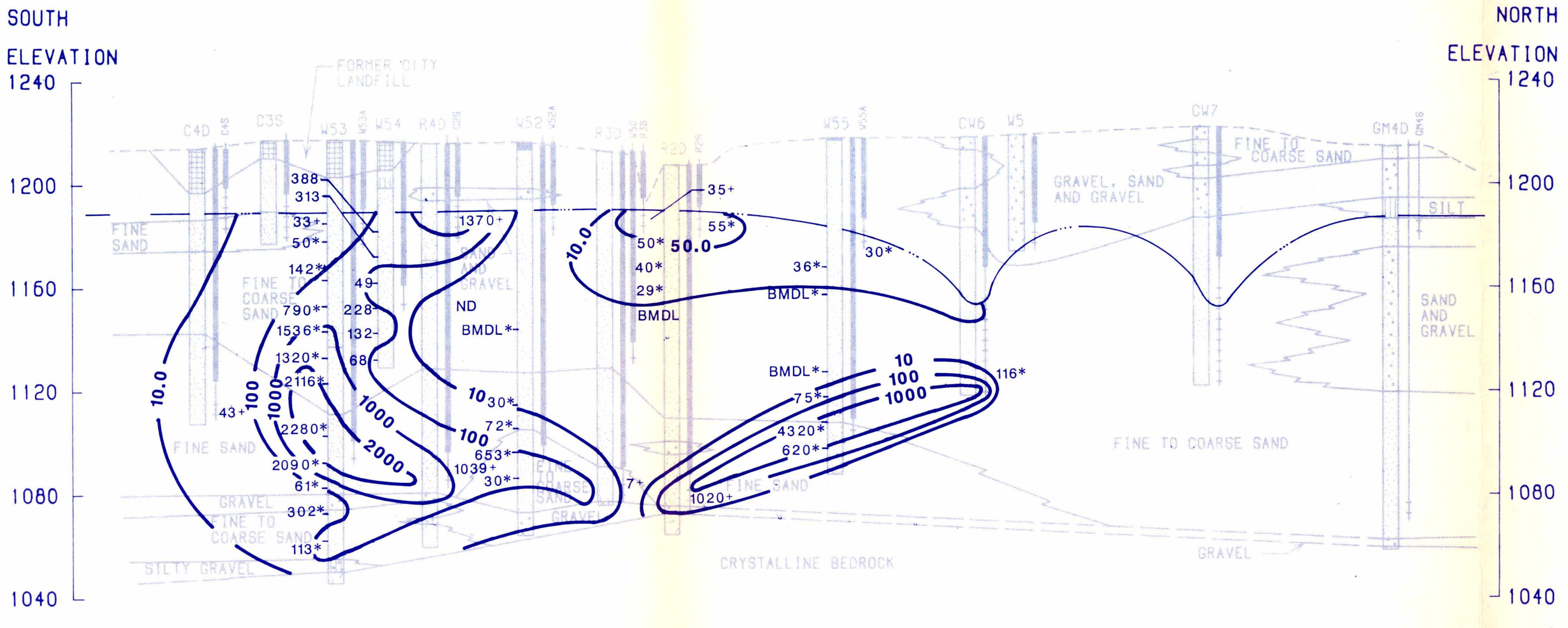
FIGURE 6



SECTION B-B'

HORIZONTAL SCALE: 1" = 400' (APPROXIMATE)
VERTICAL SCALE: 1" = 40'

LEGEND

72* / 653* / 30*	TOTAL CHLORINATED ETHENES CONCENTRATIONS IN ug/L DETERMINED FROM GC ANALYSIS OF GROUNDWATER SAMPLE OBTAINED DURING DRILLING (OCTOBER 12, 1987 TO DECEMBER 12, 1987).
43+	TOTAL CHLORINATED ETHENES CONCENTRATIONS IN ug/L DETERMINED FROM CONTRACT LABORATORY ANALYSIS OF ROUND 1 SAMPLES OBTAINED FROM SEPTEMBER 29, 1987 TO OCTOBER 6, 1987.
BMDL	TOTAL CHLORINATED ETHENES AT CONCENTRATIONS BELOW MINIMUM REPORTABLE DETECTION LIMITS.
ND	TOTAL CHLORINATED ETHENES NOT DETECTED.
—— **100** ——	CONTOUR OF EQUAL TOTAL CHLORINATED ETHENES CONCENTRATION, DASHED WHERE INFERRED.

NOTES

1. REFER TO DRAWINGS 13076-B39 (FIGURE 4) FOR ADDITIONAL NOTES AND LEGENDS.
2. REFER TO DRAWING 13076-B41 (FIGURE 6) FOR AREAL VIEW OF TOTAL CHLORINATED ETHENES DISTRIBUTION IN THE AQUIFER.
3. REFER TO APPENDICES F AND G RI TECHNICAL MEMORANDUM (WARZYN, 1988). FOR SUMMARY OF ANALYTICAL DATA AND DETECTION LIMITS.
4. CROSS SECTION VERTICAL EXAGERATION IS 10 X.
5. REFER TO DRAWING 13076-B38 (FIGURE 3) FOR CROSS SECTION LOCATION

FIGURE 7

Checked By OLI
Date 7/6/88
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Scale AS SHOWN

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ISOCONCENTRATION SECTION BB'

FEASIBILITY STUDY
WAUSAU WATER SUPPLY NPL SITE
WAUSAU, WISCONSIN

APR 20 1989

Project Number
13076 B42

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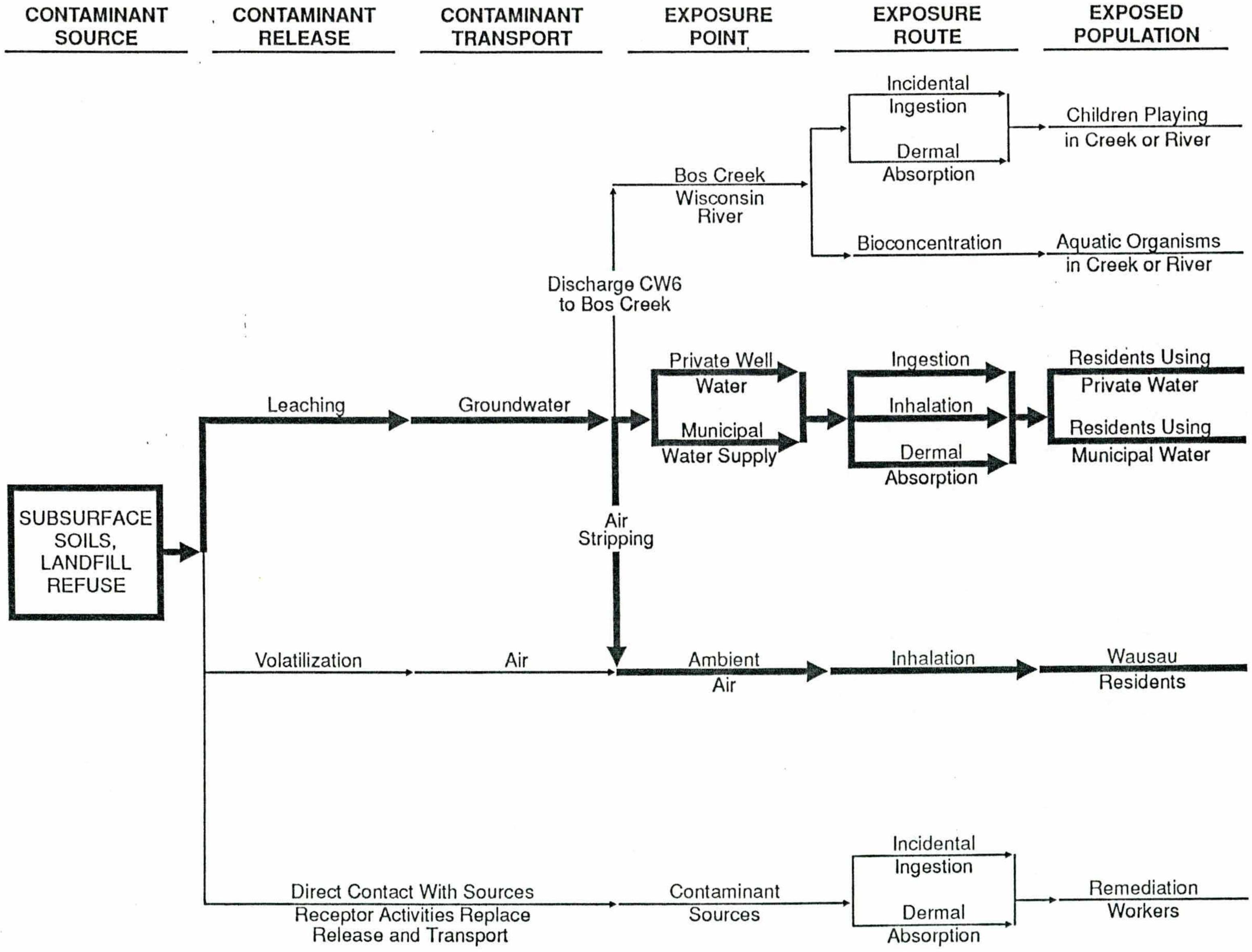

Pathways of greatest concern are in bold.

FIGURE 8
POTENTIAL EXPOSURE PATHWAYS
WAUSAU WATER SUPPLY NPL SITE

APPENDIX A

STRIPPING TOWER ANALYSIS

APPENDIX A

STRIPPING TOWER ANALYSIS

In late 1984, the Wausau Water Utility began operation of two VOC stripping towers installed to allow continued use of Production Wells CW-3 and CW-4 to produce potable water. During the first four months of operation, the Production Well CW4 (8 ft) tower was studied extensively. Results of the process analyses and design, and of tower operation were reported by Hand, et al. (1986)

The transfer unit model (Colburn, 1935), based on the two-resistance theory of gas-liquid mass transfer (Lewis and Whitman, 1924), has long been used in analysis and design of countercurrent flow strippers and absorbers for chemical engineering applications (Treybal, 1980; Perry, 1984). More recently, these concepts have been applied to dilute aqueous solutions of volatile synthetic organic compounds (Kavanaugh and Trussell, 1980).

Cummins (1982) demonstrated the feasibility of VOC removal at Wausau using a pilot scale packed tower stripper to treat water from Production Well CW3. Hand, et al. (1986) reported on the design and performance of one of the Wausau stripping towers designed using the transfer-unit concept. Mass transfer coefficients were estimated using correlations developed by Onda et al. (1968). Henry's Law constants were measured using contaminated Production Well CW4 water. Other solute, packing and fluid properties were obtained from the literature.

The 8-ft diameter tower was designed for a 1500 gpm water flow rate with a design air:water volumetric ratio of 30:1. The tower size was optimized based on a target performance level of 95% removal of trichloroethene. A 9-ft diameter tower was also designed to treat water from Production Well CW3. A summary of design parameters for the two towers is presented in Table A-1.

Performance data for the towers are summarized in Table A-2. The available data indicate performance of the strippers has met or exceeded design target levels.

Data for the 8-ft diameter tower was collected by Hand, et al. (1986), during the first few months of tower operation. The water flow rate was varied from approximately 1170 to 1500 gpm, and the air flow rate was varied from approximately 8200 to 9650 cfm. Resulting air:water ratios were 41, 53 and 62 for the three operating conditions reported. Trichloroethene influent concentrations ranged from 66 to 72 ug/L, and effluent concentrations ranged from 1.0 to 1.8 ug/L (97.3 to 98.5 percent removal).

Data for the 9-ft diameter tower was reported by the Wausau Water Utility, based on influent and effluent samples collected on March 2, 1988. The influent and effluent TCE concentrations were 73.8 ug/L and 0.5 ug/L respectively (99.3% removal). No water and air flow rates were reported.

An analysis of stripper performance was conducted with two goals in mind: (1) to compare predicted removal efficiencies with reported performance, and (2) to predict tower performance under a range of water and air flow rates corresponding to the range of viable operating conditions. The transfer unit model was used in the analysis. Predicted removal efficiencies for the 8-ft and 9-ft diameter towers are shown in Table A-3, along with the removal efficiencies calculated from operating data. Predicted removal efficiencies exceeded measured removal efficiencies for 1,2-dichloroethene. Predicted removal efficiencies for trichloroethene and tetrachloroethene were not consistently either higher or lower than measured values. In general, the measured and predicted values are relatively close. Therefore, the model used for predictions should provide reasonable estimates of tower performance.

A range of water and air flow rates were used in the analysis of stripping tower performance. It was assumed that either stripper might be used to treat water from a single well, or that flow from a single well could be split to the two strippers. During high demand periods, individual wells may be pumped at a high rate, resulting in high loadings to strippers. The highest water flow rates used correspond to hydraulic loadings of approximately 40 gpm/ft^2 of tower cross sectional area. Low loadings would be anticipated in cases where flow from a single well was split between the two strippers. The lowest water flow rates used correspond to hydraulic loadings of approximately 14 gpm/ft^2. Air flow rates were varied from design loadings up to near maximum blower capacity. In summary, the following flow rates were used in the analysis:

Water Flow	8 ft tower	600 to 2100 gpm
	9 ft tower	900 to 2400 gpm
Air Flow	8 ft tower	6000 to 12000 cfm
	9 ft tower	8000 to 16000 cfm

Packing depths of 23 ft (8-ft tower, due to reported settling) and 24.5 ft (9-ft tower, design value) were used. The operating temperature was held constant at 10°C. Packing properties of 3-in. Intalox saddles were used. The compounds reported as detected in CW4 water by Hand, et al. (1986) were used in the analysis. Solute properties are summarized in Table A-4. Air and water properties were obtained from handbooks (Weast, 1984; Perry, 1984).

Results of the analysis are summarized in Table A-5 for the 8-ft tower, and in Table A-6 for the 9-ft tower. It is apparent that for the major contaminants of concern at present (TCE and PCE), high removal efficiencies can be anticipated under the range of air and water flow rates used in the analysis. For a given air flow rate, removal efficiency decreases as the water flow rate increases. The best performance is predicted at low water flow and high air flow, although the performance is less sensitive to air flow rates at low water flow rates. The analysis indicates that both towers could treat water containing higher concentrations of TCE and PCE than have been observed at Production Wells CW3 or CW6 under a range of air and water flow rates.

Based on the available information and on the analysis conducted, the following conclusions can be drawn regarding the VOC stripping towers at the water utility:

- The 8-ft and 9-ft diameter towers were designed to treat 1500 gpm and 2000 gpm, respectively, and to obtain 95% removal of TCE.

- Performance data indicates the towers are capable of meeting or exceeding design requirements.

- There is adequate flexibility in the systems to allow varying water and air flow rates to obtain contaminant removal efficiencies in excess of design levels.

- Predictions of tower performance indicate that target effluent concentrations can be achieved even with substantial increases in raw water contaminant concentrations.

RLM/sss/MSR/DWH
[sss-600-61a]

TABLE A-1

SUMMARY OF DESIGN PARAMETERS FOR WAUSAU WATER UTILITY PACKED TOWER STRIPPERS
WAUSAU WATER SUPPLY NPL SITE
WAUSAU, WISCONSIN

Parameter	Production Well CW4 Tower (1)	Production Well CW3 Tower
Air: Water Ratio (v:v)	30	30
Packing Pressure Drop	0.06 in w.c./ft	0.06 in w.c./ft
VOC Removal (TCE)	95%	95%
Henry's Law Constant (TCE)	0.116	0.116
Temperature	10°C	10°C
Packing Type	3-inch plastic saddles	3-inch plastic saddles
Tower Diameter	8 ft	9 ft
Packing Depth	24.5 ft	24.5 ft
Water Flow Rate	1500 gpm	2000 gpm
Air Flow Rate	6000 cfm	8000 cfm

(1) Hand, et al., 1986

13076.15
RLM/sss/MSR/DWH
[sss-600-23f]

TABLE A-2

SUMMARY OF STRIPPING TOWER PERFORMANCE
WAUSAU WATER SUPPLY NPL SITE
WAUSAU, WISCONSIN

	Production Well CW4 Stripper (1)			Production Well CW3 Stripper (2)		
Compound	Influent	Effluent	Removal	Influent (3)	Effluent	Removal
Cis-1,2-Dichloroethene	82.3	2.6	96.8	9.8	ND	>90.0
Trichloroethene	72.0	1.4	98.0	73.8	0.5	99.3
Tetrachloroethene	59.6	0.96	98.4	14.9	ND	96.6
Toluene	30.9	0.94	96.9	NA	--	--
Ethylbenzene	5.1	<0.3	>94.0	NA	--	--
Xylenes	16.6	0.60	96.4	NA	--	--
Vinyl Chloride	8.8	<0.3	>96.5	NA	--	--

(1) Average during first four months of operation (Hand, et al., 1986).

(2) Samples collected March 2, 1988.

(3) Sample collected at the CW3 well head.

ND Not Detected

NA Not Analyzed

13076.15
RLM/sss/MSR/DWH
[sss-600-23g]

TABLE A-3
MEASURED AND PREDICTED TOWER PERFORMANCE EFFICIENCY
WAUSAU WATER UTILITY
WAUSAU WATER SUPPLY NPL SITE
WAUSAU WISCONSIN

Compound	Water Flow (gpm)	Air Flow (cfm)	Removal Efficiency Measured (%)	Removal Efficiency Predicted (%)
		8 ft Tower		
1,2-Dichloroethene	1199.6	8496	95.9	98.8
1,2-Dichloroethene	1499.1	8196	93.9	98.3
1,2-Dichloroethene	1169.5	9648	97.4	98.9
Trichloroethene	1199.6	8496	98.5	98.5
Trichloroethene	1499.1	8196	97.3	97.8
Trichloroethene	1169.5	9648	98.4	98.6
Tetrachloroethene	1199.6	8496	98.6	98.5
Tetrachloroethene	1499.1	8196	98.8	97.9
Tetrachloroethene	1169.5	9648	98.5	98.6
		9 ft Tower		
1,2-Dichloroethene	1600*	10000*	ND	98.8
Trichloroethene	1600*	10000*	99.3	98.5
Tetrachloroethene	1600*	10000*	ND	98.5

* - Assumed Flow Rates
ND - Not detected in effluent

[sss-600-23e]

TABLE A-4
SUMMARY OF SELECTED VOC PROPERTIES
WAUSAU WATER SUPPLY NPL SITE
WAUSAU, WISCONSIN

Compound	Henry's Law Constant (1) -	Mol. Weight g/gmol	Lebas Molar Volume (2) cm3/mol	Diff. in Water (3) m2/s	Diff. in Air (4) m2/s
Vinyl Chloride	0.533	62.5	65.3	8.3e-10	1.0e-05
1,2-Dichloroethene	0.207	96.94	86.2	7.1e-10	8.6e-06
Trichloroethene	0.207	131.39	107.1	6.2e-10	7.6e-06
Tetrachloroethene	0.289	165.83	128.0	5.6e-10	6.9e-06
1,1,1-Trichloroethane	0.417	133.41	114.5	6.0e-10	7.4e-06
Toluene	0.134	92.14	118.2	5.9e-10	7.6e-06
Ethylbenzene	0.143	106.17	140.4	5.3e-10	6.9e-06
Xylene (as o-Xylene)	0.0861	106.17	140.4	5.3e-10	6.9e-06

(1) Ratio of molar concentration in each phase at 10 C. Vinyl chloride est. from data of Hayduk and Laudie (1974), tetrachloroethene est. from data of Gossett and Lincoff (1981), and all others est. from data of Mumford (1987)
(2) Calculated using additive volume increments from Lyman, et al. (1982)
(3) Estimated at 10 C using method of Hayduk and Laudie (Lyman, et al., 1982)
(4) Estimated at 10 C using method of Fuller, Schettler and Giddings (Lyman, et al., 1982)

TABLE A-5
SUMMARY OF ESTIMATED VOC STRIPPER PERFORMANCE: 8 FT TOWER
WAUSAU WATER SUPPLY NPL SITE
WAUSAU, WISCONSIN

Water Flow gpm	Air Flow cfm	A:W Ratio v/v	VC Removal Eff. %	1,2-DCE Removal Eff. %	TCE Removal Eff. %	PCE Removal Eff. %	1,1,1-TCA Removal Eff. %	TOL Removal Eff. %	EBZ Removal Eff. %	XYL Removal Eff. %
600	6000	74.8	99.81	99.49	99.29	99.25	99.46	98.85	98.65	97.74
900	6000	49.9	99.62	98.97	98.63	98.63	99.02	97.74	97.44	95.55
1200	6000	37.4	99.39	98.31	97.83	97.93	98.52	96.39	96.03	92.97
1500	6000	29.9	99.13	97.55	96.93	97.17	97.99	94.85	94.46	90.12
1800	6000	24.9	98.85	96.70	95.94	96.36	97.42	93.17	92.78	87.11
2100	6000	21.4	98.54	95.77	94.89	95.51	96.83	91.38	91.01	84.04
600	8000	99.7	99.82	99.57	99.39	99.33	99.50	99.06	98.88	98.25
900	8000	66.5	99.65	99.14	98.84	98.79	99.11	98.20	97.92	96.64
1200	8000	49.9	99.45	98.62	98.20	98.20	98.67	97.17	96.82	94.74
1500	8000	39.9	99.22	98.03	97.49	97.56	98.21	96.02	95.61	92.65
1800	8000	33.2	98.98	97.38	96.72	96.89	97.72	94.76	94.33	90.42
2100	8000	28.5	98.71	96.67	95.91	96.20	97.22	93.43	92.98	88.10
600	10000	124.7	99.83	99.61	99.45	99.37	99.53	99.18	99.00	98.53
900	10000	83.1	99.67	99.24	98.97	98.88	99.16	98.45	98.18	97.23
1200	10000	62.3	99.48	98.80	98.41	98.35	98.76	97.60	97.26	95.70
1500	10000	49.9	99.28	98.30	97.81	97.78	98.33	96.65	96.25	94.03
1800	10000	41.6	99.05	97.75	97.15	97.19	97.89	95.63	95.18	92.24
2100	10000	35.6	98.81	97.16	96.47	96.59	97.44	94.55	94.07	90.38
600	12000	149.6	99.84	99.64	99.48	99.40	99.54	99.26	99.08	98.71
900	12000	99.7	99.69	99.30	99.05	98.95	99.19	98.61	98.35	97.59
1200	12000	74.8	99.51	98.90	98.55	98.45	98.81	97.87	97.53	96.30
1500	12000	59.8	99.31	98.46	98.00	97.93	98.42	97.05	96.65	94.88
1800	12000	49.9	99.10	97.98	97.43	97.39	98.01	96.17	95.72	93.38
2100	12000	42.7	98.88	97.47	96.82	96.84	97.59	95.24	94.76	91.81

Temperature:	10 C
Packing Height:	23 ft
Packing Size:	3 in
Packing Type:	Intalox Saddles
Tower Diameter:	8 ft

Abbreviations - VC: Vinyl Chloride; 1,2-DCE: 1,2-Dichloroethenes; TCE: Trichloroethene; PCE: Tetrachloroethene; 1,1,1-TCA: 1,1,1-Trichloroethane; TOL: Toluene; EBZ: Ethylbenzene; XYL: Xylenes

TABLE A-6
SUMMARY OF ESTIMATED VOC STRIPPER PERFORMANCE: 9 FT TOWER
WAUSAU WATER SUPPLY NPL SITE
WAUSAU, WISCONSIN

Water Flow gpm	Air Flow cfm	A:W Ratio v/v	VC Removal Eff. %	1,2-DCE Removal Eff. %	TCE Removal Eff. %	PCE Removal Eff. %	1,1,1-TCA Removal Eff. %	TOL Removal Eff. %	EBZ Removal Eff. %	XYL Removal Eff. %
900	8000	66.5	99.83	99.52	99.33	99.30	99.51	98.88	98.68	97.70
1200	8000	49.9	99.72	99.18	98.90	98.90	99.23	98.14	97.88	96.20
1500	8000	39.9	99.58	98.78	98.40	98.46	98.92	97.26	96.95	94.44
1800	8000	33.2	99.43	98.31	97.83	97.97	98.59	96.26	95.93	92.50
2100	8000	28.5	99.26	97.79	97.21	97.46	98.23	95.17	94.82	90.42
2400	8000	24.9	99.08	97.22	96.54	96.91	97.86	93.99	93.63	88.23
900	10000	83.1	99.84	99.58	99.41	99.36	99.54	99.06	98.88	98.16
1200	10000	62.3	99.74	99.30	99.05	99.01	99.29	98.46	98.22	96.99
1500	10000	49.9	99.61	98.97	98.63	98.62	99.01	97.76	97.46	95.64
1800	10000	41.6	99.48	98.59	98.16	98.20	98.71	96.97	96.64	94.13
2100	10000	35.6	99.33	98.16	97.65	97.76	98.40	96.11	95.74	92.51
2400	10000	31.2	99.17	97.70	97.11	97.30	98.07	95.19	94.80	90.81
900	12000	99.7	99.85	99.62	99.46	99.40	99.56	99.17	99.00	98.44
1200	12000	74.8	99.75	99.37	99.14	99.08	99.32	98.66	98.42	97.47
1500	12000	59.8	99.64	99.08	98.77	98.73	99.07	98.07	97.78	96.36
1800	12000	49.9	99.51	98.75	98.36	98.35	98.79	97.41	97.07	95.12
2100	12000	42.7	99.37	98.39	97.92	97.95	98.50	96.69	96.32	93.80
2400	12000	37.4	99.22	98.00	97.45	97.54	98.20	95.92	95.52	92.39
900	14000	116.4	99.85	99.65	99.50	99.43	99.58	99.25	99.08	98.62
1200	14000	87.3	99.76	99.42	99.20	99.13	99.35	98.79	98.57	97.79
1500	14000	69.8	99.65	99.16	98.87	98.80	99.11	98.27	97.99	96.83
1800	14000	58.2	99.53	98.87	98.50	98.45	98.85	97.69	97.37	95.78
2100	14000	49.9	99.40	98.55	98.11	98.09	98.58	97.07	96.70	94.65
2400	14000	43.6	99.26	98.20	97.69	97.71	98.30	96.40	96.00	93.45
900	16000	133.0	99.86	99.67	99.52	99.45	99.59	99.30	99.14	98.75
1200	16000	99.7	99.77	99.46	99.25	99.17	99.37	98.89	98.67	98.01
1500	16000	79.8	99.66	99.22	98.94	98.86	99.14	98.42	98.14	97.17
1800	16000	66.5	99.55	98.95	98.60	98.53	98.89	97.90	97.58	96.24
2100	16000	57.0	99.42	98.66	98.24	98.19	98.63	97.34	96.98	95.25
2400	16000	49.9	99.29	98.34	97.86	97.83	98.37	96.74	96.35	94.20

Temperature:	10 C
Packing Height:	24.5 ft
Packing Size:	3 in
Packing Type:	Intalox Saddles
Tower Diameter:	9 ft

Abbreviations - VC: Vinyl Chloride; 1,2-DCE: 1,2-Dichloroethenes; TCE: Trichloroethene; PCE: Tetrachloroethene; 1,1,1-TCA: 1,1,1-Trichloroethane; TOL: Toluene; EBZ: Ethylbenzene; XYL: Xylenes