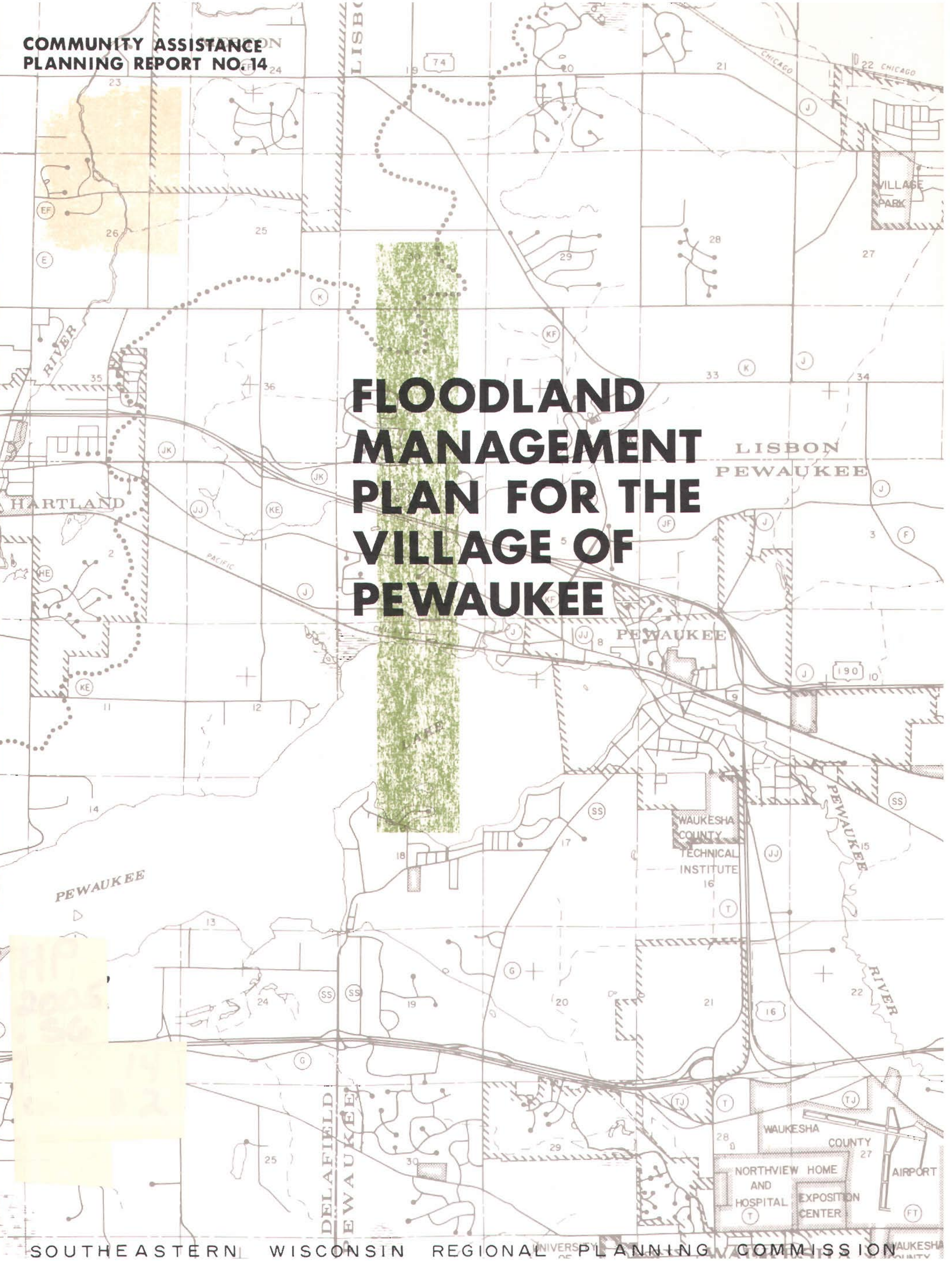
COMMUNITY ASSISTANCE
PLANNING REPORT NO. 14

FLOODLAND MANAGEMENT PLAN FOR THE VILLAGE OF PEWAUKEE



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Special acknowledgement is due Mr. Stuart G. Walesh, P.E., SEWRPC Water Resources Engineer, and Mr. Daniel F. Snyder, SEWRPC Associate Engineer, for their efforts in the conduct of this study and in the preparation of this report.

COMMUNITY ASSISTANCE PLANNING REPORT NUMBER 14

FLOODLAND MANAGEMENT PLAN FOR THE VILLAGE OF PEWAUKEE

Southeastern Wisconsin Regional Planning Commission
P. O. Box 769
Old Courthouse
916 N. East Avenue
Waukesha, Wisconsin 53187

The preparation of this report was financed in part by the Village of Pewaukee, in part through a planning grant from the Wisconsin Department of Local Affairs and Development pursuant to Section 22.14 of the Wisconsin Statutes, and in part through a planning grant from the U. S. Department of Housing and Urban Development pursuant to Section 701 of the Housing Act of 1954.

February 1978

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SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

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February 22, 1978

Mr. Clarence Muehl
President
Village of Pewaukee
235 Hickory Street
Pewaukee, Wisconsin 53702

Dear Mr. Muehl:

On September 22, 1976, the Village of Pewaukee requested that the Regional Planning Commission staff prepare a Floodland Management Plan for lands lying along the Pewaukee River, Pewaukee Lake Outlet, and Pewaukee Lake within the Village of Pewaukee. The Regional Planning Commission staff has now completed the study and is pleased to transmit herewith the findings and recommendations of that study as documented in the attached report entitled "Floodland Management Plan for the Village of Pewaukee."

This report discusses historic flood problems and future flood risks; presents floodland management alternatives; provides a comparative evaluation of the technical, economic, and environmental features of each alternative; recommends a floodland management plan for the Village of Pewaukee consisting of various structural and nonstructural measures; and sets forth an implementation program identifying the responsibilities of various governmental units and agencies concerned with plan implementation.

The report recommends construction of a turf-lined channel along the Pewaukee River within the Village, enclosure of the Pewaukee Lake Outlet, and placement of an earthen dike-concrete floodwall along the eastern edge of Pewaukee Lake. In addition, the following supplemental nonstructural measures are recommended as part of the floodland management plan: floodproofing of selected residential and commercial structures in the Village; reservation of remaining floodlands for recreational and related open space uses and for floodwater storage and conveyance purposes; vigorous administration of the existing floodland regulations and revision to the regulations upon completion of the recommended structural flood control works; regulation of land outside of the floodlands in the Pewaukee River subwatershed in conformance with the SEWRPC year 2000 land use plan; conduct of a flood insurance rate study under the National Flood Insurance Program; adoption of utility and facility policies and procedures consistent with the flood-prone status of riverine areas; and development of emergency procedures to provide floodland residents and other property owners with information about impending flooding.

This floodland management study, although essentially single purpose in nature—being intended to resolve existing and to prevent the development of new flood problems in the village—was conducted within the context of and is fully coordinated with the Commission's comprehensive regional planning program including the adopted Comprehensive Plan for the Fox River Watershed. The floodland management plan for the Village of Pewaukee as described herein was endorsed and recommended for approval by the Fox River Watershed Committee on February 20, 1978.

It is recommended that the plan be adopted by the Plan Commission of the Village of Pewaukee as part of the master plan for the Village by resolution pursuant to Section 62.23(3)(b) of the Wisconsin Statutes and be certified to the Village Board for adoption by the Board. Contingent upon such adoption by the Village, the Regional Planning Commission will also adopt the plan and certify it as an amendment to the previously adopted Fox River watershed plan.

We trust that you will find the enclosed report useful in your efforts to mitigate flood problems within the Village of Pewaukee. The Commission staff stands ready to assist the Village in interpreting the findings and recommendations contained in the enclosed report.

Sincerely,

Kurt W. Bauer

Kurt W. Bauer
Executive Director

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF MAPS

Chapter I

INTRODUCTION

The purpose of this report is to set forth within the overall framework of the adopted comprehensive plan for the Fox River watershed, a recommended floodland management plan for lands lying along the Pewaukee River; the Pewaukee Lake Outlet, a tributary to the Pewaukee River; and Pewaukee Lake within the Village of Pewaukee, Waukesha County, Wisconsin. More specifically, this report 1) discusses historic flood problems and future flood risks; 2) presents floodland management alternatives; 3) provides a comparative evaluation of the technical, economic, and environmental features of each alternative; 4) recommends a floodland management plan for the Village of Pewaukee consisting of various structural and nonstructural measures; and 5) sets forth a plan implementation program identifying the responsibilities of various governmental units and agencies concerned.

DEFINITION OF FLOODLAND MANAGEMENT

Floodland management may be defined as the planning and implementation of a combination of measures intended to reconcile the floodwater conveyance and storage function of floodlands with the space and related social-economic needs of the resident population. Specific purposes of floodland management include elimination of loss of life, lessening of danger to human health and safety, minimization of monetary damage to private and public property, reduction in the costs of utilities and services, and minimization of disruption in community affairs. A broader goal is enhancement of the overall quality of life of the residents of an area by protection of those environmental values—recreational, aesthetic, ecological, and cultural—normally associated with and concentrated in riverine areas.

RELATIONSHIP BETWEEN THIS AND PREVIOUS FLOOD-RELATED STUDIES

This report was prepared by the Southeastern Wisconsin Regional Planning Commission (SEWRPC) in response to a formal request made on September 22, 1976, by the Village Board of the Village of Pewaukee. The Village Board request was an outgrowth of a SEWRPC study completed in October 1976[1] which refined flood hazard information and detailed some of the floodland management recommendations initially set forth by the SEWRPC in its adopted comprehensive plan for the Fox River watershed.[2] The studies on which this report is based were conducted by the Commission from December 1976 through August 1977.

Research into historic flooding in the Fox River watershed, which was conducted in 1966 under the Fox River watershed planning program, did not identify major historic flood problems in the Village of Pewaukee and environs. The only reported flood problem was that of scattered instances of lawn inundation and basement damage in April 1960 along the Fox and Pewaukee Rivers in the Village and Town of Pewaukee. Furthermore, subsequent hydrologic-hydraulic analyses and floodland delineations carried out along the Pewaukee River under the watershed study indicated the existence of a relatively narrow 100-year recurrence interval floodland suggesting the absence of a potential flood problem in the Village. However, historic flood research and hydrologic-hydraulic studies carried out under this floodland management study and under the recently completed floodland information study reveal the existence of moderate historic flooding in the Village and of a serious flood threat under 100-year recurrence interval flood flow conditions. The differences between the more recent findings and the findings of earlier studies may be attributed to the following four factors:

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[1] *SEWRPC Community Assistance Planning Report No. 9, Floodland Information Report for the Pewaukee River-Village of Pewaukee, Waukesha County, Wisconsin, October 1976, 43 pp.*

[2] *SEWRPC Planning Report No. 12, A Comprehensive Plan for the Fox River Watershed, Volume One, "Inventory Findings and Forecasts," and Volume Two, "Alternative Plans and Recommended Plan," February 1970, 942 pp.*

- Major floods or, more specifically, the meteorological events and other conditions that cause such floods are random events, and it is possible for those events to occur in such a manner that major flooding simply does not occur in a particular geographic area for a relatively long period of time. This has been the experience in the Pewaukee area. The recently completed floodland information report reveals that, as of the time of the Fox River watershed planning program in the late 1960's, only two historic floods had occurred in the Village of Pewaukee—the June 26, 1940, flood and the April 1, 1960, flood. These floods caused relatively minor damage and disruption in the Village compared to the damage and disruption associated with two very recent floods on September 19, 1972, and on April 21-22, 1973. Thus, the two most serious floods of record occurred subsequent to the Fox River watershed planning program and within nine months of each other. The two recent floods have increased the awareness of Village officials and citizens of the potential flood problems in the Village and have created a concern with finding a solution to that problem—a concern that apparently did not exist at the time of the Fox River watershed planning program.

- Large-scale topographic maps of riverine areas in the Village, which were available for use in both the floodland information study and in this floodland management study, were not yet prepared or available during the earlier Fox River watershed planning program. These maps consist of 1" = 200' scale, two-foot contour interval maps obtained by the Village of Pewaukee in 1975 and 1976 and 1" = 200' scale, two-foot contour interval maps obtained by the SEWRPC in 1976 under its areawide water quality management planning program. These maps, compared to the smaller scale, larger contour interval maps available at the time of the Fox River watershed study, provide a more accurate representation of the channel-floodplain topography for use both in calculating the flood discharges and stages and in delineating the lateral extent of the corresponding flood-prone areas. These maps also permit a more accurate assessment of monetary flood risks in the Village.

- Physical changes have occurred along the Pewaukee River and Pewaukee Lake Outlet in the Village of Pewaukee since completion of the Fox River watershed study. These physical changes may have created hydraulic restrictions, thereby increasing flood stages for given flood flows, and may have resulted in alteration of riverine area topography, thereby changing the lateral limits of the floodlands. For example, a portion of the Pewaukee Lake Outlet downstream and east of Wisconsin Avenue was enclosed in a conduit subsequent to the Fox River watershed planning study to permit construction of a parking lot. Scattered floodland fill and building construction have occurred along the Pewaukee River within the Village including that which has occurred in the Pewaukee Park Hills development on the west side of the Pewaukee River north of Capitol Drive.

- The Fox River watershed planning study was limited to those riverine areas lying along the Pewaukee Lake Outlet and along the Pewaukee River within the Village downstream of its confluence with the Pewaukee Lake Outlet. The floodland information report and this floodland management study included not only a reexamination of those reaches but also an analysis of flood flows and stages and floodland limits along the Pewaukee River within the Village upstream of its confluence with the Pewaukee Lake Outlet. Thus, the more recent investigations included additional stream reaches within the Village.

RELATIONSHIP TO ADOPTED REGIONAL PLAN ELEMENTS

This floodland management study for the Village of Pewaukee, although essentially single purpose in nature—intended to resolve existing and prevent the development of new flood problems in the Village—was conducted within the context of and is fully coordinated with the Commission's comprehensive regional planning program. Thus, for example, the flood flows and volumes used to test floodland management alternatives reflect the year 2000 land use plan for southeastern Wisconsin in general and for the Pewaukee River subwatershed in particular. The water control facility objectives and standards utilized in the design and evaluation of floodland management alternatives are those adopted in the Comprehensive Plan for the Fox

River Watershed and refined in the subsequent Milwaukee, Menomonee, and Kinnickinnic River watershed plans. Furthermore, the potentially adverse downstream effects of floodland management measures recommended for implementation within the Village of Pewaukee were examined.

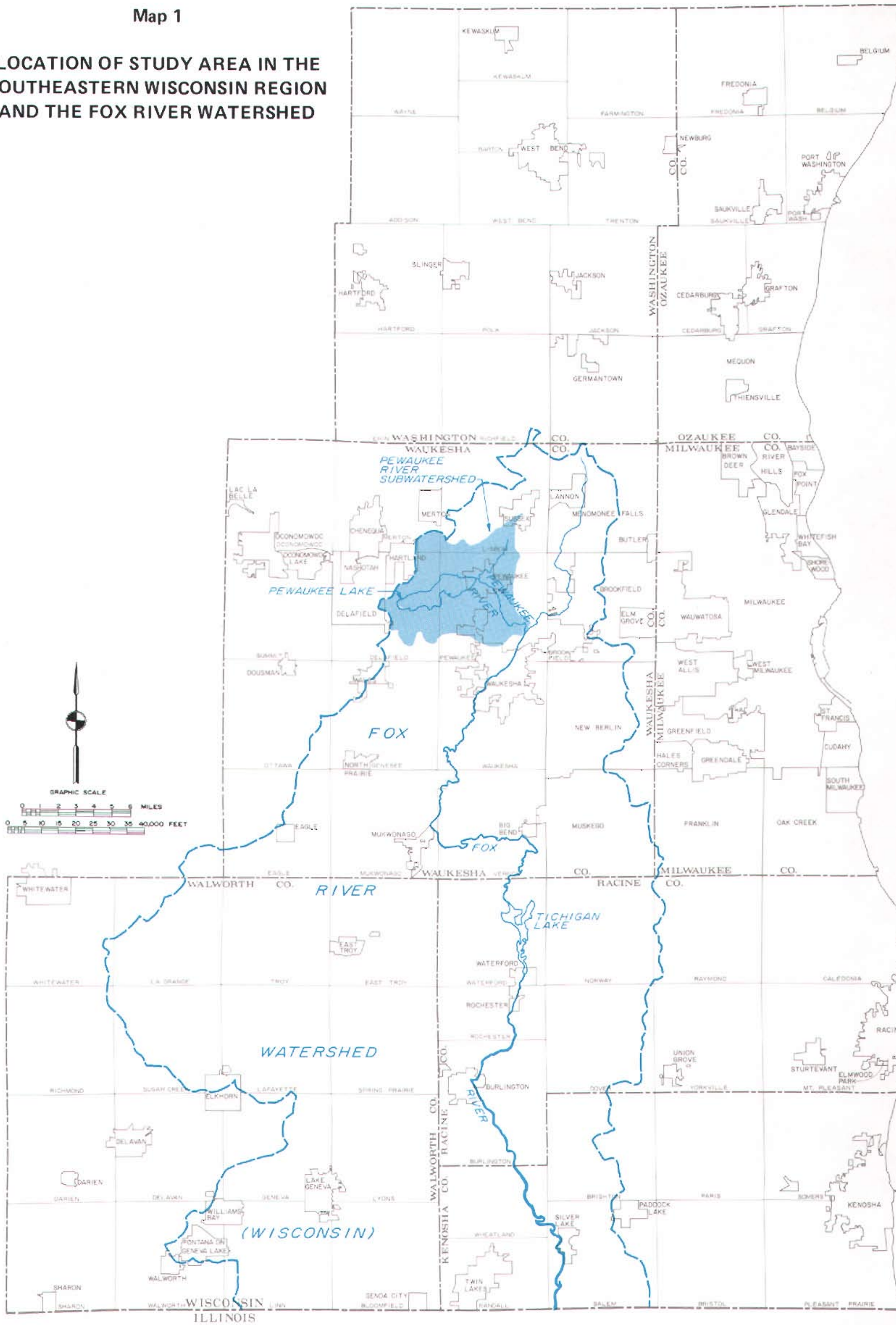
AREAL LIMITS OF STUDY

The Floodland Information Report for the Pewaukee River analyzed the entire 38.35 square-mile drainage area tributary to the Pewaukee River at its confluence with the Fox River as shown on Map 1. As a result of that study, 10-, 25-, 50-, 100-, and 500-year recurrence interval flood discharges and stages were developed for the 9.3-mile-long reach of the Pewaukee River in and near the Village of Pewaukee—bounded at the upstream end by CTH K and at the downstream end by the Fox River—and for the 0.1-mile-long reach of the Pewaukee Lake Outlet—bounded at the upstream end by Pewaukee Lake and at the downstream end by Pewaukee River. In addition, 10-, 25-, 50-, 100-, and 500-year recurrence interval flood stages and corresponding areas of inundation were developed for lands lying along Pewaukee Lake in the Village.

This floodland management planning study is directed primarily to resolution of flood problems existing along the Pewaukee River, the Pewaukee Lake Outlet, and Pewaukee Lake within the limits of the Village of Pewaukee as shown on Map 2. The process of evaluating alternative solutions to these flood problems did, however, include identification and quantification of flooding and other problems that may occur either upstream or downstream of the Village as a result of a possible implementation of any of the alternatives considered.

Map 1

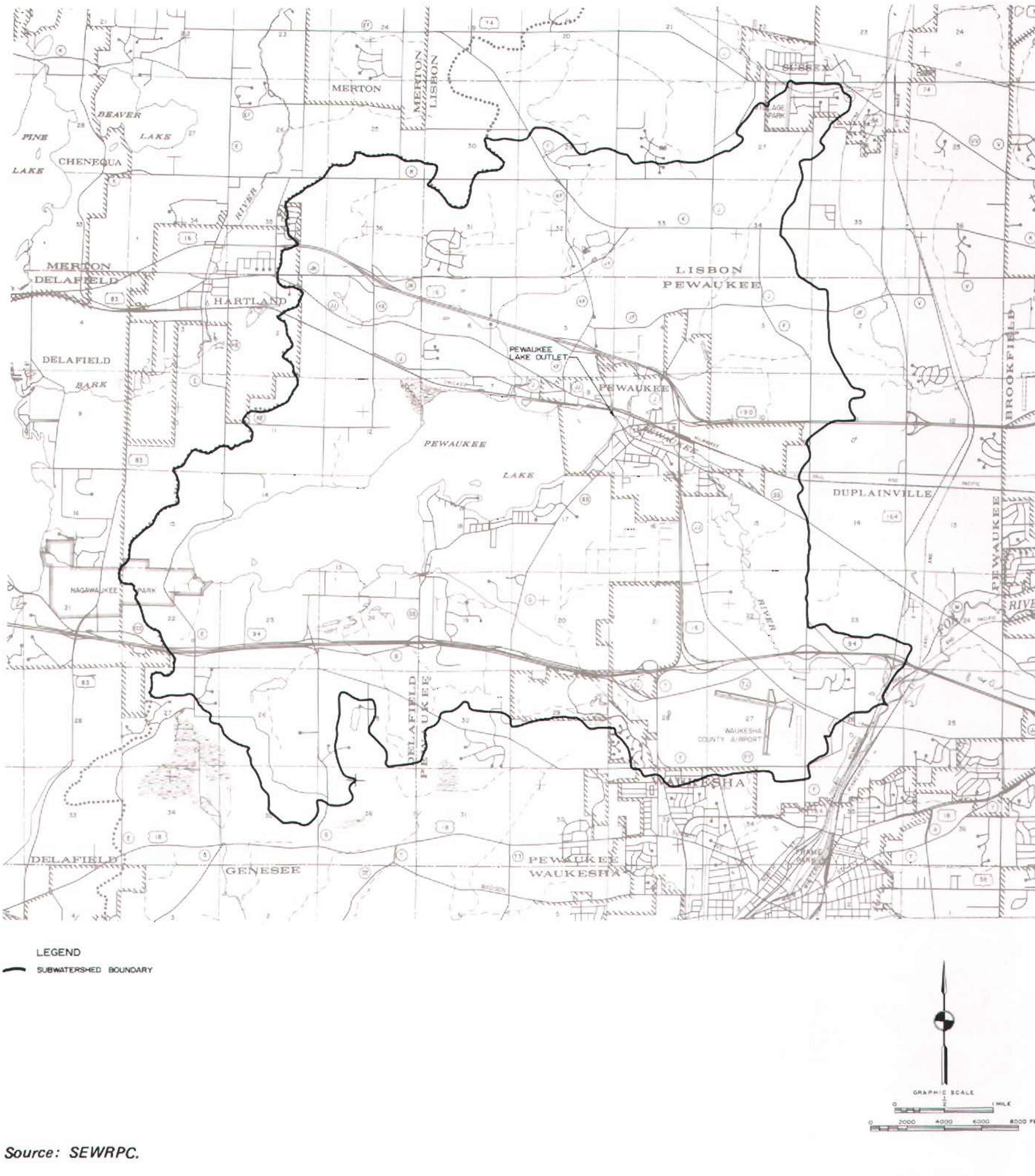
LOCATION OF STUDY AREA IN THE SOUTHEASTERN WISCONSIN REGION AND THE FOX RIVER WATERSHED



Source: SEWRPC.

Map 2

THE PEWAUKEE RIVER SUBWATERSHED



Source: SEWRPC.

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Chapter II

MAGNITUDE OF THE FLOOD PROBLEM

INTRODUCTION

Flooding is defined, for the purpose of this report, as the inundation of floodplains lying along major streams and around lakes as a direct result of water moving out of and away from those streams and lakes. Flood flows and stages can be determined by engineering analyses carried out on a watershedwide basis and may be used to accurately and precisely delineate on large-scale topographic maps areas subject to flooding.

Flooding is not necessarily synomymous with the presence of flood problems. Flood problems—and the demand for flood control works and measures—are created only when flood-damage-prone land uses are allowed to intrude upon the natural floodlands of an area in such a fashion and to such an extent that the certain, although random, inundation of floodlands results in disruption, monetary damages, and risk to human health and life.

Storm water inundation may be defined as the localized ponding of storm water runoff which occurs when storm water runoff moving towards streams and other low lying areas via small intermittent channels, storm sewers, or other drainageways or as overland or sheet flow either exceeds the conveyance capacity of those channels, sewers, or drainageways and flows onto adjacent low-lying areas or, in the case of overland flow, encounters flow resistance or obstruction and temporarily accumulates on the land surface. In contrast to areas experiencing flooding, areas experiencing storm water inundation tend to be discontinuous, consisting of a series of relatively small and scattered pockets, not necessarily located in the lowest areas or near major streams or even near small intermittent channels or other well defined drainageways. With the exception of storm water control problems directly related to flood stages on the Pewaukee River, the Pewaukee Lake Outlet, and the Pewaukee Lake, the analysis of storm water drainage problems is beyond the scope of this report.

The magnitude of serious existing or potential flood problems must be clearly defined and understood prior to developing and evaluating alternative floodland management measures. The purpose of this chapter is to describe the historic, existing, and potential flood problems along the Pewaukee River, the Pewaukee Lake Outlet, and Pewaukee Lake within and near the Village of Pewaukee in terms of historic flood events, the lateral extent of floodlands and the proportion of those floodlands containing urban development and monetary flood risks.

HISTORIC FLOOD EVENTS

An account of historic flood events within the Village of Pewaukee is set forth in SEWRPC Community Assistance Planning Report No. 9, Floodland Information Report for the Pewaukee River. Based on historic flood data and information, the Village of Pewaukee has experienced one major flood—in April 21-22, 1973—and a series of lesser flood events—September 19, 1972; April 1, 1960; and June 26, 1940. Historic flood problems in the Village appear to have been concentrated at the eastern end of Pewaukee Lake in the vicinity of the Pewaukee Lake Outlet—including overtopping of Wisconsin Avenue due to a combination of high lake levels and waves—and along the Pewaukee River in the Village.

Flood problems within the Village have been serious enough to necessitate several "flood-fighting" measures by the Village, including sand-bagging operations along Wisconsin Avenue, along Capitol Drive, and in the vicinity of the Sentry Store and pumping from the sanitary sewerage system to relieve surcharged conditions.

The maximum flood of record—the April 1973 event—is estimated to have had a recurrence interval of approximately 50 years and, therefore, was significantly less severe than the 100-year recurrence interval flood specified for floodland regulation purposes by the Wisconsin Department of Natural Resources and used by the Commission as a design flood for floodland management purposes. The absence of a flood of record approximating the 100-year recurrence interval event does not mean that such an event will not occur in the Pewaukee River subwatershed. Major floods or, more specifically, the meteorologic events and other conditions that cause such floods are random events and may not occur in a particular geographic area, such as the Village of Pewaukee, for a relatively long period of time. The longer the time since a major flood, however, the greater the probability that such a flood will be reached or exceeded one or more times.[1]

AREAL EXTENT OF FLOODLANDS

One-hundred year recurrence interval flood flow discharges under existing and year 2000 plan land use conditions, along with the corresponding flood stages and areas of inundation, have been determined for the Pewaukee River, the Pewaukee Lake Outlet, and Pewaukee Lake as described in detail in Floodland Information Report for the Pewaukee River. Map 3 shows the lateral extent of the 100-year recurrence interval floodlands—channel plus 100-year floodplain—under year 2000 plan land use conditions for the Pewaukee River and Pewaukee Lake Outlet and the eastern extremities of Pewaukee Lake, all within the Village of Pewaukee. The floodplains contiguous with the Pewaukee River, Pewaukee Lake Outlet, and Pewaukee Lake encompass a total area of about 0.43 square miles, or about 14.5 percent of the 2.9-square-mile area of the Village of Pewaukee. The lateral extent of these floodplains exceeds that of any historic flood since, as noted above, the Village has not in its recorded history experienced a flood as severe as the 100-year recurrence interval event.

It is important to note that the lateral extent of the floodlands, as shown on Map 3, corresponds to year 2000 planned land use and floodland development conditions in the Pewaukee River subwatershed. As noted in Floodland Information Report for the Pewaukee River, a comparison of flood stages under existing and planned year 2000 land use conditions within the Village of Pewaukee indicated no significant increases associated with the planned land use relative to existing conditions. The relative insensitivity of flood discharges, stages, and areas of inundation in and near Pewaukee to planned incremental urban development is due to the fact that the subwatershed is proposed to continue to remain primarily rural in character. Whereas about 20 percent of the subwatershed is currently devoted to urban land use, a total of about 33 percent is proposed to be devoted to such use under the year 2000 regional land use plan. The relative insensitivity of flood discharges, stages, and areas of inundation to planned urban development also results from the fact that the year 2000 regional land use plan assumes that floodlands not in or committed to urban uses will be preserved as essentially natural, open space partly for the purpose of retaining the floodwater conveyance and storage function of such areas.

Analyses conducted for the present report indicate that approximately 0.15 square mile, or 35 percent of the 0.43 square mile of floodplain along the Pewaukee River, Pewaukee Lake Outlet, and Pewaukee Lake area, as shown on Map 3, are in various urban uses incompatible with the flood-prone nature of these lands. These existing or committed uses include low- and medium-density residential development and commercial and industrial uses. The large areal extent of flood-prone land within the Village of Pewaukee and the extensive amount of existing urban development within those flood-prone areas is of concern to the Village in terms of its present and the future development and was the primary purpose for undertaking the floodland management planning study.

PERSONAL INTERVIEW SURVEY

Research of historic flood events in and near the Village of Pewaukee was conducted for two major reasons. First, inasmuch as flood flows, stages, and areas of inundation to be used in the plan preparation were to be developed by mathematical simulation modeling techniques, sound engineering practice required calibration of the model through careful comparisons between the model results and reliable observations of the actual hydrologic-hydraulic behavior of the stream system. Such comparisons permit adjustments to and refinements in the modeling and thereby result in a more accurate representation of watershed hydrology and hydraulics. Second, experience indicates that public memory of, and concern over, flood problems tends to diminish rapidly with the passage of time after a major flood event.

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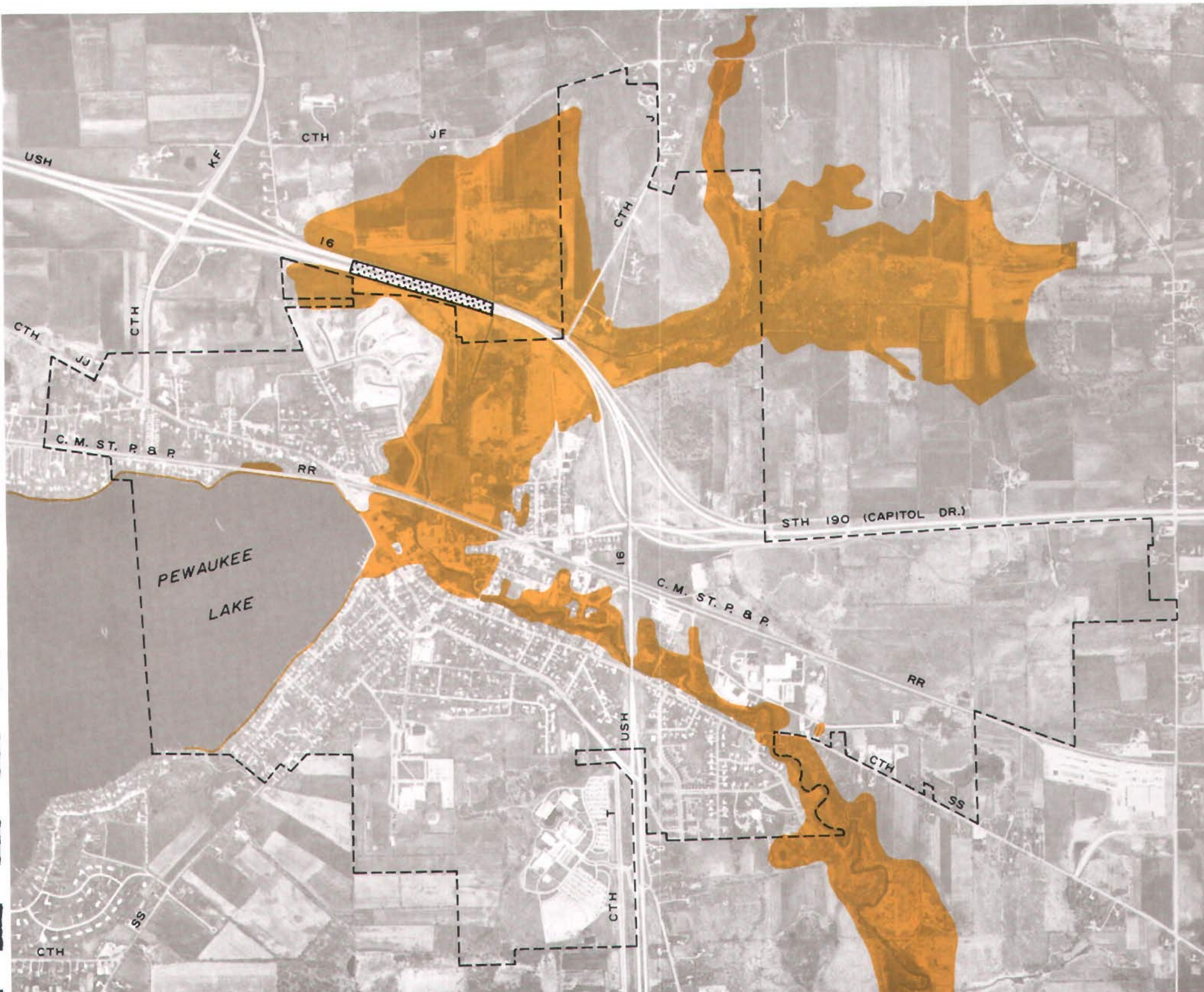
[1] *For example, the probability that a 100-year recurrence interval flood discharge will be reached or exceeded during the first year following the occurrence of such a flood is 1 percent, whereas the probability that a 100-year recurrence interval flood discharge will be reached or exceeded one or more times during the first 5, 10, 25, 50, and 100 years following the occurrence of such a flood is 5, 10, 22, 39, and 63 percent, respectively.*

Map 3

100-YEAR RECURRENCE INTERVAL FLOODLANDS IN THE VILLAGE OF PEWAUKEE: YEAR 2000 LAND USE PLAN

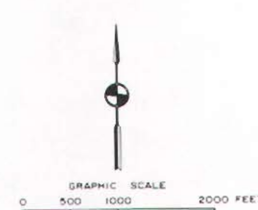


LEGEND

VILLAGE OF PEWAUKEE CORPORATE LIMITS

100-YEAR RECURRENCE INTERVAL FLOODLANDS UNDER 2000 PLAN LAND USE AND EXISTING CHANNEL CONDITIONS

AREA WHERE TOPOGRAPHY HAS BEEN ALTERED SINCE DATE OF MAPPING



Source: SEWRPC.

Documented and historic flood information is an effective way to bring the seriousness of flood problems into proper focus and perspective and provides the common basis for understanding the nature of the problem in a particular locality, thus promoting implementation of recommended flood control measures.

The Need for a Survey

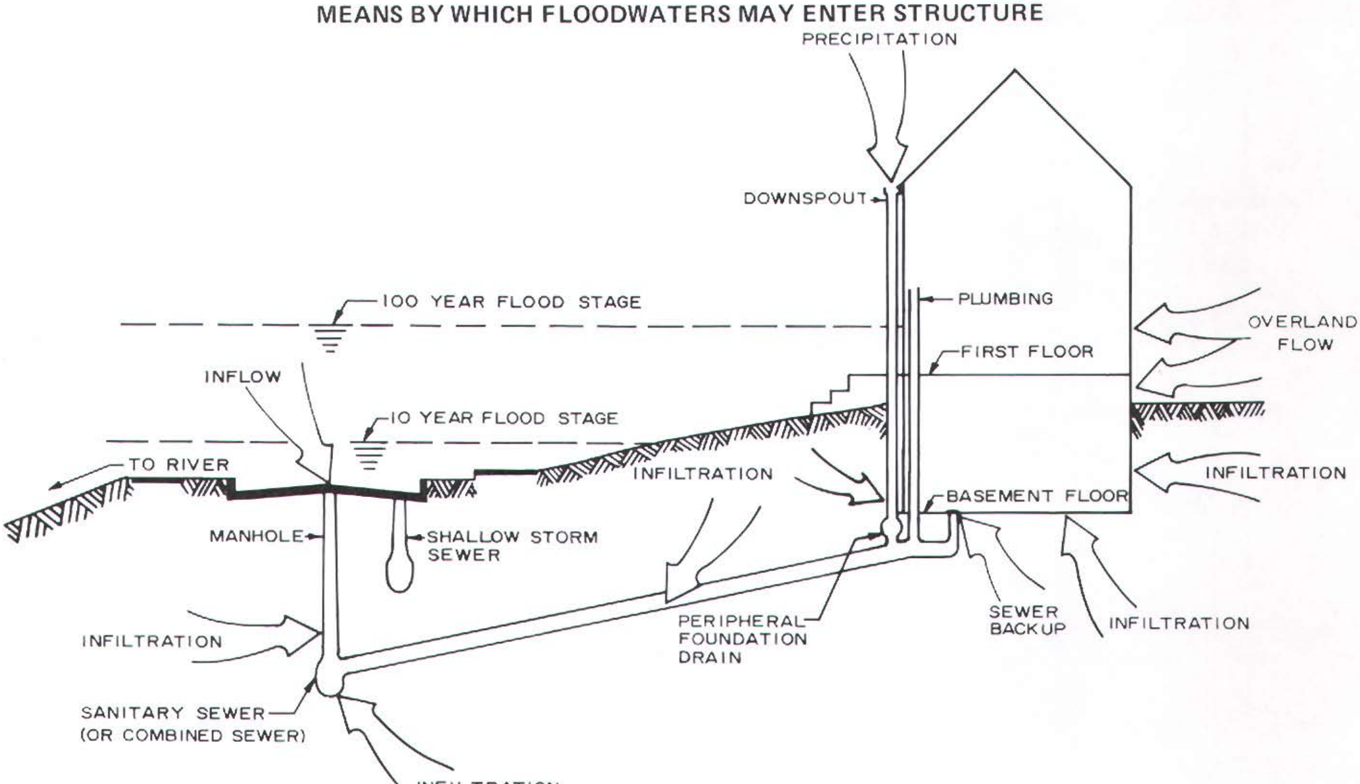
While research into the characteristics of historic flood events, as discussed above, is sufficient for a study, such as Floodland Information Report for the Pewaukee River which culminated in the delineation of flood hazard areas, additional data and information on historic floods are needed to successfully complete a floodland management planning study such as this. Accordingly, earlier Commission investigations of historic flood characteristics were supplemented with a personal interview survey carried out by the Commission staff during the period of January to February 1977. Interviews were conducted with a sampling of the Village of Pewaukee residents along the Pewaukee River, the Pewaukee Lake Outlet, and Pewaukee Lake, with residents of the Town of Pewaukee along the Pewaukee River and Pewaukee Lake, and with residents of the Town of Delafield around Pewaukee Lake.

The collection, collation, and analysis of historic flood information based primarily on a personal interview survey is an important element in any study of floodland management alternatives. More specifically, the personal interview survey was conducted for four reasons:

The first reason was that, while the location and extent of some flood-prone areas within the Pewaukee River subwatershed were known at the outset of the floodland management planning study, the location and extent of all such areas within and near the Village were not known. One important use of the personal interview survey, therefore, was to assist in the identification of all areas within the Village that not only are subject to flooding but that result in flooding either causing or potentially causing significant monetary flood damages.

Figure 1

MEANS BY WHICH FLOODWATERS MAY ENTER STRUCTURE



NOTE: TYPICAL AND GENERALLY PREFERABLE VARIATIONS INCLUDE DOWNSPOUTS DISCHARGING TO THE GROUND SURFACE AND FOUNDATION DRAINS CONNECTED TO STORM SEWERS OR CONNECTED TO A SUMP FROM WHICH WATER IS PUMPED TO THE GROUND SURFACE AT SOME POINT AWAY FROM THE STRUCTURE

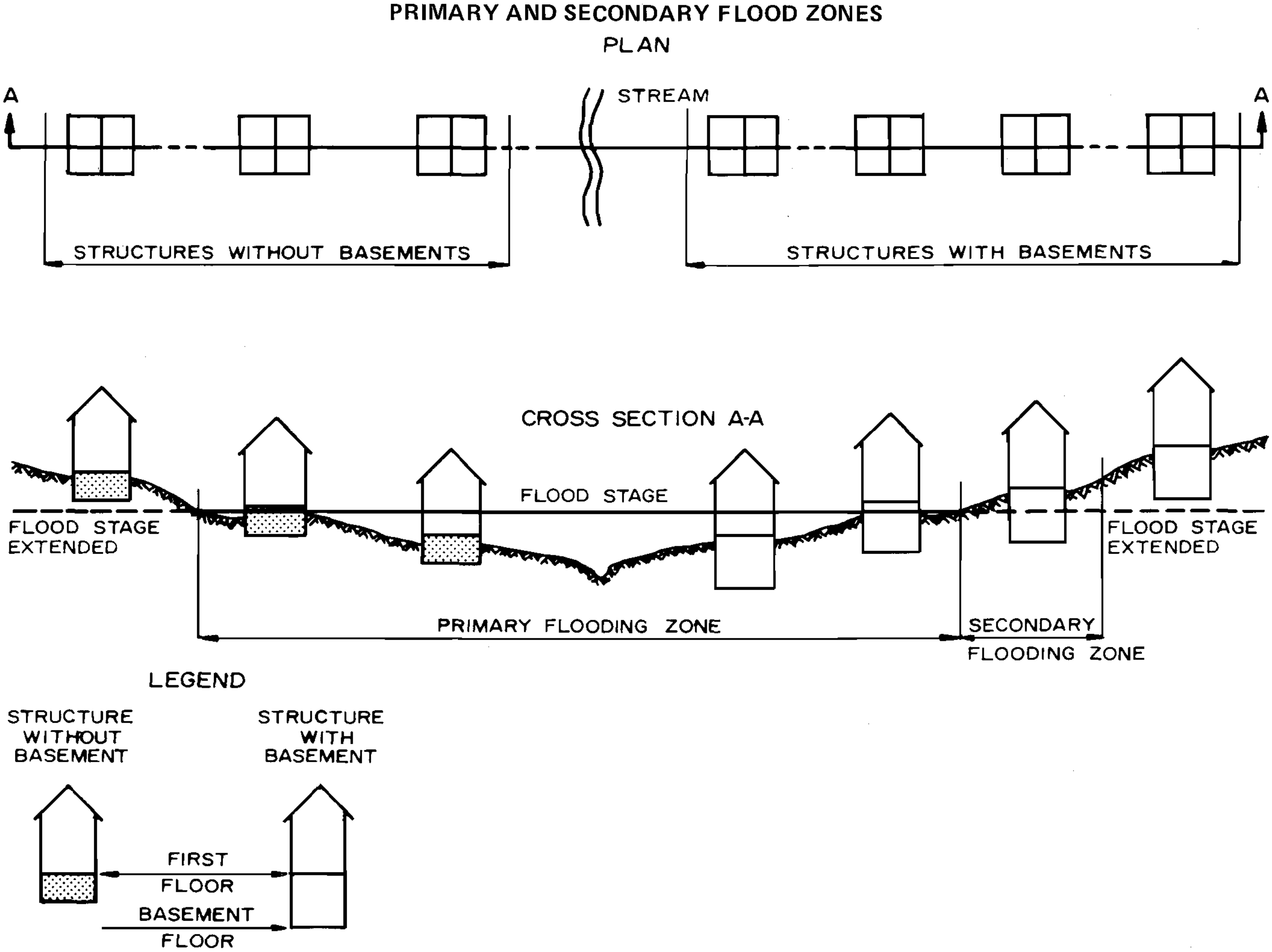
Source: SEWRPC.

Residential, commercial, and industrial structures are particularly vulnerable to flood damage partly because of the many ways in which floodwaters can enter such structures. As illustrated in Figure 1, an unprotected floodland structure is a virtual "sieve" for the entry of floodwaters. Rising flood waters may surcharge sanitary, storm, or combined sewers in urban areas, thereby reversing the flow in those sewers and forcing water into the structures through basement floor drains, plumbing fixtures, and other openings connected to the sewer system. As a result of saturated soil conditions around the structure foundation, water may enter through the cracks or structural openings in basement walls or floors. If overland flooding occurs—that is, flood stages rise above the elevation of the ground near a particular residential, commercial, or industrial structure—additional floodwaters may enter the basement of the structure through basement doors, windows, and structural openings. If flood stages rise high enough, floodwaters similarly may gain access to the first or main floor of the structure. In addition to the inundation damage to the structure and its contents, external hydrostatic pressures may cause the uplift and buckling of basement floors and the collapse of basement walls. Finally, floodwaters may exert hydrostatic or dynamic forces of sufficient magnitude to lift or otherwise move a structure from its foundation.

It should be noted that flood damage can occur to the basements of structures located outside of the geographic limits of the overland flooding when flood waters gain access to the basements via the hydraulic connections that are provided by the sanitary, storm, or combined sewer systems between the inundated area—the area of primary flooding—and the basements. Such flooding of basements outside of, but adjacent to, the area of primary flooding is defined here as secondary flooding. Primary and secondary flooding zones are illustrated in Figure 2.

Figure 2

PRIMARY AND SECONDARY FLOOD ZONES



Source: SEWRPC.

The second reason, therefore, for conducting the personal interview study was to ascertain the cause of flood problems or, more specifically, to determine how floodwaters enter or could enter structures in flood-prone areas along the Pewaukee River, the Pewaukee Lake Outlet, and Pewaukee Lake.

The third reason for conducting the personal interview survey was to provide information for computation of monetary flood risks. Monetary flood risks for flood events of specified recurrence intervals, as well as average annual risks under probable future land uses, must be determined for selected stream reaches in order to permit an economic evaluation of alternative flood control measures. The information required to compute monetary flood risks includes: data on the type of structures affected; the elevation of the ground at the structure and elevation of the first floor; the existence of a basement; and the market value of structure and land excluding structure contents. Some of the necessary data for representative structures were obtained as a part of the personal interview survey.

The fourth reason for conducting the personal interview survey was to provide information useful in the formulation of alternative flood control measures. To be technically feasible, the measures and combinations of measures formulated for flood control in each flood-prone reach must be directed at the primary cause of the flooding. For example, earth dikes and concrete floodwalls are technically feasible solutions in river reaches that historically have been subjected to overland flooding but, if used alone, are not effective in those riverine areas that incur extensive secondary flooding. Formulation of alternative flood control measures for a particular reach, therefore, is influenced by the nature and causes of the flood problems in that reach as determined largely by the personal interviews survey.

Survey Procedure

After reviewing data and information on the historic flood events as set forth in Floodland Information for the Pewaukee River, the Commission staff conducted field surveys during which personal interviews were completed with the owners or tenants of structures located within and near the floodplains of Pewaukee River, the Pewaukee Lake Outlet, and Pewaukee Lake in the Village of Pewaukee and in the Towns of Pewaukee and Delafield. Selected information from the interviews is set forth in Table 1, while the riverine areas included in the interview program are shown on Map 4.

The first step in conducting a survey is to identify the universe or total population about which

Table 1

SELECTED INFORMATION ON INTERVIEWS CONDUCTED TO OBTAIN HISTORIC FLOOD INFORMATION AND STRUCTURE DATA IN THE PEWAUKEE RIVER SUBWATERSHED

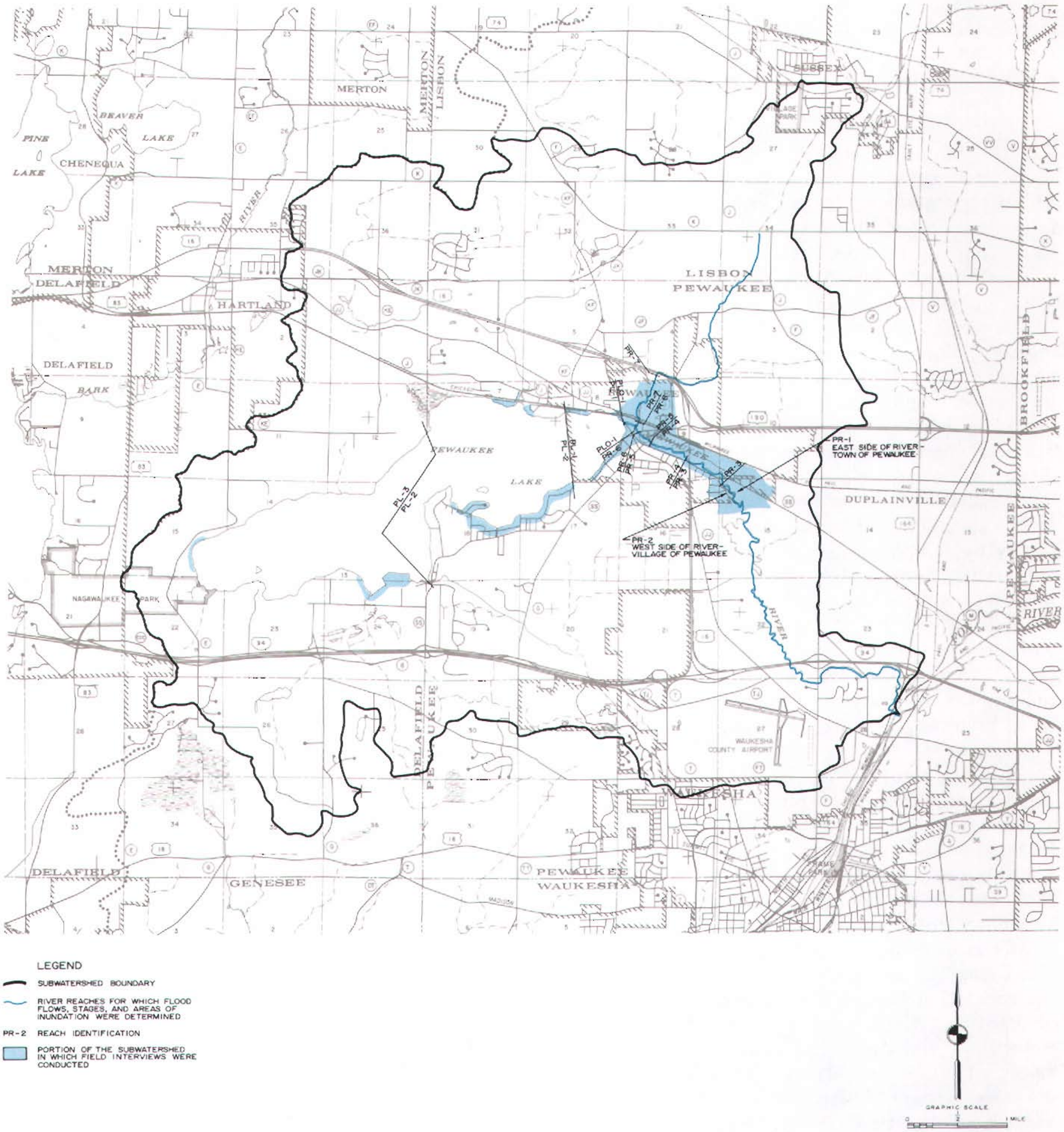
Reach Description			Total Number of Structures in Reach	Sample Size: Number of Structures for Which Personal Interviews[a] were Completed—By Structure Type												
Civil Division	Stream or Lake	Identification Number		Single-Family Residence	Two-Family Residence	Multi-Family Residence	Mobile Home	Residence Under Construction	Business Commercial	Manufacturing Industrial	School	Church	Other	Total	Interviews Attempted	Percent Completed
Village of Pewaukee	Pewaukee River	PR-2	34	10	--	--	--	--	1	--	--	--	1	12	34	35
		PR-3	39	7	--	--	--	--	3	3	--	--	1	14	38	37
		PR-4	60	8	5	5	--	--	8	2	--	--	1	29	56	52
		PR-5	42	7	1	1	--	--	9	--	--	--	--	18	42	43
		PR-6	22	6	1	--	--	--	7	--	--	--	--	14	21	67
		PR-7	90	14	--	4	--	--	5	1	--	--	--	24	67	36
	Pewaukee Lake Outlet	PLO-1	4	--	--	--	--	--	4	--	--	--	--	4	4	100
	Pewaukee Lake	PL-1	124	32	--	--	--	--	12	--	--	--	1	45	124	36
	Subtotal		415	84	7	10	--	--	49	6	--	--	4	160	386	41
Town of Pewaukee	Pewaukee River	PR-1	15	1	--	--	--	--	2	--	--	--	--	3	15	20
	Pewaukee Lake	PL-2	137	41	--	--	--	--	2	--	--	--	--	43	131	33
	Subtotal	--	152	42	--	--	--	--	4	--	--	--	--	46	146	32
Town of Delafield	Pewaukee Lake	PL-3	57	9	--	--	--	--	1	--	--	--	--	10	35	29
	Total	--	624	125	7	10	--	--	54	6	--	--	4	216	567	38

[a] *Interviews were conducted during January and February 1977.*

Source: SEWRPC.

Map 4

LOCATION OF FIELD INTERVIEWS CONDUCTED TO OBTAIN HISTORIC FLOOD INFORMATION AND STRUCTURE DATA IN THE PEWAUKEE RIVER SUBWATERSHED



Source: SEWRPC.

information is desired. In the case of the personal interview survey, the population consisted of riverine area structures located along those reaches of the watershed stream system (see Map 3) where the above research indicated that flooding or flood-related problems have occurred or could occur. Within each reach, the lateral extent of the riverine area included in the survey was selected to approximate that area subject to primary or secondary flood damage under a major flood event.

The second step in conducting a survey is to identify the sample—that is, the portion of the total population that has characteristics representative of that population. In the case of the personal interview survey, the interviews were conducted to be spatially representative of the target area and of the types of structures present in that area. Thus, interviews were carried out along the length of each reach and were not limited to structures located closest to the stream. Furthermore, personal interviews were completed with the owners or tenants of a variety of structure types including single- and multiple-family residences and business, commercial, and industrial buildings.

The Village of Pewaukee assisted the Planning Commission in conducting the personal interview survey by sending notices of the impending survey, along with water utility bills, to Village residents in the targeted areas. Also, prior to the survey, officials of the Pewaukee Lake Sanitary District were contacted to inform them of the intent of the survey and to obtain their permission to conduct the survey in those parts of the District involved, permission which the residents willingly gave.

Recent large-scale topographic mapping was not available for those portions of the Towns of Pewaukee and Delafield lying along Pewaukee Lake. In order to identify structures in these areas that should be sampled in the survey because basement floor and/or first floor elevations were located at or below the 100-year recurrence interval flood stage on Pewaukee Lake, data provided by the consulting firm of John A. Strand & Associates of Madison, Wisconsin were used. Strand & Associates had obtained, by field survey methods, basement floor elevations for use in sanitary sewerage system design for the Pewaukee Lake Sanitary District. With the cooperation of the Pewaukee Lake Sanitary District and of Strand and Associates, these data were made available to the Regional Planning Commission.

A total of 216 interviews were completed with the owners or tenants of a wide variety of structure types including single- and multiple-family residences, business and commercial enterprises, and manufacturing and industrial facilities. Of the 216 completed interviews, 160 were conducted within the Village of Pewaukee, 46 in the Town of Pewaukee, and 10 in the Town of Delafield.

The form used to interview the owner or tenant of a structure is reproduced as Figure 3. As indicated by the sample form, the interviews were intended to provide information about the structure occupied by the owner or tenant as well as information about historic flood events that either affected the structure or the land used in conjunction with the structure.

Survey Findings

Results of the personal interview survey related to the historic and existing flood problems are summarized by reach in Table 2. For each reach, Table 2 indicates the total number of structures for which interviews were completed, the number of structures at which flood and flood-related problems have been observed one or more times, and the nature of those problems. The principal findings of the personal interview survey on historic and existing flood problems and probable future problems are as follows:

1. Flooding of basements or crawl spaces as the result of seepage through walls or floors was the most serious problem reported, with the owners or tenants of 66, or 31 percent, of the 216 structures surveyed reporting having experienced this type of problem one or more times.

2. Sanitary sewer backup into a basement or crawl space was reported for six structures, or about 3 percent of the 216 structures surveyed. Overland flooding onto the building site was reported for five structures, or about 2 percent of the 216 structures surveyed.

3. No incidence of first floor flooding or overland flooding leading to floodwater flow into a structure was reported by the 216 owners or tenants interviewed. Therefore all reported historic flooding was secondary, as opposed to primary, flooding.

4. Of the 160 structures surveyed within the Village of Pewaukee, 47, or 29 per-

Figure 3

FORM USED TO INTERVIEW OWNER OR TENANT OF A STRUCTURE WITH POTENTIAL FLOOD PROBLEMS

FIELD SURVEY
of
STRUCTURE DATA AND FLOOD INFORMATION
for the
PEWAUKEE FLOODLAND MANAGEMENT STUDY

INTERVIEWER: ______________________ DATE: __________

(Take the following items into the field: topographic maps, low flight aerial photographs, folding rule, camera, hand level.)

STRUCTURE IDENTIFICATION:

1. Civil Division Name: __________ 2. Civil Division No. ______ 3. Structure Ident. No.: ______

4. Address: ______________________

5. Type: Indicate one of the following:

1 single family residence
10 two family residence
20 multi-family residence
30 mobile home
40 residence under construction
100 business-commercial
200 manufacturing-industrial
300 school
400 church
500 other public __________
600 other private __________
700 other __________

6. Comments, Condition, etc: ______________________

INTERVIEWEE:

1. Name(s): ______________________

2. No answer: __________ 3. Refused to Cooperate: __________

4. How long have you lived here? ______________________

5. Comments: ______________________

STRUCTURE DATA:

1. Basement: Yes ____ No ____ If yes, is it used as living quarters? __________

2. Vertical distance from yard grade to main entrance of structure to first liveable floor: __________

3. Estimated market value of structure and land excluding structure contents: $ __________

4. Floodproofing measures available or in effect: ______ *sump pump*
______ drain tile
______ glass block windows
______ other (describe below)

5. Comments: ______________________

STRUCTURE IDENTIFICATION:

1. Civil Division Name: __________ 2. Civil Division No. ______ 3. Structure Ident. No. ______

FLOOD INFORMATION:

1. Event

a. Date: ______________________

b. Water in basement?: Yes ____ No ____ Depth ____ c. Water on first floor? Yes ____ No ____ Depth ____

d. Means by which water entered structure: Indicate one or more of the following:

1 sanitary sewer back-up through floor drain, sink, etc.
2 cracks or other openings (other than floor drain or sump reservoir) in basement floor.
3 cracks or other openings (other than windows) in basement wall.
4 back-up through sump reservoir.
5 overland flow through basement windows.
6 overland flow through doorways.
7 overland flow through first floor windows.
8 other __________

e. Floodproofing or protection measures used: __________

f. Peak stage relative to structure or other nearby reference point: __________

g. Type(s) of damage sustained including cost(s) if known: __________

h. Planimetric extent of surface inundation near structure: Shown on aerial photograph __________

i. Personal records or photos of flooding available? __________

j. Comments: __________

2. Event

a. Date: ______________________

b. Water in basement?: Yes ____ No ____ Depth ____ c. Water on first floor?: Yes ____ No ____ Depth ____

d. Means by which water entered structure: Indicate one or more of the following:

1 sanitary sewer back-up through floor drain, sink, etc.
2 cracks or other openings (other than floor drain or sump reservoir) in basement floor.
3 cracks or other openings (other than windows) in basement wall.
4 *back-up through sump reservoir.*
5 overland flow through basement windows.
6 overland flow through doorways.
7 overland flow through first floor windows.
8 other __________

e. Floodproofing or protection measures used: __________

f. Peak-stage relative to structure or other nearby reference point: __________

g. Type(s) of damage sustained including cost(s) if known: __________

h. Plainimetric extent of surface inundation near structure: Shown on aerial photograph __________

i. Personal records or photos of flooding available? __________

j. Comments __________

Source: SEWRPC.

Table 2

SELECTED RESULTS OF PERSONAL INTERVIEW SURVEY

Reach Description			Number of Structures in Reach[a]	Sample Size: Number of Structures for Which Personal Interviews Were Completed				Structures Having Sump Pumps		Structures for Which Flood Problems Were Reported		Types of Flood Problems and Number of Structures Affected One or More Times: Overland Flooding							Comments
Civil Division	Stream or Lake	Identification Number		With Basements	With Crawl Space	Without Either	Total	Number	Percent of Sample	Number	Percent of Sample	Property	On Property and into Structure	First Floor Flooding	Sanitary Sewer Backup into Basement or Crawl Space	Seepage Through Walls or Floor into Basement or Crawl Space	Other	Total[b]	
Village of Pewaukee	Pewaukee River	PR-2	34	11	--	1	12	10	83	2	17	0	0	0	0	2	--	2	--
		PR-3	39	11	--	3	14	5	36	3	21	0	0	0	1	2	--	3	--
		PR-4	60	20	--	9	29	15	52	7	24	0	0	0	1	6	--	7	--
		PR-5	42	14	3	1	18	6	33	10	56	1	0	0	1	8	--	10	--
		PR-6	22	12	--	2	14	3	21	4	29	1	0	0	0	3	--	4	--
		PR-7	90	21	--	3	24	2	8	8	33	0	0	0	1	7	--	8	--
	Pewaukee Lake Outlet	PLO-1	4	3	--	1	4	1	25	0	0	0	0	0	0	0	--	0	--
	Pewaukee Lake	PL-1	124	33	4	8	45	12	27	13	29	0	0	0	2	11	--	13	A number of sump pumps in this reach were inoperative due to the electric power outage which occurred during the March 1976 ice storm
	Subtotal	--	415	125	7	28	160	54	34	47	29	2	0	0	6	39	--	47	--
Town of Pewaukee	Pewaukee River	PR-1	15	2	--	1	3	1	33	0	0	0	0	0	0	0	--	0	--
	Pewaukee Lake	PL-2	137	35	3	5	43	31	72	27	63	3	0	0	0	24	--	27	A number of sump pumps in this reach were inoperative due to the electric power outage which occurred during the March 1976 ice storm
	Subtotal	--	152	37	3	6	46	32	70	27	59	3	0	0	0	24	--	27	--
Town of Delafield	Pewaukee Lake	PL-3	57	3	2	5	10	4	40	3	30	0	0	0	0	3	--	3	A number of sump pumps in this reach were inoperative due to the electric power outage which occurred during the March 1976 ice storm
	Total	--	624	165	12	39	216	90	42	77	36	5	0	0	6	66	0	77	--

[a] *Major structures within the area defined by the 100-year recurrence interval event plus 10 feet—approximate area in which basements are at or below the 100-year flood stage and, therefore, may be subject to flooding.*

[b] *May exceed sample size since some structures have experienced more than one type of flood problem.*

Source: SEWRPC.

cent, reported experiencing one or more flood problems. In the Town of Pewaukee, 23 structures, or 59 percent of the 43 structures surveyed, reported flood problems whereas in the Town of Delafield three structures, or 30 percent of the 10 structures surveyed, reported flood problems. Overall, about one out of three surveyed structures reported one or more instances of flooding.

5. Areas which have experienced significant flood or flood-related problems in the Village include the 0.3-mile reach of the Pewaukee River extending from Clark Street to the Chicago, Milwaukee, St. Paul and Pacific Railroad and the perimeter of Pewaukee Lake. Pewaukee Lake residents in the Towns of Pewaukee and Delafield also reported numerous flood problems.

6. Sump pumps appear to be effective in preventing basement damage to structures along Pewaukee Lake. A number of persons participating in the interviews reported up to several feet of water in the basements of their structures in March 1976 when sump pumps were inoperable as the result of an electric power service failure.

7. Pewaukee Lake residents expressed mixed concern about the present Pewaukee Lake level control with some residents indicating a desire to increase lake levels for aesthetic and recreational purposes and other residents, especially those experiencing flood problems, wanting a lower lake level particularly in the spring.[2]

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[2] *The Pewaukee Lake Outlet control structure is equipped with a sluice gate that facilitates drawing down the level of Pewaukee Lake a distance of about 1.5 feet below the dam crest. Based on Wisconsin Department of Natural Resources operating regulations, this dam is to be operated so as to maintain the level of Pewaukee Lake at an elevation of 852.8 feet above National Geodetic Vertical Datum during the period May 15 through October 1. During the October 1 to October 15 period, the Lake is to be drawn down to an elevation of 852.2 feet above National Geodetic Vertical Datum, and is to be maintained at that level for the period from October 15 through May 1. During the period from May 1 to May 15, the Lake is to be gradually raised back to elevation 852.8 feet. Therefore, the Lake level is to be maintained within a very narrow range of only 0.6 feet.*

MONETARY FLOOD RISKS FOR SELECTED REACHES

Sound economic analysis of alternative floodland management measures requires that the flood damage susceptibility of the flood-prone area be expressed in dollars for comparison to the costs of alternative floodland management measures. The average annual flood damage risks expressed in dollars for year 2000 plan land use conditions was selected as the uniform, quantitative means of expressing flood damages for the purpose of the Village of Pewaukee Floodland Management Planning Study. The average annual flood risks were computed for selective reaches to provide a monetary value that could be used, wholly or in part, as an annual benefit for comparison to the annual costs of technically feasible alternative floodland management plan elements.

Direct and Indirect Flood Losses

Direct flood losses or risks are defined as monetary expenditures required, or which would be required, to restore flood-damaged property to its preflood condition. This includes the cost of cleaning, repairing, and replacing residential, commercial, industrial, and agricultural buildings and contents and other objects and materials located outside the buildings on the property. Direct losses and risks also encompass the cost of cleaning, repairing, and replacing roads and bridges, storm water systems, sanitary sewer systems, and other utilities, as well as the cost of restoring damaged park and recreational lands. For the purposes of this planning study, direct losses were conservatively estimated as consisting only of monetary damages to buildings and their contents.

Indirect flood losses and risks are defined as the net monetary cost of evacuation, relocation, lost wages, lost production, and lost sales; increased cost of highway and railroad transportation because of flood-caused detours; and the cost of flood fighting and emergency services provided by governmental units. The cost of postflood engineering and planning studies are also sometimes categorized as indirect losses and risks. Although often difficult to determine with precision, indirect losses and risks nevertheless constitute a real monetary burden on the economy of the community. For purposes of economic analyses conducted under this planning study and as explained below, indirect costs were estimated as a percent of direct damages incurred by structures and their contents. For each floodland management measure, indirect damages were assumed to be reduced in proportion to the reduction in direct damages.

Reach Selection

A two-step procedure was used to select those reaches for which monetary flood risks were to be determined in the Village of Pewaukee along the Pewaukee River, the Pewaukee Lake Outlet, and Pewaukee Lake; in the Town of Pewaukee along the Pewaukee River and Pewaukee Lake; and in the Town of Delafield along Pewaukee Lake. The first step involved examination of the results of the historic flood research and personal interview surveys to identify those reaches that have actually experienced flood problems as the result of direct damage to riverine area structures from primary flooding, secondary flooding, or a combination of the two. This resulted in identification of reaches located primarily within the area developed for commercial use along the Pewaukee River and Pewaukee Lake Outlet and along the perimeter of Pewaukee Lake.

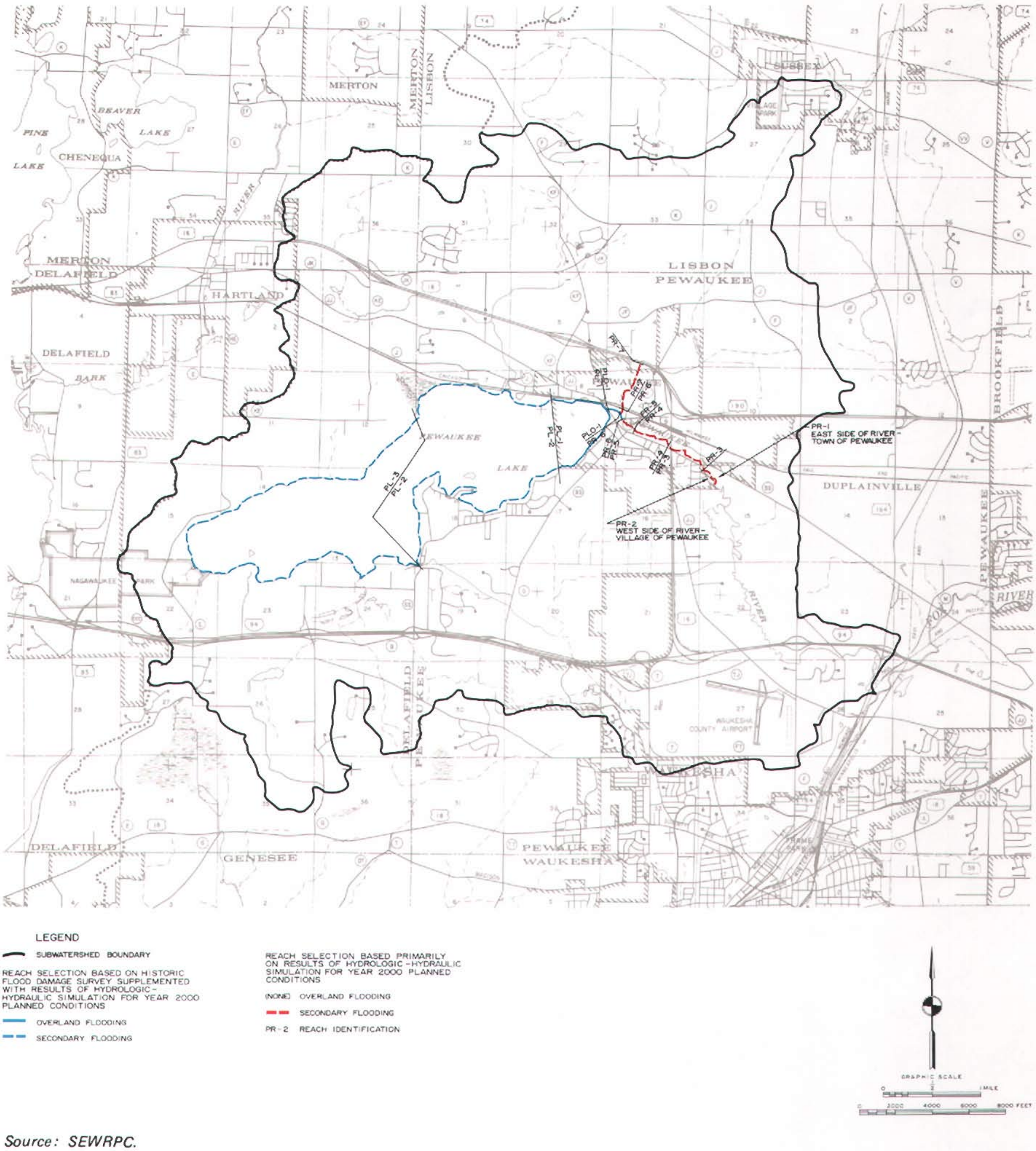
The second step in identifying reaches for which monetary flood risks were to be determined involved examination of results of the hydrologic-hydraulic modeling for year 2000 plan land use conditions as shown on Map 3. This led to the identification of additional reaches in which a 100-year recurrence interval flood could be expected to cause primary or secondary flooding of relatively large numbers of riverine area structures.

The 11 reaches identified by the above two-step procedure are shown on Map 5 and consist of six reaches along the Pewaukee River within the Village of Pewaukee; one reach along the Pewaukee Lake Outlet within the Village of Pewaukee; one reach along Pewaukee Lake within the Village of Pewaukee; one reach along Pewaukee Lake and one reach along the Pewaukee River within the Town of Pewaukee; and one reach along Pewaukee Lake within the Town of Delafield.

Map 5 also indicates those reaches in which secondary flooding is the principal cause of flood problems as compared to those reaches in which flood damages are attributable to both primary and secondary flooding. Additional information about the selected flood-prone reaches, including a description of the upstream and downstream end of each reach and the length of each reach, is set forth in Table 3. The selected reaches include 2.34 miles of the Pewaukee River, the 0.1-mile-long Pewaukee Lake Outlet, and Pewaukee Lake. It is

Map 5

REACHES SELECTED FOR COMPUTATION OF AVERAGE ANNUAL FLOOD DAMAGE RISK IN THE PEWAUKEE RIVER SUBWATERSHED



Source: SEWRPC.

Table 3

REACHES SELECTED FOR COMPUTATION OF AVERAGE ANNUAL FLOOD RISK IN THE PEWAUKEE RIVER SUBWATERSHED

Civil Division	Stream or Lake	Identification Number	Reach Description: Upstream End: State, Highway, or Other Location	Upstream End: River Station[a]	Downstream End: State, Highway, or Other Location	Downstream End: River Station[a]	Length (miles)
Village of Pewaukee	Pewaukee River	PR-2	CTH SS	354600	Village of Pewaukee Corporate Limits	351570	0.57
		PR-3	500 Feet Upstream of USH 16	357600	CTH SS	354600	0.57
		PR-4	Clark Street	359700	500 Feet Upstream of USH 16	357600	0.4
		PR-5	Oakton Avenue	360500	Clark Street	359700	0.15
		PR-6	Chicago, Milwaukee, St. Paul and Pacific Railroad	361300	Oakton Avenue	360500	0.15
		PR-7	390 Feet Downstream of USH 16	363950	Chicago, Milwaukee, St. Paul and Pacific Railroad	361300	0.50
	Pewaukee Lake Outlet	PLO-1	160 Feet Downstream of CTH JJ	--	Pewaukee River-Pewaukee Lake Outlet Confluence	360900	0.1
	Pewaukee Lake	PL-1	Village of Pewaukee Corporate Limits	--	160 Feet Downstream of CTH JJ	--	--
Town of Pewaukee	Pewaukee River	PR-1	CTH SS	354600	Parallel to Village of Pewaukee Corporate Limits	351570	0.57
	Pewaukee Lake	PL-2	Town of Delafield Limits	--	Village of Pewaukee Corporate Limits	--	--
Town of Delafield	Pewaukee Lake	PL-3	Western Shoreline of Pewaukee Lake	--	Town of Pewaukee Limits	--	--

[a] *Stationing in feet along the stream system referenced to the Wilmot Dam on the main stem of the Fox River in Kenosha County.*

Source: SEWRPC.

important to note that the selected reaches exclude areas within and near the Village of Pewaukee that may exhibit storm water drainage deficiencies since, as noted above, this report is directed to the resolution of flooding as opposed to storm water inundation problems.

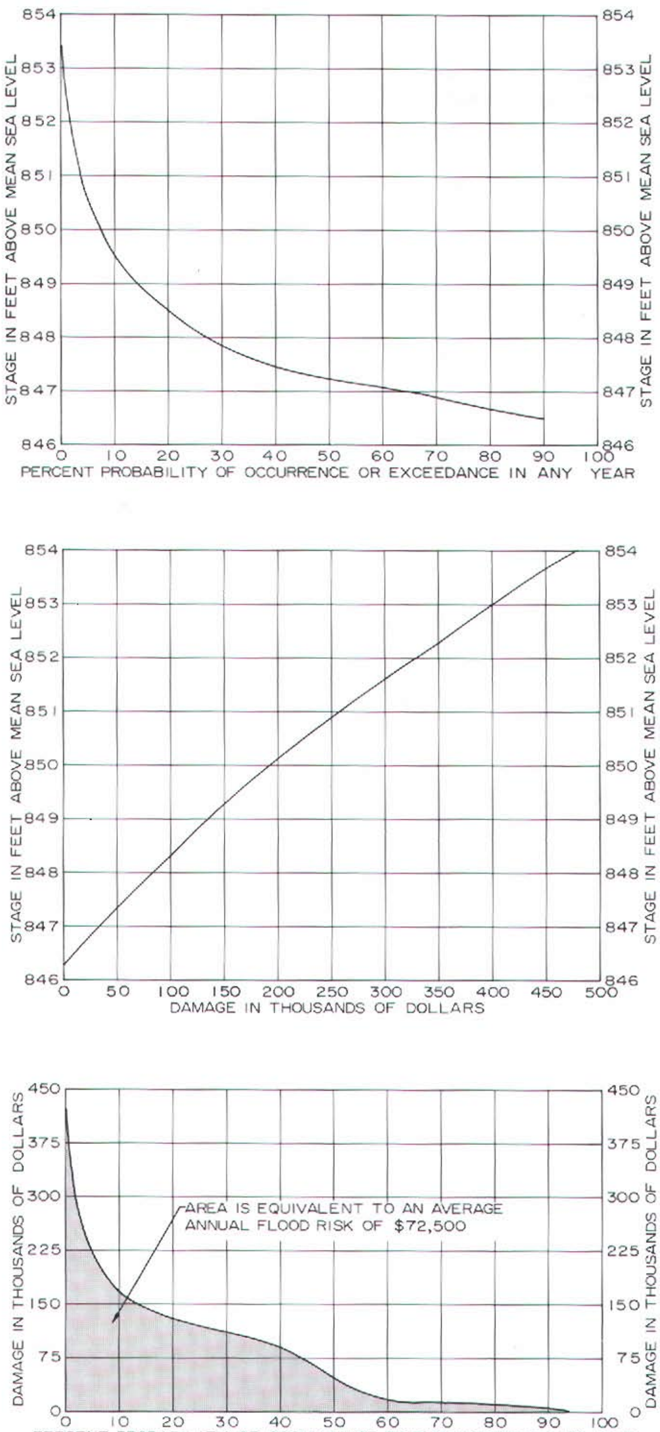
Methodology Used to Determine Average Annual Flood Risk

The average annual flood damage risk for a reach is defined as the sum of the direct and indirect monetary flood losses resulting from floods of all probabilities, each weighed by its probability of occurrence or exceedance in any year. If a damage-probability curve is constructed, such as the graph of dollar damage versus flood probability illustrated in Figure 4, the average annual risk is represented by the area beneath the curve. The damage-probability curve for each flood-prone reach is developed by combining the reach stage-probability relationship with the reach stage-damage curve as illustrated in Figure 4. The determination of average annual flood risk for a particular flood-prone reach depends, therefore, upon construction of the stage-probability and stage-damage relationships for the reach.

Synthesis of Reach Stage-Probability Relationships: The stage-probability relationship for a particular reach is determined by the hydraulic characteristics

Figure 4

EXAMPLE OF CURVES USED TO DETERMINE AVERAGE ANNUAL FLOOD RISK FOR A RIVER REACH



NOTE: EXAMPLE PERTAINS TO FLOOD DAMAGE FOR THE PEWAUKEE RIVER REACH (PR-6) BETWEEN OAKTON AVENUE AT STATION 3605.00 AND THE CHICAGO, MILWAUKEE, ST. PAUL, AND PACIFIC RAILROAD BRIDGE AT STATION 3616.00 IN THE VILLAGE OF PEWAUKEE

Source: SEWRPC.

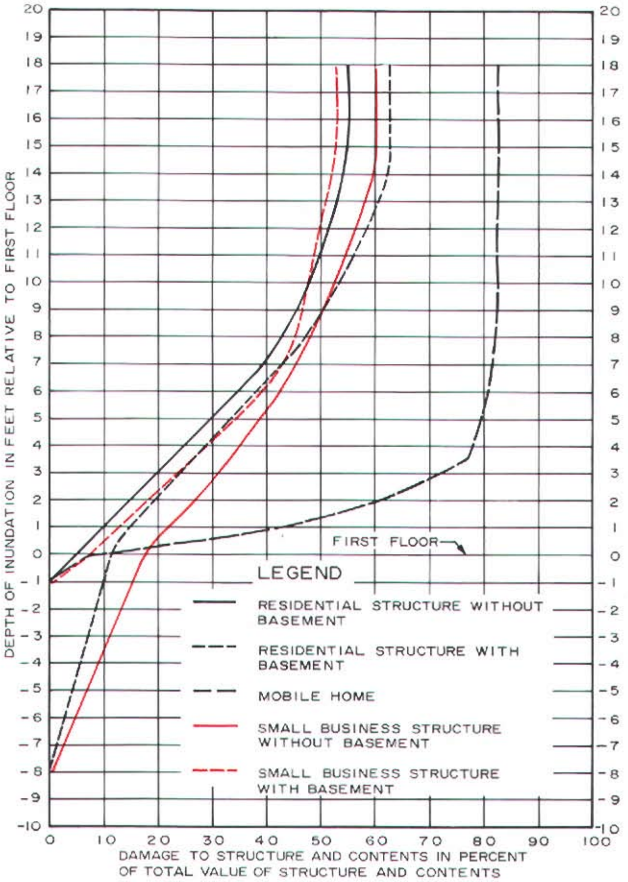
of the reach, such as the shape of the floodland cross sections; the resistance to flood flows as determined by the character of the floodlands and the presence of bridges, culverts, and other structures—all of which are influenced by the activities of man; and the magnitude of flood flows expected in the reach. These flood flows are in turn a function of upstream hydraulics and hydrology which are also, because of man's activities, continuously undergoing change or having the potential to do so. It follows, therefore, that each reach does not have a unique stage-probability curve but instead there are many possible stage-probability curves, each of which is associated with a given combination of hydrologic-hydraulic conditions in and upstream of the reach in question. Figure 4 shows an example of a stage-probability curve for a reach of the Pewaukee River.

Synthesis of Reach Stage-Damage Relationships: The stage-damage curve for a reach is determined by the nature and extent of flood-prone structures and other property contained within the reach. It follows, therefore, that there is a separate stage-damage curve for each possible combination of riverine area land uses. Development of the stage-damage relationship for a particular combination of riverine area land uses in a reach begins with computation of the flood losses that may be expected for an arbitrarily selected flood stage slightly above the elevation of the river channel. These flood losses consist of estimates of the direct and indirect monetary flood losses. Upon completion of the summation of flood losses at the initial flood stage, a higher stage is considered. This process is repeated so as to consider the full spectrum of flood stages from just above the river bank up to the 500-year recurrence interval flow stage. Figure 4 presents an example of a synthesized stage-damage curve for a reach of the Pewaukee River.

Synthesis of a reach stage-damage relationship requires the use of stage-damage relationships for the various types of structures, facilities, and activities likely to be present in or to occur in floodlands. A stage-damage relationship for a particular type of structure is a graph of depth of inundation in feet relative to the first floor versus dollar damage to structure and contents expressed as a percent of the total dollar value of the structure and its contents. The stage-damage relationships for five types of structures are shown in Figure 5. These stage-damage relationships were developed by the Commission staff using Federal Insurance Adminis-

Figure 5

DEPTH-DAMAGE CURVES FOR SELECTED STRUCTURES



Source: Federal Insurance Administration and SEWRPC.

tration tables as published in 1970 and revised in 1974 and 1975.

Determination of Indirect Damage: Stage-damage relationships reflect the direct damage to each of the various types of structures as the function of the depth of inundation. Indirect damage, which can be a significant fraction of the total monetary losses incurred during a flood event, was computed as a percentage of the direct damage to the various types of structures. The direct damage to commercial and industrial structures was increased by 40 percent to account for indirect damage whereas the direct damage to residential and all other types of structures was increased by 15 percent to reflect indirect damage.[3]

[3] *R. W. Kates, "Industrial Flood Losses: Damage Estimation in the Lehigh Valley" the University of Chicago, Department of Geography, Research Paper No. 98, 1965, pp. 15-17.*

Flood Economics Submodel: The above methodology was used to compute event and average annual flood risks for selected reaches under existing and hypothetical flood control conditions. The voluminous computations were carried out with the Flood Economics Submodel which is a digital computer program developed by the Commission staff and operated in sequence with the Hydrologic Submodel, Hydraulic Submodel 1, and Hydraulic Submodel 2. The function and use of the latter three submodels are described in Floodland Information Report for the Pewaukee River. Figure 6 graphically illustrates the overall structure of the model package used in this floodland management planning study; identifies the four submodels or computer programs within the model that perform the calculations; shows relationships between the submodels; indicates the input and output of each submodel; and indicates the use of the simulation model results.

The Flood Economics Submodel fulfills two functions in a total flood simulation modeling effort. The first function is to calculate average annual monetary flood risks for urban riverine areas under a variety of developmental conditions which can then be used in benefit-cost analyses of floodland management alternatives. The second function of the Flood Economics Submodel is to calculate the costs of alternative flood control and floodland management measures, including the costs of floodproofing and removal of flood-prone structures, the cost of alternative configurations of earthen dikes and concrete floodwalls, and the cost of major channel modifications. Capital costs as well as operation and maintenance costs are calculated by the submodel and the total cost is summarized on both the present worth and average annual basis.[4]

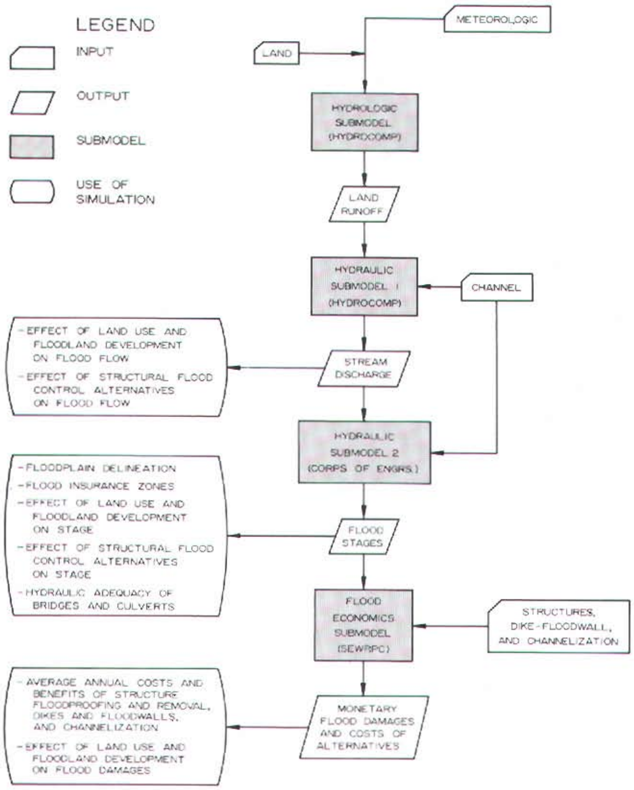
Results: Monetary Flood Risk

The Economic Submodel was used to calculate the sum of the direct and indirect monetary flood risk for each of the 11 selected flood-prone reaches—seven along the Pewaukee River, one along the Pewaukee Lake Outlet, and three along Pewaukee

[4] *For additional description of the Flood Economics Submodel, refer to SEWRPC Planning Report No. 26, A Comprehensive Plan for the Menomonee River Watershed, Volume One, "Inventory Findings and Forecasts," Chapter VIII, "Water Resource Simulation Model," pp. 323-339, October 1976, and SEWRPC Planning Report No. 32, A Comprehensive Plan for the Kinnickinnic River Watershed, 1978.*

Figure 6

HYDROLOGIC-HYDRAULIC-
FLOOD ECONOMICS MODEL



Source: SEWRPC.

Lake. The risk computations were carried out for year 2000 plan land use and floodland conditions in the Pewaukee River subwatershed. The plan envisions about one-third of the tributary watershed to be in urban land use and two-thirds in rural use. The calculations assume that floodlands not yet occupied by or committed to urban uses will be retained in a natural or seminatural condition and retained for recreation, agriculture, and other open space uses. The monetary flood risk calculations also assume that no additional flood-prone development will be constructed in floodlands. If additional floodland development is constructed in the floodland fringes—as could be permitted in those riverine areas already in or committed to urban development—it is assumed that the structures involved would be floodproofed or otherwise protected against flood damage. Thus, the computed monetary flood risks for any given reach are quite conservative, since the computations assume very strict control over the form, if not the location, of additional urban development in the flood-prone areas.

The results of the monetary flood risk analysis for the 11 selected flood-prone reaches are set forth in Table 4. The table presents the average annual flood damage risk for each reach as well as the flood damage risks associated with the 10- and 100-year recurrence interval flood stages. While the average annual flood damage risk was determined for use in the economic analyses of alternative floodland management measures, the flood damage risk associated with the 10- and 100-year recurrence interval flood events is presented to show the monetary losses that can be expected to accompany a given major flood event in and near the Village. Average annual and 10- and 100-year recurrence interval flood damage risks are depicted in graphic form on Map 6.

As set forth in Table 4, average annual flood risks along the Pewaukee River, Pewaukee Lake Outlet, and Pewaukee Lake in the Village of Pewaukee for year 2000 plan land use and floodland development conditions are estimated at $132,500, $2,900, and $34,400, respectively, for a total of $169,800. If a 100-year recurrence interval flood were to occur simultaneously along the Pewaukee River, Pewaukee Lake Outlet, and Pewaukee Lake in the Village of Pewaukee, the total damages are estimated at $875,800.

Average annual flood risks along Pewaukee Lake in the Town of Pewaukee and the Town of Delafield for year 2000 plan land use and floodland development conditions are estimated at $23,700 and $13,900, respectively, for a total of $37,600. If a 100-year recurrence interval flood were to occur on Pewaukee Lake, the total damages in the Towns of Pewaukee and Delafield are estimated at $67,400.

Average annual flood risks along the Pewaukee River in the Town of Pewaukee immediately downstream of CTH SS for year 2000 plan land use and floodland development conditions are estimated at $500. If a 100-year recurrence interval flood were to occur along the Pewaukee River, the total damages in the Town of Pewaukee immediately downstream of CTH SS are estimated at $4,300.

Concluding Statement: Monetary Flood Risk

The above reach-by-reach analysis of average annual flood damage quantifies the monetary flood risks involved and provides the basis for subsequent economic analysis of alternative floodland management measures. It is important to note that

Table 4

MONETARY FLOOD RISK FOR SELECTED REACHES IN THE PEWAUKEE RIVER SUBWATERSHED

Reach Description			Monetary Flood Risks in $1000[a,b]		
Civil Division	Stream or Lake	Identification Number	10-Year Recurrence Interval	100-Year Recurrence Interval	Average Annual
Town of Pewaukee	Pewaukee River	PR-1	0.4	4.3	0.5
	Pewaukee Lake	PL-2	27.9	34.5	23.7
	Subtotal		28.3	38.8	24.2
Village of Pewaukee	Pewaukee River	PR-2	2.1	8.2	1.4
		PR-3	4.0	8.2	2.4
		PR-4	2.6	16.2	1.8
		PR-5	77.1	311.3	47.5
		PR-6	162.4	346.4	72.5
		PR-7	17.2	55.4	7.0
		Subtotal	265.4	745.7	132.5
	Pewaukee Lake Outlet	PLO-1	4.0	34.5	2.9
	Pewaukee Lake	PL-1	51.1	95.6	34.4
	Subtotal	--	320.5	875.8	169.8
Town of Delafield	Pewaukee Lake	PL-3	21.3	32.9	13.9
Total	--	--	370.1	947.5	207.9

[a] *Includes direct damage to structures and contents plus indirect damages associated with that structural damage.*

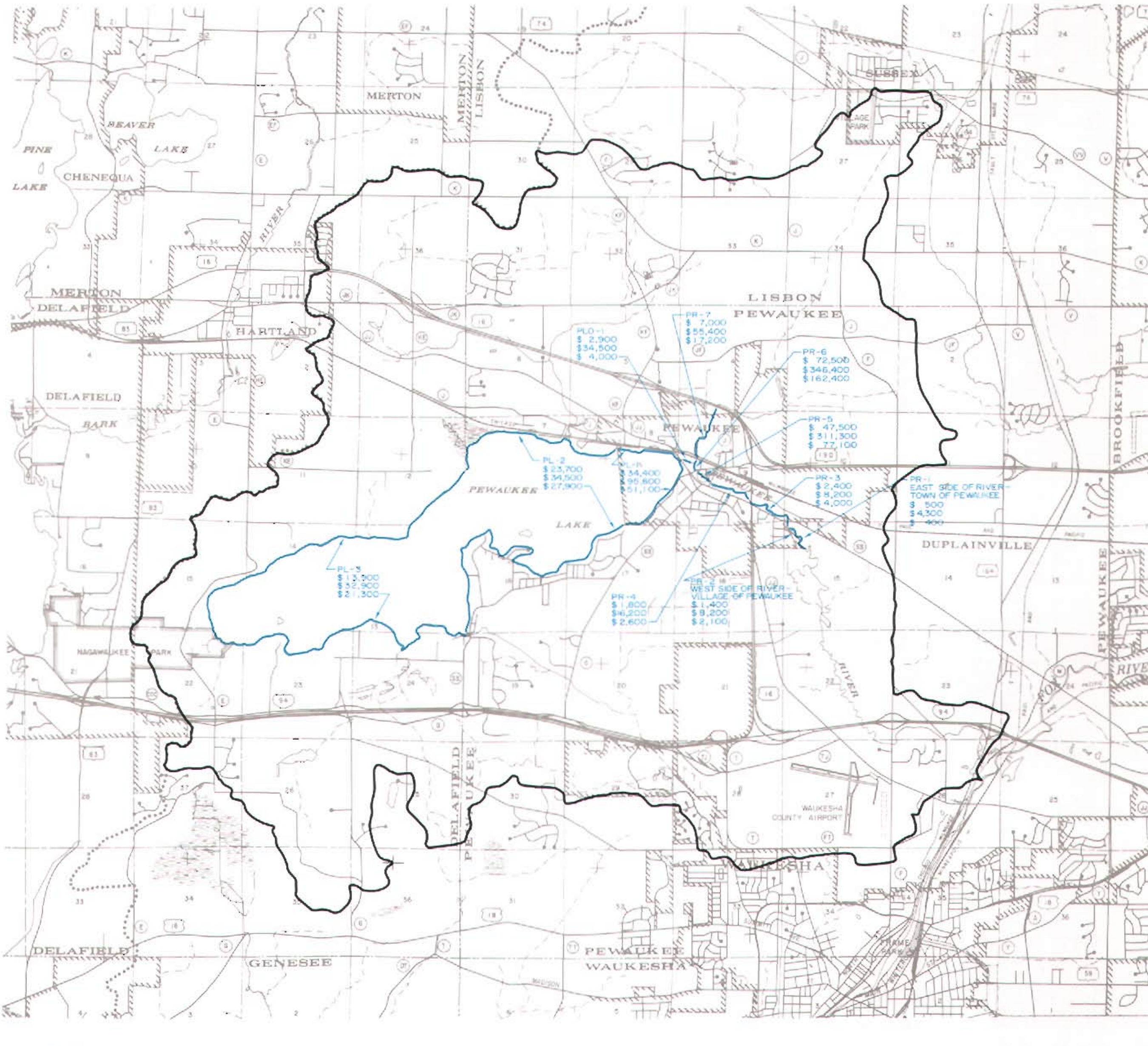
[b] *Under 2000 plan land use and floodland development conditions.*

Source: SEWRPC.

monetary flood risk in a given reach may be expected to be very sensitive to decisions concerning upstream land use development both in the floodlands and in the subwatershed as a whole. The manner in which presently undeveloped land, both within and outside of the Pewaukee River subwatershed floodlands, is used in the future may be expected to be an important determinant of future monetary flood damage experienced in the subwatershed, particularly within the Village of Pewaukee. As noted above, the hydrologic, hydraulic, and flood economics analyses carried out under the floodland management planning study for the Village of Pewaukee assume implementation of the year 2000 land use plan as set forth in SEWRPC Community Assistance Planning Report No. 9, Floodland Information Report for the Pewaukee River. An important recommendation of this land use plan is the retention of floodland areas in essentially natural open uses partly to assure maintenance of the floodwater conveyance and storage capacity of those floodlands. In the event that extensive filling occurs in the floodlands or that extensive urbanization occurs outside of the floodlands in variance of the land use plan, the resulting flood flows and stages as well as the monetary flood risks may be expected to be significantly higher than values included in this report which are based on year 2000 plan land use and floodland development conditions.

Map 6

AVERAGE ANNUAL AND 10- AND 100-YEAR RECURRENCE INTERVAL FLOOD DAMAGE IN THE PEWAUKEE RIVER SUBWATERSHED: YEAR 2000 LAND USE PLAN



LEGEND

SUBWATERSHED BOUNDARY

SELECTED FLOOD DAMAGE REACH

ESTIMATED FLOOD DAMAGES YEAR 2000 PLAN

$ 500 AVERAGE ANNUAL
$4,300 100-YR RECURRENCE INTERVAL
$ 400 10-YR RECURRENCE INTERVAL

NOTE: ESTIMATED YEAR 2000 PLAN FLOOD DAMAGES ASSUME YEAR 2000 PLANNED LAND USE CONDITIONS AND EXISTING CHANNEL CONDITIONS

PR-2 REACH IDENTIFICATION

Source: SEWRPC.

Chapter III

ALTERNATIVE FLOODLAND MANAGEMENT MEASURES AND RECOMMENDED FLOODLAND MANAGEMENT PLAN

INTRODUCTION

SEWRPC Community Assistance Planning Report No. 9, Floodland Information Report for the Pewaukee River, and the additional inventory and analyses carried out under this floodland management planning study for the Village of Pewaukee have identified and quantified the flooding problems along the Pewaukee River, the Pewaukee Lake Outlet, and Pewaukee Lake. As stated in the introductory chapter, the purpose of this report is to set forth a recommended floodland management plan for the Pewaukee River, the Pewaukee Lake Outlet, and Pewaukee Lake that will substantially assist in the abatement of existing flood problems and the prevention of future flood problems within the Village and that will be fully coordinated with the Commission's regional planning program including the adopted comprehensive plan for the Fox River watershed.

The purpose of this chapter is to present the floodland management alternatives from which a recommended floodland management plan was synthesized for the Village of Pewaukee. The structural and nonstructural floodland management alternatives described herein were designed for, and should be considered as adjuncts to, the basic year 2000 plan land use-floodland development conditions for the Pewaukee River subwatershed.

The evaluation of the particular floodland management alternative relative to other alternatives intended to resolve the flood problem is a sequential process in which the alternative is subjected to several levels of review and evaluation including technical, economic, environmental, financial, legal, and administrative feasibility and political acceptability. In anticipation of making such a comparative evaluation of the various floodland management alternatives considered and to facilitate selection of the recommended comprehensive floodland management plan for the Village of Pewaukee, the most important technical, economic, and environmental aspects of each alternative are presented in this chapter.

Concerning organization of the material presented in this chapter, structural and nonstructural floodland management measures available for resolution or prevention of flood problems are first described. Alternatives using essentially single structural measures such as storage, diversion, channel modification, dikes and floodwalls, and bridge and culvert alteration are developed followed by a presentation of alternatives employing various combinations of the above structural measures. A discussion of nonstructural, supplemental floodland management plan subelements suitable for application in the Village of Pewaukee is then presented. The chapter concludes with a discussion of miscellaneous floodland management considerations.

AVAILABLE FLOODLAND MANAGEMENT MEASURES

The techniques of floodland management may be broadly subdivided into two categories: structural measures and nonstructural measures. Structural measures include floodwater storage facilities such as reservoirs and impoundments, diversions, floodwater containment facilities such as earthen dikes and concrete floodwalls, floodwater conveyance facilities such as major channel modifications, and bridge and culvert modifications or replacements. Nonstructural measures include reservation of floodlands for recreational and open space uses, floodland use regulations, land use controls outside of the floodlands, structure floodproofing, structure removal, flood insurance, lending institution policies, realtor policies, community utility policies, and emergency programs. Table 5 lists structural and nonstructural measures of floodland management that may apply, individually or in combination, to flood-prone areas lying along the Pewaukee River, Pewaukee Lake Outlet, and Pewaukee Lake and summarizes the function of each. Structural measures tend to be more effective in achieving the objectives of floodland management in riverine areas that have already been urbanized, while nonstructural measures are preventive in that they are generally more effective in riverine areas that have not yet been converted to flood damage-

Table 5

ALTERNATIVE FLOODLAND MANAGEMENT MEASURES CONSIDERED IN THE VILLAGE OF PEWAUKEE FLOODLAND MANAGEMENT PLANNING PROGRAM

Alternative: Major Category	Alternative: Name	Function	Comment
Structural	Storage	To detain floodwaters upstream of flood-prone reaches for subsequent gradual release	May be accomplished by on-channel reservoirs or by off-channel or underground storage
	Diversion	To divert waters from a point upstream of the flood-prone reaches and discharge to an acceptable receiving watercourse outside of the watershed or to divert floodwaters around a flood-prone area on a completely new alignment	--
	Dikes and floodwalls	To prevent the occurrence of overland flow from the channel to floodland structures and facilities	--
	Channel modification and enclosure	To convey flood flows through a river reach at significantly lower stages	May be accomplished by straightening, lowering, widening, lining, and otherwise modifying a channel or by enclosing a major stream
	Bridge and culvert alteration or replacement	To reduce the backwater effect of bridges and culverts	May be accomplished by increasing the waterway opening or otherwise substantially altering the crossing or by replacing it
Nonstructural	Reservation of floodlands for recreational and related open space use	To minimize flood damage by using floodlands for compatible recreational and related open space uses and also to retain floodwater storage and conveyance	May be accomplished through private development, such as a golf course, or by public acquisition of the land or of an easement
	Floodland regulations	To control the manner in which new urban development is carried out in the floodlands so as to assure that it does not aggravate upstream and downstream flood problems	May be accomplished through zoning, land subdivision control, sanitary and building ordinances
	Control of land use outside of the floodlands	To control the manner in which urban development occurs outside of the floodlands so as to minimize the hydrologic impact on downstream floodlands	--
	Structure floodproofing	To minimize damage to structures by applying a combination of protective measures and procedures on a structure-by-structure basis	--
	Structure removal	To eliminate damage to existing structures by removing them from flood-prone areas	--
	Flood insurance	To minimize monetary loss or reduce monetary impact on structure owner	Premiums may be subsidized or actuarially determined
	Lending institution policies	To discourage acquisition or construction of flood-prone structures by means of mortgage granting procedures	--
	Realtor policies	To discourage acquisition or construction of flood-prone structures by providing flood hazard information to prospective buyers	--
	Community utility policies	To discourage construction in flood-prone areas by controlling the extension of utilities and services	--
	Emergency programs	To minimize the danger, damage, and disruption from impending flood events	Such a program may include installation of remote stage sensors and alarms, road closures, and evacuation of residents

Source: SEWRPC.

prone rural and urban development but have the potential for such development. Exceptions to the above generalization are structure floodproofing and structure removal which, although they are classified as nonstructural measures and are effective when incorporated into new construction, may also be effective for mitigating damages to existing structures in riverine areas that have already been urbanized.

Structural Measures
Each of the five structural floodland management measures set forth in Table 5 is discussed briefly below. Emphasis is placed on the function of each measure, key factors and basic requirements used to determine if the given alternative applies to a particular riverine area or portion of the watershed, and some of the more significant positive and negative features of each measure.

Storage: From the perspective of floodland management, the function of floodwater storage facilities is to detain floodwaters upstream of flood-prone areas for subsequent gradual release, thereby substantially decreasing downstream discharges and stages and, consequently, flood damage. A key factor in the potential application of this alternative is the existence of sites of sufficient volume that are positioned upstream of all or a significant portion of the flood-prone riverine areas and are located so as to control the runoff from a significant portion of the total watershed area tributary to the flood-prone areas. In addition, the site must be "available" in the sense that it does not contain significant rural or urban development.

Floodwater storage facilities may be directly located on the stream system, as with a conventional reservoir, or may be located off the channel system, as in an abandoned quarry or in excavated chambers in the underlying bedrock. In the off-channel situation, the floodwaters are diverted to the storage area during a flood event and later returned to the stream by pumping.

A positive feature of reservoirs in the context of a comprehensive floodland management plan element is their potential for mitigating flooding in several downstream communities in contrast with most other structural floodland management measures which provide only local flood relief. Another favorable aspect of reservoirs is their potential for serving several water resource-related uses—in addition to flood mitigation—such as recreation, low-flow augmentation, and water supply. Negative aspects of reservoirs include the large capital cost, large land area required, potentially adverse water quality conditions both within and downstream of the impoundment, and the false sense of security about the flood dangers that may be engendered in downstream reaches leading to the possible influx of urban development into the remaining flood-prone areas.

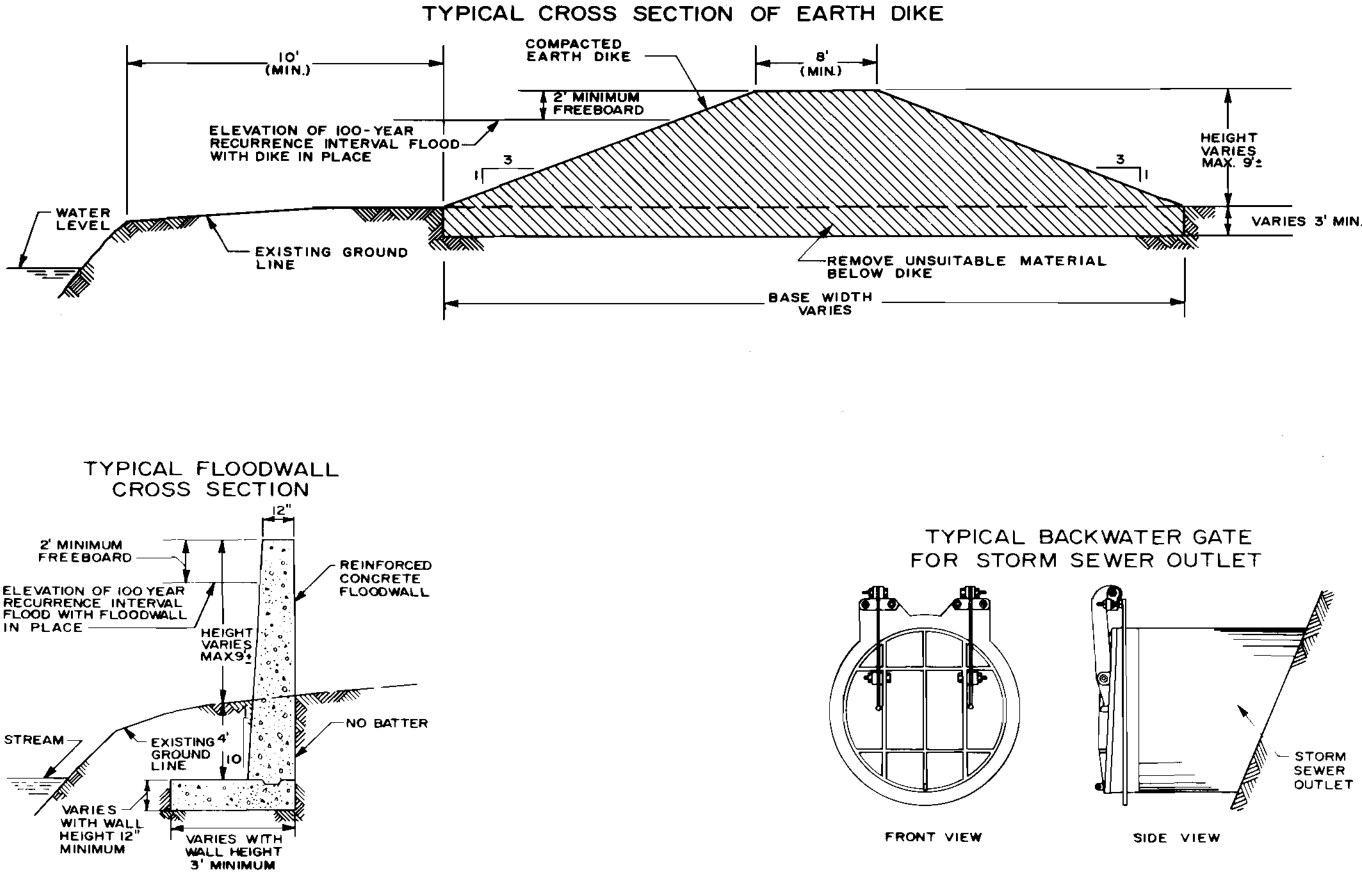
Diversion: The function of a diversion is to intercept potentially damaging floodwaters at a point upstream of flood-prone reaches and to route those floodwaters along a completely new alignment so as to bypass the flood-prone reach. Diverted flood flows are sometimes discharged to receiving watercourses outside of the subwatershed or watershed in which flood mitigation is desired. Upon completion of a diversion, all or a portion of the original natural channel may be retained to provide for conveyance of local storm water runoff. Two structural elements are entailed in a diversion alternative: 1) the control structure located on the stream channel that establishes the river stage at which the diversion process will begin and the rate at which it will occur and 2) the open channel or closed conduit that conveys the diverted floodwaters from the stream channel to the point of discharge. A key factor in assessing the application of this alternative is the availability of a suitable diversion route or alignment and of an adequate receiving watercourse or other point of discharge.

A favorable feature of the diversion technique, shared with the reservoir alternative, is the potential which a single major facility may have to mitigate flood problems in several communities. A negative aspect, also shared with impoundments, is the false sense of security about downstream flood dangers that may develop as a result of the construction of a diversion facility. Another negative feature of diversions for flood control purposes is the potential legal restrictions on the transfer of water between subwatersheds or watersheds.

Dikes and Floodwalls: Earthen dikes and concrete or sheet steel floodwalls, like those shown on Figure 7, are technically feasible means of providing flood control in certain flood-prone riverine areas. The principal function of dikes and floodwalls is to contain the floodwaters, that is, to prevent the occurrence of overland flow laterally from the channel to adjacent floodland areas containing flood damage-prone structures and facilities. A key physical factor in the potential application

Figure 7

TYPICAL EARTH DIKE, CONCRETE FLOODWALL, AND BACKWATER GATE



Source: SEWRPC.

of this structural alternative is the availability of sufficient space between the stream channel and the land uses that are to be protected to permit the construction of the dikes or floodwalls, the latter having the advantage of requiring a narrower strip of land.

In order to be effective in reducing flooding, dikes and floodwalls must normally be supplemented by the installation of backwater gates on storm sewer outfalls and other drainage outlets penetrating the dikes and floodwalls that have street inlets or other entry points in the area to be protected at elevations approximating or below the 100-year recurrence interval river flood stage. A storm water drainage system, which typically includes street storm water inlets and storm sewer outfalls, normally provides for the conveyance of storm water runoff from developed urban areas to the river. During major flood events, however, high river levels can reverse the operation of the storm water drainage system, thus negating its function and resulting in the movement of floodwaters from the river into developed riverine areas, thereby producing unwanted inundation and attendant monetary damage and inconvenience. Backwater gates prevent such flow reversal by functioning as valves that normally pass the storm water to the river but close when the hydraulic head on the river side of the hinged gate exceeds the head on the opposite side of the gate.

While backwater gates, operating as described above, will prevent the movement of floodwaters from the river, they may, depending on topographic conditions, create local storm water inundation problems attributable to the accumulation of storm water runoff which does not have access to the river because of the closed storm sewer outfall. Areas susceptible to this problem can be afforded protection by making provision for temporary or permanent pumping facilities to convey the impounded storm water over the dikes and floodwalls to the river during major flood events.

An important factor which must be considered in the design of dikes and floodwalls is the anticipated stage of the design flood in passing through the reach to be protected. This design condition flood stage may be several feet higher than the "natural" condition stage as a result of the lateral constriction imposed on the stream by the dikes and floodwalls and is used with an appropriate freeboard to establish the crest elevation of the dikes and floodwalls.

A favorable feature of dikes and floodwalls is that they are a means whereby a given community can readily and by unilateral action protect existing development within its own corporate boundaries. It must be recognized, however, that serious negative aspects of dikes and floodwalls are their potential for increasing upstream flood stages as a result of the hydraulic constriction imposed on the river and the possibility that a series of successive dike-floodwall projects along a stream could substantially reduce the natural floodwater storage capability of the river reach so as to increase downstream discharges and associated stages. Other significant negative characteristics of dikes and floodwalls include the potentially high aesthetic cost, or penalty, normally associated with the placement of these high, long structures in the riverine areas, particularly if those areas are devoted primarily to residential land use, and the false sense of security that may develop toward flood dangers through overtopping of the dikes or walls.

Channel Modification and Enclosure: Channel modifications—or channelization, as it is more commonly called—may include one or more of the following major changes to the natural stream channel, all designed to increase the capacity of the channel: straightening, deepening and widening; placement of a concrete invert and partial sidewalls; and reconstruction of selected bridges and culverts as needed. In some instances, a portion of the channelized reach may be constructed to bypass a segment—such as a meander loop—of the natural channel. However, such a bypass is not so extreme in terms of new alignment and total length as the diversion approach discussed above.

In the context of structural floodland management measures, channel enclosure refers to the installation of large underground conduits along or close to the alignment of major stream reaches intended to convey floodwaters through an area so as to substantially reduce overland flooding and sanitary sewer backup. An example of channel enclosure is the 0.05-mile-long reach of the Pewaukee Lake Outlet within the Village of Pewaukee.

In instances where longitudinal channel bottom slopes are extremely flat and where lateral excavation is restricted by existing buildings and other structures—as is the case for the entire length of the Pewaukee River through the Village—major channel modifications may be supplemented with low earthen dikes or concrete floodwalls. This permits a shallower channel excavation through the reach that needs flood protection. This, in turn, means that a shorter length of River downstream of the channelized reach will be needed to effect a smooth transition from the lowered channel bottom in the protected reach to the natural channel bottom downstream.

The function of channel modification or enclosure is to yield a lower, hydraulically more efficient waterway through which a given flood discharge can be conveyed at a much lower flood stage than would exist under natural or prechannelization conditions. Key factors in the potential application of this structural floodland management alternative to a flood-prone reach are the acquisition of a strip of land of sufficient width to accommodate the modified channel and careful consideration of the length of upstream and downstream natural channel that must be modified to effect an acceptable transition from the natural channel and floodplain to the channelized or enclosed reach.

A key advantage of channelization or enclosure is that it—like dikes and floodwalls—provides a means by which a community can take unilateral action to effectively provide local relief to a flood-prone area. Significant negative features of major channel modifications or enclosures include the potential high aesthetic cost, particularly of the former, and the possibility for aggravating downstream flood problems through increased downstream discharges and stages resulting from the loss of floodwater storage capacity in a long channelized or enclosed reach.

The Milwaukee-Metropolitan Sewerage Commissions, in cooperation with the Milwaukee County Park Commission, have used major channel modifications to achieve flood control in those riverine areas of Milwaukee County where urbanization has proceeded to the point where channel modifications are, in effect, the only remaining, technically feasible structural means of achieving flood relief. In recent years some major channel modification proposals in Milwaukee County have met with citizen opposition on the grounds that the modifications would destroy, to varying degrees, the beauty and aesthetic quality of the natural riverine environment. A commonly cited example used by such opposition to illustrate the potentially negative aesthetic aspects of major channel alternations is the reach of the Kinnickinnic River extending from S. 6th Street to S. 16th Street in the City of Milwaukee. In this reach the natural channel has been replaced by a trapezoidal, concrete-lined channel with steep side slopes and has been converted, in effect, to no more than a large open storm drain. In contrast, there are riverine areas in Milwaukee County where major channel modifications have been accomplished while retaining some of the aesthetic attributes of the natural channel and its floodplain. This has generally been achieved by paving only the lower portions of the modified cross section and then landscaping the remainder of the channel with grass, shrubbery, and trees. The Kinnickinnic River just upstream of the aforementioned reach serves as an example of such channel modification.

Bridge and Culvert Alteration or Replacement: Existing or new highway and railway bridges and culverts, or modifications to existing bridges and culverts, may significantly affect downstream flood flows and upstream and downstream flood stages and thereby aggravate existing flood problems or create new flood hazards. Furthermore, increased regulatory flood stages are reflected in enlarged floodland regulatory zones, thereby creating administrative, legal, and political problems for community officials. Flood events, on the other hand, can interfere with the proper functioning of the regional transportation system by inundating highways or railroad bridges or their approaches, thereby rendering them impassable during major floods.

The function of the bridge and culvert alteration or replacement alternative is to avoid or minimize the aforementioned adverse effects of existing bridges and culverts on flood flow characteristics and the adverse effects of flood flows on the functioning of the transportation system. These adverse effects are eliminated by increasing the size of the waterway opening or by otherwise substantially altering the crossing or by replacing it. The potential usefulness of this structural alternative depends upon identifying those existing bridges and culverts that produce major backwater effects as a result of their inadequate hydraulic capacity and identifying those structures that are impassable during major flood events.

Contemporary bridge design generally employs larger waterway openings that yield relatively small, and in effect insignificant, backwater effects. Therefore, this structural floodland management alternative is most likely to apply to older waterway crossings that will be replaced as part of the normal transportation improvement process.

Nonstructural Measures

Each of the 10 nonstructural floodland management measures presented in Table 5 is discussed briefly below. The function of each measure is described and the key factors and basic requirements needed to determine if the given alternative applies to a riverine area or portion of the watershed are discussed. In addition, some of the more significant positive and negative features of the various measures are identified.

Reservation of Floodlands for Recreational and Related Open Space Uses: Comprehensive land use planning recognizes that there is, and will continue to be, a need for active and passive recreational and open space lands readily accessible to residents of the metropolitan area. Floodlands provide an ideal location for such lands and supporting facilities because the floodlands and the environmental corridors of which they are a part provide sufficient space, assure the presence of water and other key recreation elements, improve the accessibility of the recreation areas to the urban population, and are compatible with recreation use and supporting facilities.

Recreational and related open space uses of floodlands may be accomplished by several mechanisms, including public or private acquisition of the land or acquisition of an easement followed by development for recreational use such as a golf course. The principal advantage of this floodland management alternative is its definitiveness and legal incontestability, whereas the key disadvantage of public acquisition of the lands is the public cost. Public acquisition of floodland areas for recreational and related open space use can sometimes be accomplished at no major direct cost to the municipalities by encouraging developers of large tracts of land to dedicate the land and adjacent environmental corridor portions of those tracts to a local government unit or agency for public maintenance and use. Since floodlands are not well suited for residential development not only because of flooding but also because of soils, utility, and other problems; since land subdivision regulations often require developers to provide a minimum amount of recreational and open space land; and since existing floodland regulations may limit the extent of floodland development, the land developer may be receptive to the idea of dedicating the floodlands and adjacent environmental corridors to a local government unit or agency.

In addition to preventing additional flood-prone development, minimizing aggravation of upstream and downstream flood problems, and providing prime and readily accessible outdoor recreational land, the reservation of floodlands for recreational and related open space uses also may be expected to have a significant and favorable impact on the value of residential property near the riverine area parkways. A land value study was recently conducted by the Commission under the regional park and open space planning program[1] to investigate the effects of public open space land on residential areas. The emphasis was upon the extent to which residential property values may be influenced by proximity to public open space areas. A variety of information sources and analysis procedures was used to carry out the study, including personal interviews of assessors, appraisers, and developers; collection and collation of census housing value data; analysis of residential housing sales information; analysis of locally assessed property values; and a survey of occupants of riverine area residential property.

The study indicates that most public open space lands have a positive impact on the value of residential property situated adjacent to or with a view toward the public open space areas. Furthermore, this impact is directly related to the size of the open land as well as to the value of the natural resource amenities which it contains.

Public open space areas, such as that in the Village of Pewaukee along the Pewaukee River upstream of Capitol Drive, that preserve and enhance high value elements of the natural resource base have the greatest impact on the value of adjacent developed residential property. The Commission study indicated that the value of developed property situated adjacent to or with a view toward riverine parkways exceeds the value of property located away from the parkway land by an average of about 30 percent. The analysis also indicated that, within a given subdivision that is under development, the sale prices of lots situated adjacent to or with a view toward such parkways exceeds by an average of 12 percent the sale prices of lots situated away from parkway lands.

The land value study also indicated that smaller parks which are intensively developed for active recreation use and which provide only a limited amount of "green" space have little or no positive impact on the value of adjacent residential property. This finding is due to negative factors associated with such locations including increased traffic and parking problems, noise, rowdyism, and undesirable glare from nighttime lighting of athletic fields. Information presented in the study strongly suggests that a community "benefit-cost" or "revenue-cost" analysis of preserving floodlands for recreational and related open space uses should consider the significant property value enhancement that accrues to properties adjacent to or situated with a view toward riverine area parkways. The same favorable property value condition is true for other large public open space lands that preserve and enhance high value elements of the natural resource base.

Floodland Regulations: Floodland regulations take the form of or are incorporated into zoning, land subdivision, sanitary, and building ordinances adopted by counties, cities, villages, and towns under police powers granted by state legislatures. Such regulations are ordinarily intended for the single purpose of flood damage mitigation by controlling the manner in which new urban development is carried out in the floodlands so as to assure that it is not flood-prone and, equally important, that it does not aggravate upstream and downstream flood problems. The regulation of floodlands in Wisconsin is governed primarily by the rules and regulations adopted by the Wisconsin Department of Natural Resources pursuant to Wisconsin Statutes. All counties, cities, and villages are expected to adopt reasonable and effective floodland regulations under the enabling Wisconsin Statutes. The principal advantage of floodland regulations is that they control the

[1] *SEWRPC Planning Report No. 27, A Regional Park and Open Space Plan for Southeastern Wisconsin—2000, Chapter X, "Impact of Public Open Space Lands on Residential Property Values Based On Analyses in Milwaukee County," November 1977, pp. 247-277.*

manner in which new development occurs in riverine areas. The principal disadvantage of floodland regulations is that they offer no relief to existing flood-prone structures other than to encourage their ultimate removal from floodland areas.

Floodland use regulations in Wisconsin generally employ the two-district floodway-floodplain fringe approach as incorporated in the State of Wisconsin Floodplain Management Program. That program was recently modified[2] to require that floodways be delineated so as to cause no increase in the regulatory or 100-year recurrence interval flood stage.

Although stipulation of a "no-stage increase" floodway eliminates or reduces some of the potenial problems associated with the two-district floodway-floodplain fringe approach to floodland regulations, one significant negative aspect remains. The two-district floodway-floodplain fringe approach to floodland regulations may lead to the destruction of the environmental corridors of a watershed since it encourages floodland fill and development outside of the floodway limits, but within environmentally critical areas. There is the possibility of making floodland and other land use recommendations more effective for environmental corridor protection as well as flood damage mitigation. Such more comprehensive floodland regulations typically incorporate a floodway, a developable floodplain fringe, and an undevelopable conservancy district.

Floodland regulations adopted by the Village of Pewaukee in February 1977 employ a floodway-floodplain approach. However, the above potentially adverse features of the floodway-floodplain approach have been essentially eliminated by use of a "no-stage increase" floodway supplemented with conservancy districts in some floodland fringe areas.

Control of Land Use Outside of the Floodlands: It is important to regulate the manner in which urban development occurs outside of the floodlands of a watershed or subwatershed, as well as within the floodlands, so as to minimize the hydrologic impact on floodland areas receiving direct runoff from tributary watershed areas. Although planning for land use outside of floodland areas has not traditionally been considered a floodland management alternative, the hydrologic-hydraulic interdependence between the land surface and the streams of the watershed system indicates that land use planning may indeed be an effective floodland management measure.[3] It is vital that land use planning consider the hydrologic-hydraulic consequences of location of future urban development, the amount of impervious surface in that development, and the manner in which storm water runoff from that new development is controlled. This floodland management planning study assumes implementation of the year 2000 regional land use plan and floodland development conditions as described in Chapter II of this report and in Chapter IV of Floodland Information Report for the Village of Pewaukee.

Structure Floodproofing: As discussed in Chapter II of this report, residential, commercial, and industrial structures located within or adjacent to floodlands are particularly vulnerable to flood damage because of the variety of ways by which floodwaters can enter such structures. It is possible and generally practicable for individual owners to make certain structural adjustments to their private properties and to employ certain measures or procedures, all of which are intended to significantly reduce potential flood damages. This approach is referred to as floodproofing, and may be more specifically defined as a combination of physical measures applied to existing structures in combination with selected emergency procedures, all of which are intended to eliminate or significantly reduce damage to the structure and its contents.

Floodproofing measures and techniques intended for application to existing structures generally can

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[2] *Wisconsin Administrative Code, "Wisconsin's Flood Plain Management Program," NR 116, July 1977.*

[3] *For a graphic demonstration of the potential impact of land use changes outside of floodland areas on flood discharges, stage and damage, refer to SEWRPC Planning Report No. 26, A Comprehensive Plan for the Menomonee River Watershed, Volume Two, Alternative Plans and Recommended Plan, October 1976, pp. 72-97.*

be divided into one of three categories:[4] 1) techniques for preventing entry of floodwaters; 2) techniques for insuring continuation of, or at least protection of, utilities and other services during flood events and for protecting structure contents in the event that the water does—by design or otherwise—enter the building; and 3) the techniques of raising—that is, elevating—the structure so that the first or the other most damage-prone floor is above the design flood stage supplemented with measures to protect the basement and other portions of the structure below the design flood stage from damage.

The particular combination of floodproofing measures applied to a given structure must be tailored to the function of the structure, the nature of its construction, and the vertical and horizontal position of the structure within the floodplain. Extensive floodproofing should be applied only under the guidance of a registered professional engineer who has carefully inspected the building and contents, has analyzed its structural integrity, and has evaluated the flood threat. It is important to emphasize that, even if a successful floodproofing program is instituted in a flood-prone area, overland flooding and the associated inconvenience will continue to occur.

Prevention of Floodwater Entry: A variety of floodproofing measures and techniques are available to prevent the entry of floodwaters. Sanitary sewer backup through basement floor drains may be prevented by installation of backwater valves or the use of vertical standpipes screwed into a fitting in the floor drain provided that the building sewer can withstand the attendant pressure that will be exerted. Sump pumps, preferably provided with stand-by gasoline-powered electrical generators, can remove water that enters the basement of a structure through foundation drains or other openings provided that the discharge point is above and not affected by flood stage. Waterproof seals can be installed at structural joints—such as the contact between basement walls and the basement floor—and impermeable materials can be applied to the outside of basement walls. Overland flood damage may be prevented by the construction of earthen berms or concrete or masonry walls around the perimeter of the structure or cluster of structures. Glass block[5] may be placed in basement window openings, and flood shields have been designed for quick installation over doorways, windows, and other structural openings.

It is important to reemphasize the critical need for a complete analysis of the ability of a given structure to withstand the external hydrostatic forces that would be applied to the walls and basement floor of a structure prior to implementing floodproofing procedures that are intended to prevent water from entering the basement of such structures. Generally speaking, the concrete block basements widely used in residential construction in southeastern Wisconsin are not capable of withstanding hydrostatic forces associated with complete saturation of the soil surrounding the buildings.[6] A realistic alternative, therefore, to

[4] *For detailed descriptions of floodproofing measures and techniques see: John R. Sheaffer, et al, "Introduction to Floodproofing: An Outline of Principles and Methods," University of Chicago Center for Urban Studies, April 1967, 61 pp. U. S. Army Corps of Engineers, "Floodproofing Regulations," Washington, D.C., June 1972. Shelton R. McKeever, "Floodproofing: An Example of Raising a Private Residence," Department of the Army, Corps of Engineers, South Atlantic Division, Atlanta, Georgia, March 1977, 19 pp. William K. Johnson, Physical and Economic Feasibility of Nonstructural Flood Plain Management Measures, U. S. Army Corps of Engineers-Hydrologic Engineering Center and Institute for Water Resources, May 1977, 281 pp. William D. Carson, Estimating Costs and Benefits for Nonstructural Flood Control Measures, U. S. Army Corps of Engineers-Hydrologic Engineering Center, October 1975.*

[5] *The Wisconsin Uniform Building Code states that basement windows must have a minimum openable area of 1 percent of the floor area unless ventilation is provided by other means such as mechanical ventilation units. Furthermore, the current policy of the interpretation committee of the Southeastern Wisconsin Building Inspectors Association is to require the use of glass block for basement windows in flood-prone areas and to require that this be supplemented with mechanical ventilation equipment.*

[6] *For example, see "Investigation of Basement Construction in Fargo, North Dakota and Moorhead, Minnesota Area," prepared for the Federal Insurance Administration by the National Association of Home Builders Research Foundation, Inc., Rockville, Md., June 1975.*

attempting to prevent floodwater from entering the basement of such structures is to intentionally flood the basement with clean water prior to the inflow of floodwater, thereby maintaining its structural integrity while minimizing the entry of sanitary sewage, sediment, and other objectionable materials normally associated with basement flooding and, as discussed below, incorporating measures to maintain utilities and services and protect structure contents.

Maintenance of Utilities and Services and Protection of Contents: The second category of floodproofing measures applicable to existing residential, commercial, industrial, and other structures consists of techniques designed to insure the maintenance of utilities and other services needed for the building to function possibly during, but certainly immediately after, a flood event. Also included in this category are procedures intended to protect structural contents. Because of the above structural problems, this second category of floodproofing measures should be considered for structures having concrete block basements.

Mechanical equipment such as heating and air conditioning units or manufacturing equipment may be placed on upper floors, elevated above the floor on which it is placed, surrounded by low walls to prevent intrusion of floodwaters, temporarily covered with impermeable sheet material, or altered so as to be mobile for removal from flood-prone areas prior to the occurrence of a flood event. Electrical circuits servicing flood-prone sections of a structure should be altered so that they can be easily shut off, and consideration should be given to moving the electrical service box to the first floor of the structure above anticipated flood levels and to the use of waterproof electrical fixtures in flood-prone areas of the structure. Some mechanical and electrical equipment may be protected by removal of critical water-vulnerable components—for example, the blower motor on a forced air heating unit—prior to entry of the floodwaters.

If there is a high probability that water will enter portions of the structure and damage the contents, such as furnishings in a house or stock stored in a commercial building, an emergency evacuation program should be prepared for the contents of the buildings. Flood-vulnerable contents could be temporarily moved out of the buildings or to higher floors or temporarily elevated on supports or shelves.

Some of the above floodproofing measures are contingent upon receiving adequate forewarning—at least several hours—of the impending occurrence of a flood event. It is important to recognize that such a warning, even if it were provided at the outset of a flood, would not be very effective in the Pewaukee River subwatershed since this is a relatively small headwater basin characterized by a relatively rapid response of peak flood flows to a major rainfall event.

Elevating the Structure: The third category of floodproofing measures is raising the structure—that is, elevating it—on its present site so that the first floor or other most damage-prone floor is above the design flood stage. Structure raising is supplemented with basic floodproofing measures like those described above to protect the basement and other portions of the elevated structure that remain below the design flood stage.

While basic floodproofing measures like those discussed above are generally considered feasible for most nonresidential structures—such as business and commercial buildings and schools—even if the design flood stage is above the first floor elevation, such measures are not generally technically feasible or practical for single-family residences when the design flood stage is above the elevation of the first floor. This is the condition for which structure raising is often the most appropriate floodproofing measure.

A typical structure raising procedure applied for floodproofing purposes is as follows: remove shrubs and other landscaping materials, concrete porches, walks and driveway, and other objects attached to or located close to the building; excavate as needed near the structure and place beams or other supports beneath the structure; disconnect utilities and services; use jacks to raise the structure; extend the basement walls upward and use the jacks to lower the structure down onto the extended walls; reconnect utilities and services; apply basic floodproofing measures to the basement as described above, possibly including raising the basement floor approximately the same distance that structure was raised; fill and grade the yard around the structure to match the structure's new elevated position; replace shrubs, porches, walks, and driveway and restore landscaping; and paint and redecorate the exterior of the house as needed.

The total capital cost of elevating a structure is composed of costs that are directly dependent on and increase with the extent to which the structure is elevated and fixed costs that are independent of the height through which the structure is raised. Examples of the latter, or fixed costs, include placing beams or other supports beneath the structure, disconnecting utilities, and replacing shrubs whereas examples of the former, or variable costs, include vertical extensions to the basement walls and the fill required to raise the yard grade. While the average cost of applying basic floodproofing techniques to a single-family residential structure—that is, floodproofing the structure without elevating it so as to prevent the entry of floodwaters or at least to maintain utilities and services and protect contents—is estimated at $2,500, the cost of elevating the residential structure—which would probably be required if the design flood stage were above the first floor elevation—is estimated at about $22,000 assuming that the building is raised four feet and increases about $2,000 for each additional foot that the structure is raised. While the costs of floodproofing structure elevation may be expected to greatly exceed the cost of basic floodproofing, the structure raising alternative may be expected to be considerably less costly than the structure acquisition and removal alternative described below.

Principal Advantages and Disadvantages of Floodproofing: The principal advantage of floodproofing is that it provides a means by which individual homeowners or property owners can unilaterally take definitive action to protect their flood-prone structures against future flood damage. A significant negative effect of floodproofing is the very real possibility that it will be applied without adequate professional engineering guidance, thereby leading to possible major damage to the structure as well as posing a threat to the owners, tenants, and users of the structure.

Another negative attribute of floodproofing individual structures is the very real possibility that the technique will not be applied in a coordinated way throughout the entire flood-prone portion of a given community, thereby leaving a significant residual demand for flood relief—a demand that will be focused on community officials and will be intensified during and immediately after each flood event. In such a situation and in spite of the fact that numerous individual property owners have implemented floodproofing and have incurred the necessary costs, community officials still will be faced with the problem of reducing the flood threat to those structures that have not been floodproofed.

Structure Removal: As discussed above, it is generally technically and economically feasible to apply basic floodproofing measures to well-constructed brick and masonry structures used for commercial or industrial purposes and to floodproof private residences—sometimes by raising them. There are situations, however, in which structure floodproofing is not technically practicable or economically sound such as when the structures are dilapidated and do not meet building code standards or when the cost of elevating them would be prohibitively high because of a large difference between the first floor elevation and the design flood stage.

Therefore, floodproofing measures considered in the design of alternative flood damage abatement plans are sometimes supplemented with proposals to remove those structures, usually private residences, having first floor elevations below the 100-year recurrence interval flood stage—the stage used to design floodproofing and removal alternatives. The cost of removing a residential structure from a flood-prone area is computed as the sum of the structure and site acquisition cost, structure demolition or moving cost, site restoration costs, and occupant relocation cost, the last of which is provided to the displaced homeowner or tenant in compensation for expenses incurred as a result of moving.

A positive aspect of structure removal, in addition to flood damage reduction, is that it enhances the opportunity to develop the aesthetic and recreation potential or riverine lands. Structure removal can assist in restoring river floodlands to an open, near natural state, thereby enhancing the aesthetic value of the riverine area and, in effect, recreating environmental corridors. Such restored environmental corridor lands could be used for outdoor recreation and related open space purposes.

A negative aspect of structure removal is the opposition which is likely to be encountered from some property owners even if offered an equitable price for the flood-damage-prone property. Although some of the value placed on a home may be intangible, and therefore cannot be expressed in monetary terms, it is, nevertheless, real and must be considered when structure removal alternatives are proposed.

Another potentially negative aspect of structure removal is a loss in tax base to a community as a result of removing taxable property from within the corporate limits. It should be noted, however, that, while there may be a loss in tax base to a community, the net cost to the community may be considerably smaller than the lost taxes because of the likely compensating effect of several factors including: the reduced cost of municipal services such as schools, water supply, and sewerage; the reduced cost of flood-related emergency services; and the likelihood that some of the evacuated residents will construct new residences within the civil division on previously undeveloped land, thereby restoring some of the lost tax base.

Federal Flood Insurance: The overriding objective of the National Flood Insurance Program is to encourage the purchase of flood insurance by individual land owners to reduce the need for periodic federal disaster assistance. From the perspective of the owner of the flood-prone residential, commercial, or industrial structure, federal flood insurance provides a means of distributing monetary flood losses in a relatively uniform manner in the form of an annual flood insurance premium and also actually reduces the monetary flood losses in those situations where the insurance premiums are federally subsidized.

The federal flood insurance program has been in effect in the Village of Pewaukee since March 1975. It is in the best interest of Village citizens to participate in the program—until such time as implementation of recommendations contained in this report mitigate flood problems and eliminate most of the need for flood insurance—so as to provide some relief in the event that a serious flood occurs prior to implementation of the flood control measures recommended in this report.

Lending Institution Policies: Lending institutions have gradually become more aware of the flood hazards associated with properties located in the floodland areas. The interest of lending institutions in the possible flood-prone status of property has been intensified as a result of the Federal Flood Disaster Protection Act of 1973 which expanded the National Flood Insurance Program. This Act requires the purchase of flood insurance for a structure within a flood hazard area when the purchaser seeks a mortgage through a federally supervised lending institution. The private lending institutions in the southeastern Wisconsin area have largely assumed the responsibility for the determination of whether or not a property is in a flood-prone area. This information is obtained by the lending institution from the local units of government and the Regional Planning Commission. Indications are that the lending institutions are not reluctant to provide mortgages on flood-prone structures provided that the federal flood insurance is secured by the owner of the property.

Realtor Policies: As a result of an executive order by Governor Patrick Lucey of Wisconsin on November 26, 1973, real estate brokers, salesmen, or their agents are in effect required to properly inform potential purchasers of property of any flood hazards which may exist at the site. The function of this floodland management measure is to reduce the unwitting acquisition or construction of flood-prone structures by providing flood hazard information to prospective buyers.

Community Utility Policies: Local communities may adopt policies relating to the extension of certain public utility services that discourage construction in flood-prone areas. Such policies should relate to the extension of streets as well as of such utilities as sanitary sewers and water mains. The location and size or capacity of utility facilities tend to influence the location of urban development. For example, selection of a sewer alignment that parallels and lies close to or within a floodplain or terminates at the edge of a floodplain may, in the absence of other land use controls, result in the construction of flood-prone residential, commercial, and industrial development. The sanitary sewerage system development objectives and standards which have been adopted by the Commission specify that floodlands should not be served by sanitary sewers and that analyses related to the sizing of sanitary sewer system components should not assume the ultimate urbanization of those floodlands. Similar objectives and standards can be established for water supply, transportation, and other facilities and services by the local units of government and other agencies having responsibilities for such services and utilities. In addition to contributing to sound floodland management, community utility policies that are restrictive in serving flood-prone areas may have a significant economic benefit in that the unit cost of utilities and services constructed in flood-prone areas is normally higher than the unit cost of such utilities and services constructed in nonflood-prone areas. The incremental costs associated with sanitary sewer construction in flood-prone areas will also include higher treatment cost as the result of potentially increased clear water infiltration and inflow problems that will probably develop in floodlands.

Emergency Programs: The function of an emergency program is to minimize the damage and disruption associated with flooding through a coordinated preplanned series of actions to be taken when a flood is impending or occurring. Such a program may include a variety of devices and techniques such as installation of remote upstream stage sensors and alarms, patrolling riverine areas to note when bankful conditions are imminent, monitoring of National Weather Service flash flood watch and warning bulletins during periods when rainfall or snowmelt are occurring or are anticipated, emergency messages broadcast to community residents over radio and television, use of police patrol cars or other vehicles equipped with public address systems, a siren warning system employing a special pattern to indicate that flooding is occurring, preplanned road closures and evacuation of residents, and mobilization of portable pumping equipment to relieve the surcharge of sanitary sewers.

DEVELOPMENT AND PRESENTATION OF ALTERNATIVES

As noted earlier in this chapter, preparation of a floodland management plan for a flood-prone area like the Village of Pewaukee involves the development of alternative plan subelements, a comparative evaluation of those subelements, and synthesis of the most effective subelements into an integrated, optimum plan for resolving existing flood problems and preventing future flood problems. An initial series of alternative measures were developed for all or some flood-prone areas in the Village with each measure relying primarily on a single means, structural flood control facility. Some of these structural flood control measures were contrasted with and supplemented with two nonstructural floodland management measures, floodproofing and removal, because floodproofing and removal effectively complement structural measures in a technical sense and because they, like structural measures, are amenable to benefit-cost analysis. Each single means structural flood control alternative was then subjected to a technical, economic, and environmental impact analysis. This screening procedure helped to identify those single means, structural measures most likely to be technically practicable, economically feasible, and environmentally acceptable, and, therefore, most likely to be viable measures for inclusion in a second series of alternative subelements, each consisting of combinations of two or more structural measures.

Combinations of primarily structural measures were then synthesized and subjected to technical, economic, and evnironmental impact analyses and, based on the results of such analyses, the optimum combination of structural floodland management measures was identified. Nonstructural measures were then examined to identify those measures most likely to effectively supplement the recommended combination of primarily structural floodland management measures.

ALTERNATIVE SINGLE MEANS STRUCTURAL FLOOD CONTROL MEASURES

Floodwater Storage

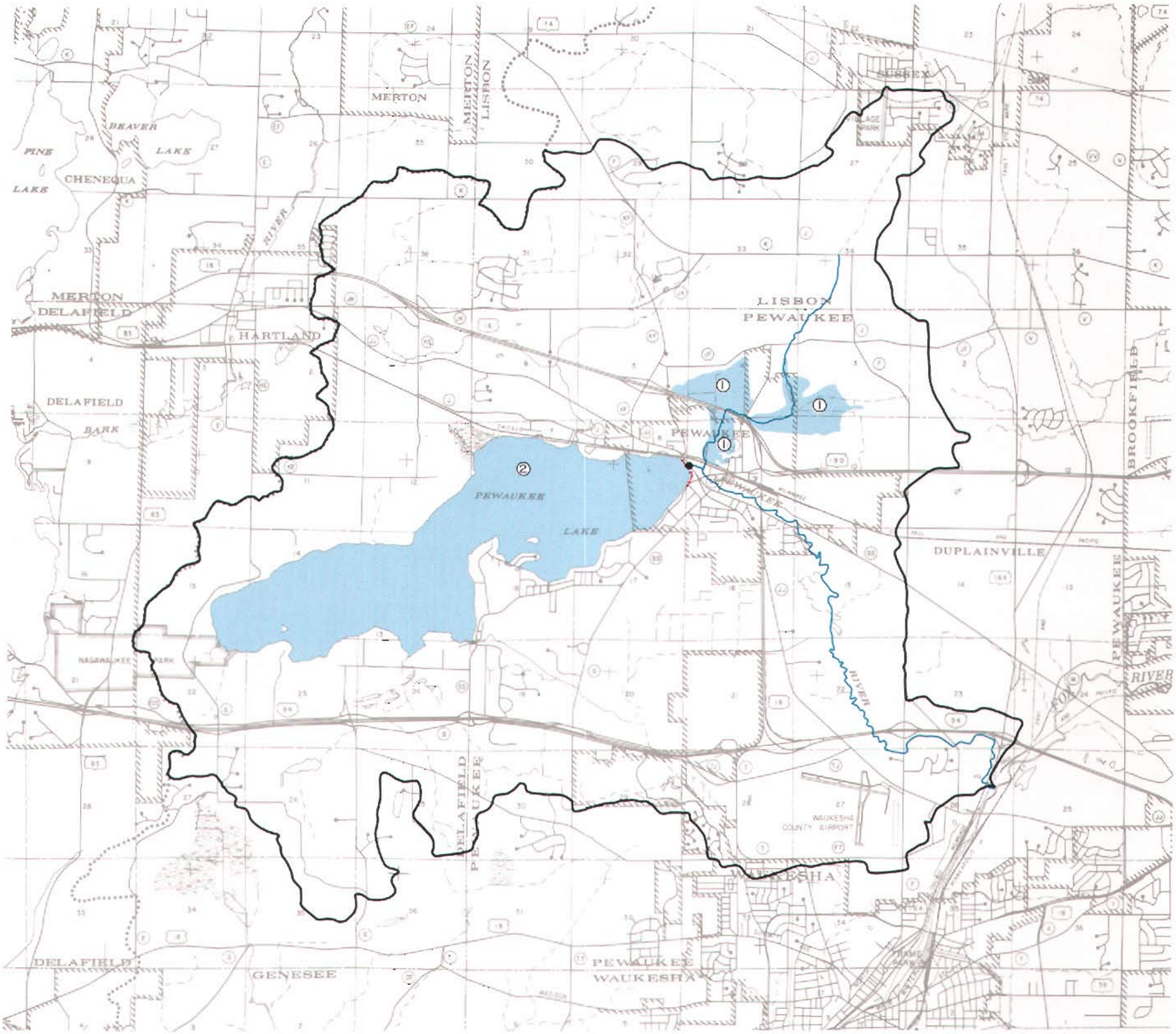
As noted earlier in this chapter, floodwater storage is a structural floodland management measure that has the potential to resolve or significantly reduce flood problems in one or more flood-prone reaches downstream of the impoundment facilities. Under the Village of Pewaukee floodland management study, two potential surface floodwater storage sites—a detention reservoir on the Pewaukee River at Capitol Drive and additional storage on Pewaukee Lake—were identified and subjected to hydrologic, hydraulic, and economic analyses with the objective of identifying one storage site that could, singly or possibly in combination with other measures, mitigate flood damages in a technically sound, economically viable, and environmentally acceptable manner.

Preliminary Identification of Surface Storage Sites: The preliminary identification of potential floodwater storage sites was initiated by an examination of watershed topography to determine locations at which a relatively large volume of water could be stored. Another factor considered in the preliminary identification was the nature of the existing land use and the value of vacant land inasmuch as intensive urban development or high land costs in or near a site would probably, as a practical matter, preclude its use for floodwater storage. A preliminary maximum flood pool elevation was determined for each of the potential sites with the principal determining factor being prevention of inundation to urban land uses or arterial streets contiguous to the sites. This maximum flood pool elevation was used to determine the total floodwater storage volume and the surface area of each site.

Map 7 shows the location and areal extent of the two sites identified in the Pewaukee River subwatershed. Selected data about each site, including surface area, maximum flood pool elevation, and maximum available storage volume are summarized in Table 6.

Map 7

POTENTIAL FLOODWATER STORAGE SITES IN THE PEWAUKEE RIVER SUBWATERSHED



LEGEND

- SUBWATERSHED BOUNDARY
- SIMULATED PORTION OF STREAM SYSTEM
- ② IDENTIFICATION NUMBER FOR POTENTIAL STORAGE SITE
- POTENTIAL FLOODWATER STORAGE SITE
- ● PEWAUKEE LAKE OUTLET STRUCTURE (EXISTING)
- EARTHEN DIKE
- CONCRETE FLOODWALL

NOTE: SITE 1 IS PEWAUKEE LAKE WHERE STORAGE WOULD BE PROVIDED ON TOP OF THE LAKE.

SITE 2 IS A DETENTION RESERVOIR. THIS FLOODWATER STORAGE FACILITY WOULD NORMALLY BE DRY BUT BE DESIGNED TO FILL DURING FLOOD EVENTS, THEREBY TEMPORARILY STORING THE FLOODWATER AND ATTENUATING FLOOD DISCHARGES AND STAGES.

GRAPHIC SCALE
0 1 MILE
0 2000 4000 6000 8000 FEET

Source: SEWRPC.

Table 6

SUMMARY OF THE PRELIMINARY IDENTIFICATION AND INITIAL EVALUATION OF POTENTIAL FLOODWATER STORAGE SITES IN THE PEWAUKEE RIVER SUBWATERSHED

Identification		Location					Impoundment Data at Approximate Maximum Flood Stage				Potential for Mitigation of Flood Problems		
					Control Structure								
Number	Name	Stream	County	Civil Division	River Station	Street, Highway, or Other Designation	Tributary Area (square miles)	Stage National Geodetic Vertical Datum (feet)	Surface Area (acres)	Volume (acre-feet)	Number of Flood-Prone Reaches Downstream of Site	Will Site Yield Significant Damage Reduction in One or More of the Downstream Reaches?	Retain Site for Hydrologic-Hydraulic Analysis?
1	Capitol Drive	Pewaukee River	Waukesha	Village of Pewaukee, Town of Pewaukee	3613+80	Capitol Drive	5.65	852	367	1,250	7	Yes	Yes
2	Pewaukee Lake	Pewaukee Lake	Waukesha	Village of Pewaukee, Town of Pewaukee, Town of Delafield	3616+00	W. Wisconsin Avenue	26.85	856	3,125	10,000	7	Yes	Yes

Source: SEWRPC.

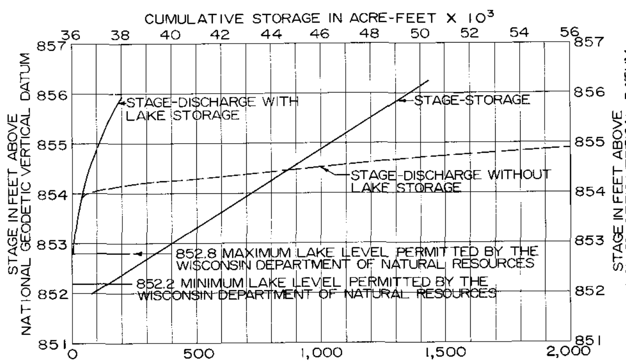
The Capitol Drive storage site, which has a storage volume of about 1,250 acre-feet, is a detention reservoir, as opposed to a retention reservoir. A detention reservoir is a flood water storage facility that is normally dry, or contains only enough water to achieve a desired aesthetic effect. A detention reservoir is designed to fill during flood events, thereby significantly attenuating downstream flood discharges and stages, and is drained by gravity or pumping after the flood event.

The Pewaukee Lake storage site is a retention reservoir, that is, a reservoir that normally contains, at a predetermined conservation pool level, a substantial volume of water available for recreational and other purposes, above which a floodwater storage volume is maintained for utilization during the flood events. Approximately 10,000 acre-feet of storage would be available on Pewaukee Lake between elevations 852.8 feet above National Geodetic Vertical Datum (Mean Sea Level Datum), the present maximum allowable lake stage established by the Wisconsin Department of Natural Resources, and 856.0 feet above National Geodetic Vertical Datum.

Evaluation of Surface Storage Sites: The Capitol Drive and Pewaukee Lake floodwater storage sites were subjected to hydrologic-hydraulic and economic analyses in order to determine whether the two sites, operated alone or in combination, could be expected to substantially reduce flood stages and, therefore, damages in some or all of the flood-prone reaches in the subwatershed. Both of the potential storage sites were represented in the simulation model by stage-storage-discharge relationships. As an example, the stage-storage-discharge relationships for Site 2 are graphically depicted in Figure 8. Such relationships reflect the topography of the detention or retention site—in the form of cumulative storage volume as a function of stage or pool elevation—and the hydraulic characteristics of the outlet control structure—in the form of total discharge through and/or over the outlet structure as a function of stage.

Figure 8

STAGE-STORAGE-DISCHARGE RELATIONSHIPS FOR PEWAUKEE LAKE IN THE PEWAUKEE RIVER SUBWATERSHED



Source: SEWRPC.

The outlet structure for Site 1 was designed as a concrete structure with a small conduit in its base at channel grade to pass low flows and to provide for gravity drainage of stored water after the occurrence of a flood event. The upstream end of the outlet structure conduit would be provided with a trash rack for safety purposes and to minimize blockage by ice and buoyant debris carried to the structure by the floodwaters. It would be necessary to provide for periodic inspection and maintenance in order to assure that the detention reservoir outlet works would always function at their design hydraulic capacity. An overflow spillway would be provided to permit the safe passage of floodwater after the storage capacity of the detention reservoir was exceeded. For preliminary design purposes, the conduit through the base of this structure was sized to pass an approximately one-year recurrence interval discharge under year 2000 plan conditions at a pool elevation coincident with the spillway crest. This small conduit size was selected to permit maximum utilization of the available storage volume during major floods.

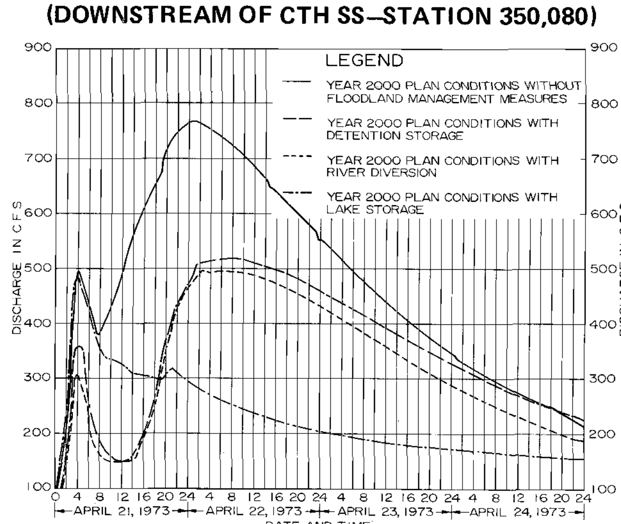
In the case of Site 2, it was assumed that an earthen dike or concrete floodwall would be constructed along the eastern end of Pewaukee Lake, as shown on Map 7, to prevent the Lake from overtopping its banks in the Village of Pewaukee. The dike, in combination with the existing lake level control structure, would substantially enhance the floodwater storage capacity of Pewaukee Lake.

Capitol Drive Detention Reservoir: The Capitol Drive detention reservoir is located on the Pewaukee River in the Village of Pewaukee and Town of Pewaukee. A 1,250 acre-foot detention reservoir could be formed by a concrete outlet structure located at the Capitol Drive crossing of the Pewaukee River in the Village of Pewaukee at Station 361380.[7] It would be located immediately upstream of seven flood-prone reaches along the Pewaukee River and Pewaukee Lake Outlet in the Village of Pewaukee and, therefore, would have the potential of reducing flood damages in those reaches.

The flood flow simulation model was applied to the Pewaukee River subwatershed using the entire available meteorological data base—consisting of 35 years of data—and year 2000 plan land use-floodland development conditions to test the potential effects of the detention reservoir. This simulation model application yielded flood flows at selected points along the Pewaukee River including two locations within flood-prone reaches in the Village of Pewaukee. The hydrologic effect of this site is illustrated in Figure 9 which depicts flood flow hydrographs for the Pewaukee River downstream of CTH SS at Station 350080 as those hydrographs would occur in response to the meteorological events which produced the April 1973 flood—a flood estimated to have a recurrence interval of 50 years near CTH SS—occurring under year 2000 plan conditions with and without the Capitol Drive detention reservoir. The temporary storage of flood flows could be expected to reduce the peak discharge from about 770 cfs to 520 cfs, a reduction of about 32 percent.

Figure 9

FLOOD FLOW HYDROGRAPHS ON THE PEWAUKEE RIVER IN THE VILLAGE OF PEWAUKEE WITH AND WITHOUT FLOODLAND MANAGEMENT MEASURES (DOWNSTREAM OF CTH SS–STATION 350,080)



NOTE: 1. HYDROGRAPHS ARE FOR THE METEOROLOGICAL EVENTS RESPONSIBLE FOR THE APRIL 21, 1973, FLOOD SUPERIMPOSED ON YEAR 2000 PLAN CONDITIONS.

2. THE UPSTREAM DETENTION RESERVOIR IS THE POTENTIAL 1,250 ACRE-FEET IMPOUNDMENT ON THE PEWAUKEE RIVER IN THE VILLAGE OF PEWAUKEE AND TOWN OF PEWAUKEE. THE OUTLET CONTROL STRUCTURE WOULD BE JUST UPSTREAM OF CAPITOL DRIVE-STATION 361380.

3. THE DIVERSION CHANNEL WOULD INTERCEPT FLOWS ON THE PEWAUKEE RIVER AT STATION 367900 AND DISCHARGE BACK TO THE PEWAUKEE RIVER DOWNSTREAM OF CTH SS AT STATION 353820.

4. LAKE STORAGE IS THE POTENTIAL 10,000 ACRE-FEET OF ADDITIONAL STORAGE ON PEWAUKEE LAKE WHICH COULD BE ATTAINED BY THE EXISTING LAKE LEVEL CONTROL STRUCTURE IN COMBINATION WITH A DIKE-FLOODWALL SEGMENT TO BE CONSTRUCTED ALONG THE EASTERN EDGE OF PEWAUKEE LAKE IN THE VILLAGE OF PEWAUKEE.

Source: SEWRPC.

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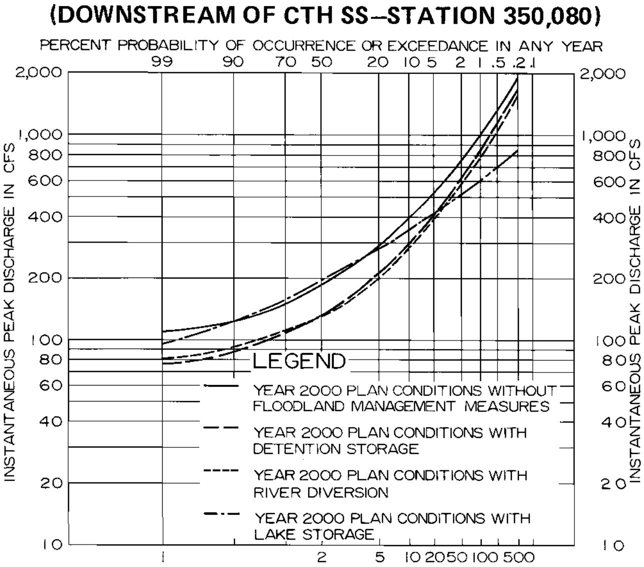
[7] *Stationing in feet along the stream system referenced to the Wilmot Dam on the main stem of the Fox River in Kenosha.*

The series of annual instantaneous peak flood flows was then used to develop Log Pearson Type III discharge-frequency relationships. Figure 10 shows the discharge frequency relationships for the Pewaukee River downstream of CTH SS at Station 350080 with and without the Capitol Drive detention reservoir and indicates that the 100-year recurrence interval discharge could be reduced by the detention reservoir from about 1,000 cfs to 850 cfs—a reduction of only about 15 percent.

The model was then used to compute flood stage profiles through the flood-prone reaches for selected recurrence intervals. The resulting flood stage profiles were found to be lower than those existing in the absence of the detention reservoir with the reduction in stage associated with the 100-year recurrence interval discharge ranging from zero to 0.7 feet with the largest stage decrease occurring just upstream of the Chicago, Milwaukee, St. Paul and Pacific Railroad bridge at Station 361350. The detention reservoir could be expected to effect an approximate 0.1 foot decrease in 100-year recurrence interval flood stage profile under year 2000 plan land use-floodland development conditions on the Pewaukee River at CTH SS—about 1.3 miles downstream of the reservoir—and of about 0.3 foot at Oakton Avenue—about 0.2 mile downstream of the reservoir. The

Figure 10

DISCHARGE-FREQUENCY RELATIONSHIPS ON THE PEWAUKEE RIVER IN THE VILLAGE OF PEWAUKEE WITH AND WITHOUT FLOODLAND MANAGEMENT MEASURES (DOWNSTREAM OF CTH SS—STATION 350,080)



Source: SEWRPC.

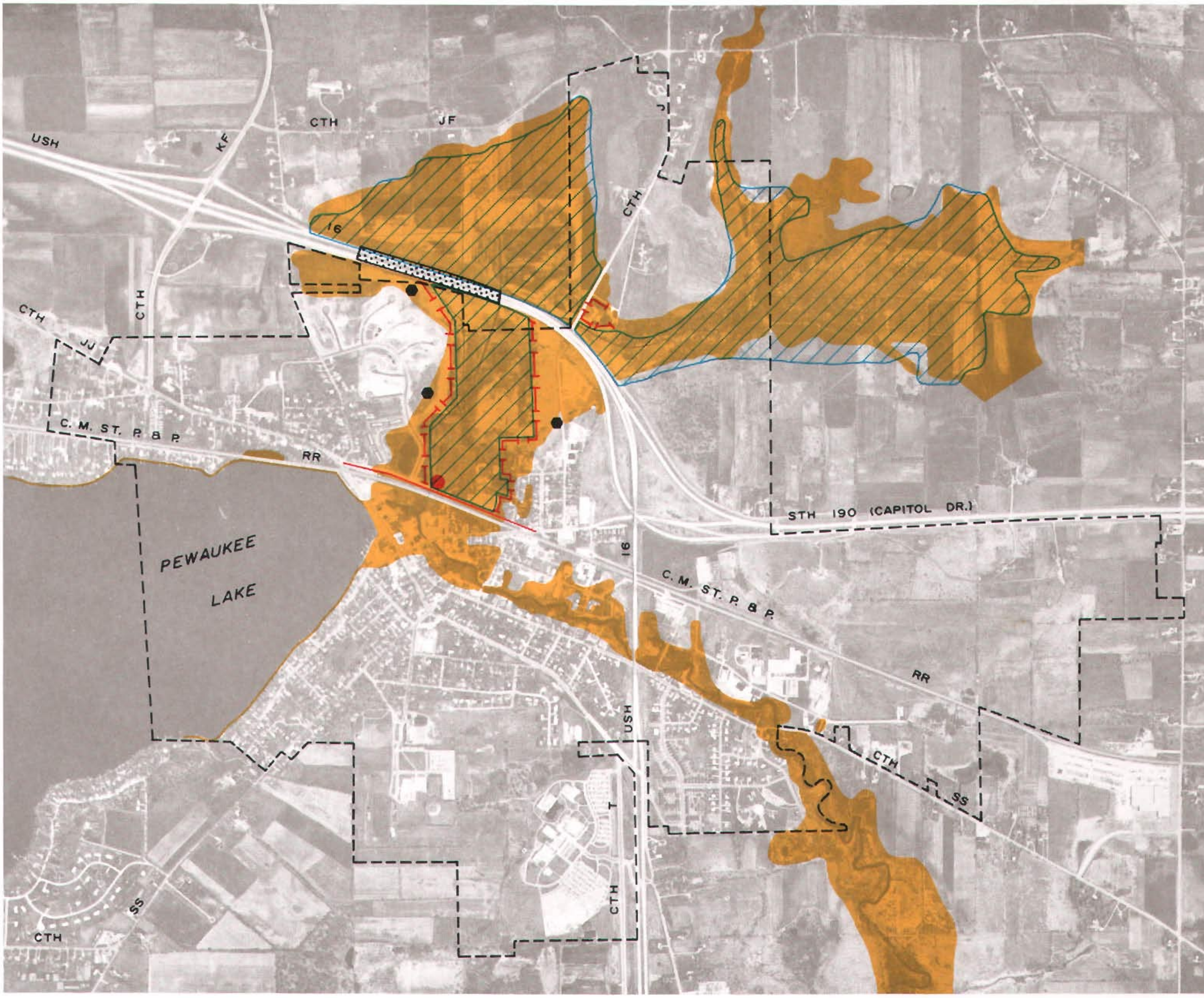
resulting stage-probability information was then used in the model to compute average annual monetary flood risks.

Although topographic conditions and existing land use would permit development of a detention reservoir with a volume of up to 1,250 acre-feet and a surface area of approximately 367 acres, the simulation studies indicate that only about 633 acre-feet of detention storage would be required to control the 100-year recurrence interval runoff volume generated by the 5.65-square-mile tributary area in response to the 35-year series of meteorological events. However, hydraulic analyses indicate that the pool elevation during major flood events in the detention site would not be determined primarily by the reservoir outlet capacity but rather by backwater from the Pewaukee River immediately downstream of the detention site. Furthermore, this analysis indicates that the 100-year recurrence interval pool elevation, as determined by the backwater effects, would be approximately 852.0 feet above National Geodetic Vertical Datum. The necessary storage, plus two feet of freeboard, could be achieved with a detention reservoir, as shown on Map 8, covering about 453 acres of land at a pool elevation of 852.0 feet above National Geodetic Vertical Datum. This area was increased 20 percent to 544 acres to provide for access to the site for maintenance purposes and to allow for refinement in the ultimate taking lines based upon consideration of real property line locations. The Village of Pewaukee currently owns approximately 72 acres of the proposed detention reservoir. Table 7 contains a schedule of the physical characteristics of the detention reservoir and the attendant costs and benefits of this alternative.

The capital cost of the Capitol Drive detention reservoir is estimated at $1,308,300, consisting of $593,000 for land acquisition, $1,000 for construction of the outlet control structure at Capitol Drive, $306,600 for elevating and improving Capitol Drive along the southern edge of the reservoir, $51,700 for constructing earthen embankments on the east and west sides of the detention reservoir between Capitol Drive on the south and USH 16 on the north to protect existing and planned residential and industrial areas, and $356,000 for the construction of four storm water control pumping facilities—three located on the western edge of the reservoir and one on the eastern edge of the reservoir. The average annual cost equivalent to the $1,308,300 capital cost of the detention

Map 8

DETENTION RESERVOIR ON THE PEWAUKEE RIVER AT CAPITOL DRIVE IN THE VILLAGE OF PEWAUKEE

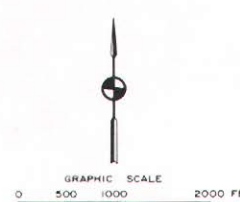


LEGEND

- VILLAGE OF PEWAUKEE CORPORATE LIMITS
- 100-YEAR RECURRENCE INTERVAL FLOODLANDS UNDER 2000 PLAN LAND USE AND EXISTING CHANNEL CONDITIONS
- AREA WHERE TOPOGRAPHY HAS BEEN ALTERED SINCE DATE OF MAPPING
- PROPOSED DETENTION RESERVOIR (STORAGE POOL ELEVATION 852.0 FEET MEAN SEA LEVEL)
- PROPOSED EARTHEN EMBANKMENT (TOP OF EMBANKMENT AT ELEVATION 854.0 FEET MEAN SEA LEVEL)
- PROPOSED PORTION OF RECONSTRUCTION OF CAPITOL DRIVE TO ELEVATION 854.0 FEET MEAN SEA LEVEL
- PROPOSED OUTLET CONTROL STRUCTURE (SPILLWAY AT ELEVATION 852.0 FEET MEAN SEA LEVEL)
- PROPOSED STORM WATER PUMPING STATION

NOTE:

1. A DETENTION RESERVOIR IS NORMALLY EMPTY BUT IS DESIGNED TO FILL DURING FLOOD EVENTS THEREBY ATENUATING DOWNSTREAM FLOOD DISCHARGE AND STAGE.
2. THE 100-YEAR RECURRENCE INTERVAL FLOODLAND WAS REDUCED UNDER THIS ALTERNATIVE,HOWEVER, THE REDUCTION IS INSIGNIFICANT WHEN SHOWN ON SMALL SCALE AERIAL PHOTOGRAPHS.



Source: SEWRPC.

Table 7

PRINCIPAL FEATURES AND COSTS AND BENEFITS OF SINGLE MEANS FLOODLAND MANAGEMENT MEASURES FOR THE VILLAGE OF PEWAUKEE

Alternative: Number	Alternative: Name	Alternative: Description	Technically Feasible	Economic Analysis[a]: Capital Cost (in $1,000)	Economic Analysis[a]: Annual Amortization of Capital Cost (in $1,000)	Economic Analysis[a]: Annual Operation and Maintenance Cost (in $1,000)	Economic Analysis[a]: Total Annual Cost (in $1,000)	Economic Analysis[a]: Annual Benefit (in $1,000)	Residual Flood Damages: Residual Average Annual Monetary Flood Risk (in $1,000)	Residual Flood Damages: Percent of Total Annual Monetary Flood Risk	Annual Benefit Minus Annual Cost (in $1,000)	Benefit Cost Ratio	Economically Feasible	Nontechnical and Noneconomic Considerations: Positive	Nontechnical and Noneconomic Considerations: Negative	Recommended
1	No Action	--	Yes	-- –	..	--	169.8	0.0	169.8	100	- 169.8	--	No	--	--	No
2	Detention Storage at Capitol Drive	Detention Reservoir on the Pewaukee River Immediately Upstream of Capitol Dirve	Yes	Land 593.0 Outlet 307.6 Dike 51.7 Pumping Stations 356.0[b] Total 1,308.3	83.0	10.9	93.9	51.6	118.2	70	- 42.3	0.55	No	● Potential to retain open space along the Pewaukee River upstream of Capitol Drive	● May encourage downstream flood-prone development ● Need for the Village of Pewaukee to purchase land outside of the Village corporate limits	No
3	Retention Storage on Pewaukee Lake	0.19 Mile of Dike 0.06 Mile of Floodwalls *Basic Floodproofing:* 8 Residential and 2 Commercial and Other Structures Elevate 2 Residential Structures	Yes	Dikes 250.6 Floodwalls 58.2 Floodproofing (basic) 40.6 Floodproofing (elevating) 37.6 Total 387.0	24.6	0.4	25.0	59.3	110.5	65	34.3	2.37	Yes	--	● May encourage downstream flood-prone development ● Creates or aggravates existing flood problems for lake shore property owners in the Towns of Pewaukee and Delafield	No
4	Lake Diversion	3.5-Mile-Long Diversion Channel Around the Village of Pewaukee Central Business District	Yes	-- --[d]	--	--	--	--	--	--	--	--	No[d]	--	● Entire diversion route lies outside of Village	No
5	River Diversion	1.2-Mile-Long Diversion Channel Around the Village of Pewaukee Central Business District	Yes	Land 40.5 Channel Construction 608.1 Dike 3.4 Diversion Structure 3.9 Bridges 568.0 Total 1,223.9	77.6[d]	0.5	78.1	47.8	122.0	72	30.3	0.61	No	--	● May encourage downstream flood-prone development	No
6	Structure Floodproofing	Basic Floodproofing: 27 Residential and 12 Commercial and Other Structures Elevate 10 Residential Structures	Yes	Floodproofing (basic) 644.7 Floodproofing (elevating) 167.4 Total 812.1	51.5	--	51.5	169.8	0	0	118.3	3.30	Yes	● Immediate partial flood relief at discretion of property owners ● Most of the costs could be borne by beneficiaries	● Complete voluntary implementation unlikely and therefore left with a significant residual flood problem ● Overland flooding and some attendant problems remain ● Some floodproofing is likely to be applied without adequate professional advice and, as a result, structure damage may occur	No
7	Minor Channel[c] Modification	2.6 Miles of Channel Cleaning and Minor Modification	Yes	Channel Work 80.1	5.1	--	5.1	36.8	133.0	78	31.7	7.25	Yes	--	● Overland flooding and attendant problems remain	No
8	Major Channel-Concrete	1.30 Miles of Major Channelization Replace 3 Stream Crossings Enclose the Lake Outlet 0.19 Mile of Dike 0.06 Mile of Floodwall Install 12 Storm Water Pumping Stations	Yes	Channelization 3,237.2 Bridges 96.0 Lake Outlet Structure 294.5 Dike 250.6 Floodwall 58.2 Pumping Stations 1,068.0[b] Total 5,004.5	317.5	16.1	333.6	143.1	26.7	16	- 190.5	0.43	No	● Opportunity to develop water oriented greenway along the Pewaukee River through the business-commercial area of the Village ● Eliminate overland flooding in the Village business area	--	No
9	Major Channel-Turf	1.30 Miles of Major Channelization Replace 3 Stream Crossings Enclose the Lake Outlet 0.19 Mile of Dike 0.06 Mile of Floodwall Install 12 Storm Water Pumping Stations	Yes	Channelization 2,079.0 Bridges 115.2 Lake Outlet Structure 294.5 Dike 250.6 Floodwall 58.2 Pumping Stations 1,068.0[b] Total 3,865.5	245.2	16.1	261.3	143.1	26.7	16	- 118.2	0.55	No	● Opportunity to develop water oriented greenway along the Pewaukee River through the business-commercial area of the Village ● Eliminate overland flooding in the Village business area	--	No
10	Dikes and Floodwalls	0.47 Mile of Dikes 0.32 Mile of Floodwalls Replace 2 Stream Crossings Install 4 Storm Water Pumping Stations Enclose the Lake Outlet	Yes	Dikes 571.4 Floodwalls 522.5 Bridges 96.0 Lake Outlet Structure 294.5 Pumping Stations 356.0[b] Total 1,840.4	116.8	4.8	121.6	138.9	30.9	18	17.3	1.14	Yes	● Eliminate overland flooding in the Village business area	● Aesthetic impact of the dikes and floodwalls on riverine property owners and Village residents	No
11	Bridge and Culvert Alteration or Replacement	*Replace the* 3 Stream Crossings Causing the Greatest Backwater	Yes	Bridges 96.0	6.1	--	6.1	40.6	129.2	76	34.5	6.66	Yes	--	● Overland flooding and attendant problems remain	No

[a] *Economic analyses are based on an annual interest rate of 6 percent and assume a 50-year amortization and project life.*

[b] *Present worth cost based on 25-year economic life.*

[c] *Assumes minor channel modification will be necessary every five years.*

[d] *Capital cost in excess of three million dollars and alternative is economically infeasible based on preliminary analysis described in text.*

Source: SEWRPC.

reservoir at a 6 percent interest rate and a project life and amortization period of 50 years would be $83,000. Adding estimated operation and maintenance costs of $10,900 per year yields a total estimated annual cost of $93,900.

The flood control benefits which could be expected to result from this expenditure would be a 30 percent reduction in average annual flood damages—from $169,800 to $118,200—to the residential, commercial, and industrial areas along the Pewaukee River in the Village of Pewaukee. Thus, the annual average benefit would approximate $51,600 in the Village of Pewaukee. The resulting benefit-cost ratio would be 0.55, and the annual excess of costs over benefits would be $42,300.

Therefore, the detention reservoir at Capitol Drive would be an economically unsound, although technically feasible, means of abating part of the Pewaukee River flood problem in the Village of Pewaukee downstream of Capitol Drive.

The principal positive noneconomic and nontechnical characteristic of the detention reservoir alternative is the potential opportunity to retain open space along the Pewaukee River upstream of Capitol Drive. Two negative features are associated with the detention reservoir alternative: 1) flood-prone development may occur along and immediately downstream of the reservoir site; and 2) approximately 350 of the 544 acres, or 64 percent of the land required for the detention reservoir, lie outside of the corporate limits of the Village and, therefore, some special plan implementation problems could be expected.

Pewaukee Lake Storage: An additional 10,000 acre-foot of storage could be obtained on Pewaukee Lake in the Village of Pewaukee and Towns of Pewaukee and Delafield by constructing an earthen or concrete embankment along the eastern shoreline in the Village of Pewaukee. This storage would be located immediately upstream of the flood-prone reaches along the Pewaukee River and Pewaukee Lake Outlet in the Village of Pewaukee and, therefore, would have the potential of reducing flood damages in the Village. A schedule of the physical characteristics of the Pewaukee Lake storage and the attendant costs and benefits is set forth in Table 6.

The flood flow simulation model was applied to the Pewaukee River subwatershed using the complete available meteorological data base—consisting of 35 years of data—and year 2000 plan land use-floodland development conditions and assuming that additional floodwater storage was utilized on Pewaukee Lake. This simulation model application yielded flood flows corresponding to the 35-year period of meteorological conditions at selected points along the Pewaukee River including three locations within flood-prone reaches in the Village of Pewaukee. The hydrologic effect of this site is illustrated in Figure 9 which depicts flood flow hydrographs for the Pewaukee River downstream of CTH SS at Station 350080 as those hydrographs would occur in response to the meteorological events which produced the April 1973 flood occurring under year 2000 plan conditions with and without the additional lake storage. The temporary storage of flood flows on Pewaukee Lake could be expected to reduce the peak discharge of this flood—which had a recurrence interval of about 50 years at this location—from about 770 cfs to 480 cfs, a reduction of about 38 percent.

The series of flood flows at these locations then was used to develop Log Pearson Type III discharge-frequency relationships. Figure 10 shows the discharge frequency relationships for the Pewaukee River downstream of CTH SS at Station 350080 with and without the additional lake storage and indicates that the 100-year recurrence interval discharge could be reduced from about 1,000 cfs to 600 cfs—a reduction of about 40 percent—as a result of utilizing the lake storage potential.

The model was then used to compute flood stage profiles through the flood-prone reaches for selected recurrence intervals. The resulting flood stage profiles were found to be lower than those existing in the absence of the Pewaukee Lake floodwater storage with the reduction in stage associated with the 100-year recurrence interval discharge ranging from 0.6 foot to 2.1 feet with the maximum stage reduction occurring just upstream of CTH J at Station 365500. The CTH J bridge is located upstream of the confluence of the Pewaukee Lake Outlet and the Pewaukee River and the stage reduction at CTH J reflects reduced stages at the confluence as a result of floodwater storage on Pewaukee Lake. This additional lake storage could be expected to effect an approximate 0.9 foot decrease in the 100-year recurrence interval flood stage profile under year 2000 plan land use-floodland development conditions on the Pewaukee River at CTH SS and of 1.7 feet on the Pewaukee River at Oakton Avenue. The resulting stage-probability information was then used in the model to compute average annual monetary flood risks.

In order to protect the existing land use along the shore of Pewaukee Lake in the Village of Pewaukee from the higher lake stages which would accompany major flood events with this alternative, a structure floodproofing and removal subelement would be required as a supplement to the lake storage alternative. In the case of residential structures in the primary flooding zone, basic floodproofing was assumed to be feasible if the design flood stage was below the first floor elevation and either structure removal or floodproofing by structure elevation was assumed to be required if the design flood stage was at or above the first floor elevation with the choice between removal or elevation based on least cost. Floodproofing was assumed to be feasible for all nonresidential structures within the primary flooding zone, irrespective of flood stage, with the floodproofing cost for stages above the first floor being a function of the distance between the flood stage and the first floor elevation. For structures located in the secondary flooding zone, that is, outside of but immediately adjacent to the 100-year recurrence interval floodlands, it was assumed that floodproofing would be applied to those structures with basement floors below the elevation of the design flood stage. The total floodproofing cost so computed for the secondary flooding zone was then reduced by 0.85 to reflect the fact that not all buildings in that zone with basement floors set at an elevation below the design flood stage would in fact incur secondary flooding. The factors assigned to each flood-prone reach were the same as those used to compute flood damage in the secondary zone. The analysis indicated that about two structures would have to be floodproofed by elevating them and a total of about 10 structures located in the primary and secondary flooding zones may require some form of basic floodproofing. Future flood damage to private residences and commercial structures along the shore of Pewaukee Lake in the Village of Pewaukee would be virtually eliminated by the floodproofing and elevation, that is, structure removal would not be required.

The capital cost of additional floodwater storage on Pewaukee Lake is estimated at $387,000, composed of $308,800 for dikes and floodwalls, $40,600 for basic floodproofing, and $37,600 for floodproofing by raising. Assuming the aforementioned structure floodproofing measures could be fully implemented, the average annual cost equivalent to the $387,000 capital cost of the lake storage at a 6 percent interest rate and for a project life and amortization period of 50 years would be $24,600. Adding estimated operation and maintenance costs of $400 per year yields a total annual cost of $25,000.

The flood control benefits which would be expected to result from this expenditure would be a 35 percent reduction in average annual flood damages—from $169,800 to $110,500 to the residential and commercial areas along Pewaukee Lake, the Pewaukee River, and the Pewaukee Lake Outlet in the Village of Pewaukee. Thus, the average annual benefit would approximate $59,300 in the Village of Pewaukee. The resulting benefit-cost ratio would be 2.37, and the annual excess of benefits over costs, would be about $34,300. Therefore, the lake storage alternative is an economically sound, as well as technically feasible, solution to part of the flood problem in the Village of Pewaukee.

The above economic analysis of Pewaukee Lake floodland storage is limited to the costs and benefits that would be incurred in the Village of Pewaukee. It is important to consider the implication of the Pewaukee Lake floodwater storage alternative on flood damages that would be incurred by lakeshore residents located in the Towns of Pewaukee and Delafield. Under existing lake outlet control conditions and year 2000 plan land use conditions, the average annual flood damages for structures located along Pewaukee Lake in the Towns of Pewaukee and Delafield are estimated at $37,600. Assuming implementation of the Pewaukee Lake storage alternative and the associated higher lake stages during major flood events, average annual flood damages to lakeshore residents of the Towns of Pewaukee and Delafield would increase about 30 percent to $48,700. Therefore, while the Pewaukee Lake storage alternative would be a technically feasible and economically feasible solution to the Village of Pewaukee flood problems, it would create or aggravate flood problems along the periphery of Pewaukee Lake in the Towns of Pewaukee and Delafield.

Inasmuch as the Pewaukee Lake floodwater storage is an economic way to mitigate some of the flood problems in the Village of Pewaukee while aggravating flood problems along Pewaukee Lake in the Towns of Pewaukee and Delafield, it is desirable to determine the net costs and benefits of the Pewaukee Lake storage when aggregated for all three affected civil divisions. Under existing lake outlet control conditions and year 2000 plan land use conditions, the average annual flood damage, for structures located along Pewaukee Lake in the Village of Pewaukee and the Towns of Pewaukee and Delafield and in the Village of Pewaukee along the Pewaukee Lake Outlet and Pewaukee River is $207,400. Assuming implementation of the Pewaukee Lake storage alternative as described above, the net effect of decreasing flood damage in the Village of Pewaukee and increasing flood damage in the Towns of Pewaukee and Delafield is an average annual flood damage of $159,200 for a net average annual benefit—flood damage reduction—of $48,200. The average annual amortization and operation and maintenance cost of Pewaukee Lake storage is $25,000, yielding a benefit-cost ratio of 1.93 and an annual excess of benefits over costs of $23,200. Therefore, although the Pewaukee Lake storage alternative would aggravate flood problems along Pewaukee Lake in the Towns of Pewaukee and Delafield, it is economically sound when all costs and benefits are considered for all three affected communities, that is, the Towns of Pewaukee and Delafield and the Village of Pewaukee. This occurs because the additional flood damage in the towns is offset by much larger damage reductions in the Village.

Although there are no significant positive noneconomic and nontechnical characteristics of floodwater storage on Pewaukee Lake, the following two negative features are associated with alternatives: 1) flood-prone development may occur along and immediately downstream of the reservoir site; and 2) lake storage will create new flood problems or aggravate existing flood problems for lakeshore property owners in the Towns of Pewaukee and Delafield.

Floodwater Diversion

In the consideration of alternative structural flood control measures, it was recognized that floodwater diversion around flood-prone reaches in the Village of Pewaukee might be technically feasible and economically sound. The preliminary screening of diversion possibilities identified the potential for constructing open channels or closed conduits for the purpose of diverting floodwaters from Pewaukee Lake or the Pewaukee River around the flood problem areas in the Village of Pewaukee. Each of these two floodwater diversion possibilities—diversion of Pewaukee Lake and diversion of the Pewaukee River—were subjected to a preliminary examination as described below.

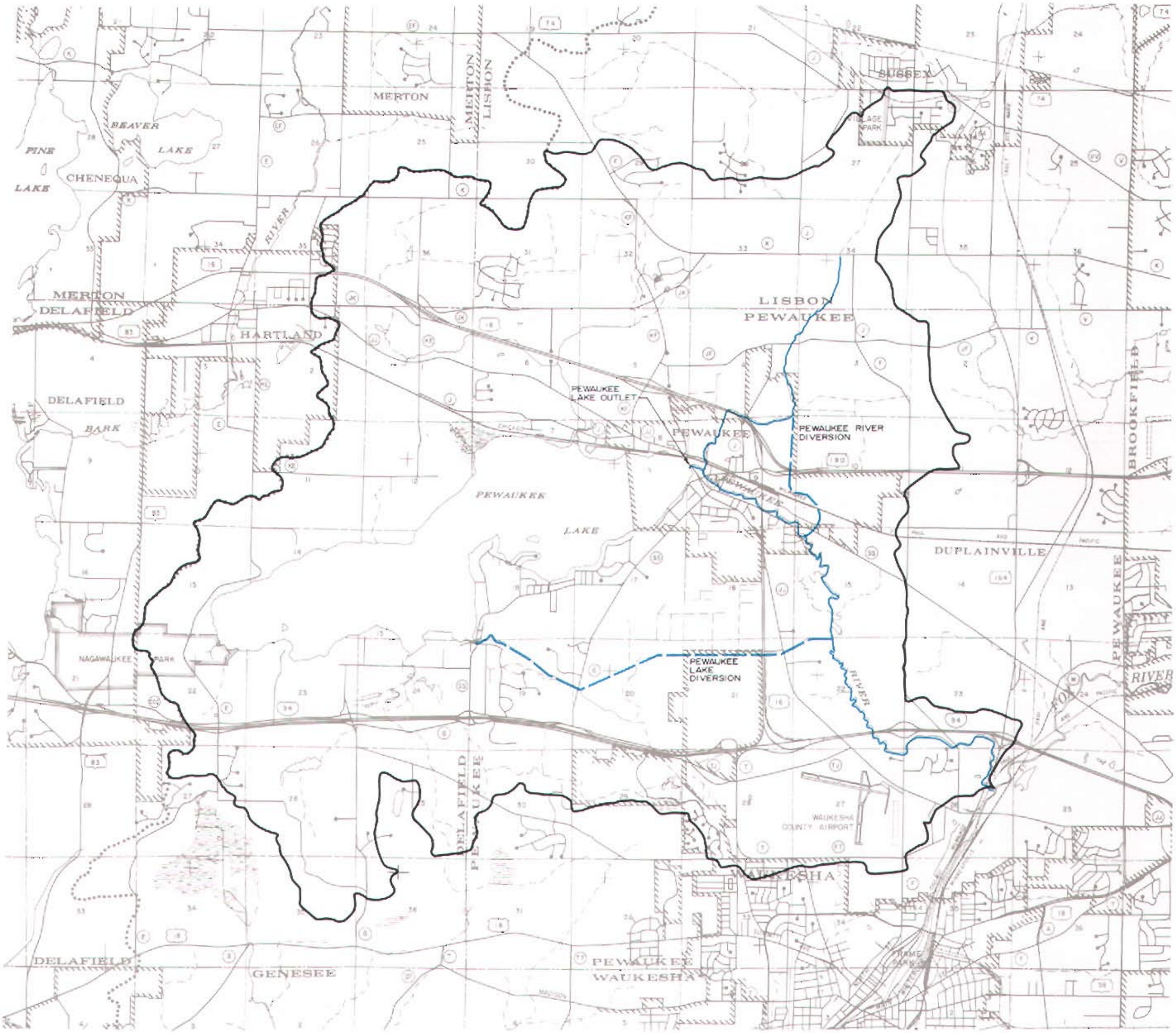
Diversion from Pewaukee Lake: An examination of the surrounding topography and existing land uses of the Pewaukee Lake area revealed one possible route for a diversion directly from Pewaukee Lake. As shown on Map 9, such a diversion would begin at the southern extremity of the Lake in the Town of Pewaukee and would flow in a generally easterly direction following the alignment of existing natural and man-made drainageways and swales, passing through the northern extremities of the City of Waukesha, and rejoining the Pewaukee River in the Town of Pewaukee. Diverted flow would enter the Pewaukee River downstream of all the flood-prone reaches along the Pewaukee River and the Pewaukee Lake Outlet and, therefore, have some potential for mitigating flood damages. The entire 3.5-mile-long length of this diversion route would lie outside the Village of Pewaukee.

This diversion of floodwaters directly from Pewaukee Lake through the Town of Pewaukee and the City of Waukesha was eliminated from further consideration for three reasons. First, inasmuch as the entire route of this diversion lies outside the Village of Pewaukee and yet is intended to resolve flood problems occurring within the Village, it would be politically and administratively difficult for the Village of Pewaukee to both implement and operate such a flood control measure. Second, the diversion of floodwaters directly from Pewaukee Lake is likely to have a flood damage mitigation effect on the Village of Pewaukee similar to that of the Pewaukee Lake storage alternative; that is, the diversion is likely to resolve only a portion of the total flood problem within the Village. Third, the preliminary cost estimates indicate that the total capital cost of the various elements comprising the 3.5-mile-long diversion—construction of a Pewaukee Lake Outlet control structure, acquisition of land, channel excavation, and bridge and culvert replacement—would be very high, in excess of three million dollars. While both the diversion from Pewaukee Lake and storage on Pewaukee Lake would yield similar flood mitigation benefits, the capital cost of the former is about 10 times that of the latter and, therefore, Lake diversion is not an economically feasible floodland management measure.

Diversion from the Pewaukee River: Another diversion possibility explored under the Village of Pewaukee floodland management study was the interception of floodwaters at a location on the Pewaukee River upstream of the residential and commercial flood problem areas in the Villlage of Pewaukee. These floodwaters would be conveyed by means of a diversion following the route shown on Map 9 and be discharged back into the Pewaukee River downstream of the flood problem areas. As shown on Map 10, the diversion would consist primarily of a turf-lined channel with short reaches of concrete conduit and would have a total length of about 1.2 miles--1.14 miles of which would lie within the Village of Pewaukee and 0.06 mile in the Town of Pewaukee. The channel bottom elevation at the upstream end would be at an elevation of about 845.0 feet above National Geodetic Vertical Datum and the downstream invert would be at an elevation of about 840.5 feet

Map 9

POTENTIAL FLOODWATER DIVERSIONS IN THE PEWAUKEE RIVER SUBWATERSHED



Source: SEWRPC.

Map 10

PEWAUKEE RIVER DIVERSION IN THE VILLAGE OF PEWAUKEE

LEGEND

- – – VILLAGE OF PEWAUKEE CORPORATE LIMITS
- 100-YEAR RECURRENCE INTERVAL FLOODLANDS UNDER 2000 PLAN LAND USE AND EXISTING CHANNEL CONDITIONS
- AREA WHERE TOPOGRAPHY HAS BEEN ALTERED SINCE DATE OF MAPPING
- PROPOSED TURF CHANNEL
- PROPOSED TURF CHANNEL WITH EARTHEN BERMS
- PROPOSED CONDUIT
- APPROXIMATE LOCATION OF PROPOSED DIVERSION CONTROL STRUCTURE
- PROPOSED BRIDGE REPLACEMENT (COSTS ASSIGNABLE TO THIS ALTERNATIVE)
- PROPOSED BRIDGE CONSTRUCTION (COSTS ASSIGNABLE TO THIS ALTERNATIVE)

NOTE:

1. THE COST OF THE CTH SS PORTION OF THE PROPOSED CONDUIT IS NOT ASSIGNABLE TO THIS ALTERNATIVE.
2. THE 100-YEAR RECURRENCE INTERVAL FLOODLAND WAS REDUCED UNDER THIS ALTERNATIVE, HOWEVER, THE REDUCTION IS INSIGNIFICANT WHEN SHOWN ON SMALL SCALE AERIAL PHOTOGRAPHS

GRAPHIC SCALE
0 500 1000 2000 FEET

Source: SEWRPC.

above National Geodetic Vertical Datum for a total drop, and therefore available hydraulic head, of 4.5 feet. For the purpose of the preliminary investigation, it was assumed that the diversion would convey the entire Pewaukee River flow which is tributary to the point of diversion along with local inflow from the surrounding topography during major flood events but remain dry, or nearly so, under normal flow conditions. The physical characteristics of the Pewaukee River diversion and the attendant costs and benefits are set forth in Table 7.

The flood flow model was applied to the Pewaukee River subwatershed using the complete available meteorological data base—consisting of 35 years of data—and assuming year 2000 plan land use-floodland development conditions and construction of the Pewaukee River diversion channel. This model application yielded flood flows corresponding to the 35-year period of meteorological conditions at selected points along the Pewaukee River, Pewaukee Lake Outlet, and the Pewaukee River diversion, including two locations within flood-prone reaches in the Village of Pewaukee.

The hydrologic effect of the Pewaukee River diversion is illustrated in Figure 9 which depicts flood flow hydrographs for the Pewaukee River downstream of CTH SS at Station 350080 as those hydrographs would occur in response to the meteorological events which produced the April 1973 flood occurring under the year 2000 plan conditions with and without the Pewaukee River diversion. The effect of the diversion should be evident at CTH SS since this bridge is located upstream of the point at which floodwaters diverted from the Pewaukee River would be returned to the Pewaukee River. The diversion of flood flows could be expected to reduce the peak discharge of this flood—which had a recurrence interval at this location of about 50 years—from 770 cfs to 500 cfs, a reduction of 35 percent.

The series of flood flows at these locations then was used to develop Log Pearson Type III discharge-frequency relationships. Figure 10 shows the discharge-frequency relationships for the Pewaukee River downstream of CTH SS at Station 350080 with and without the Pewaukee River diversion and indicates that the 100-year recurrence interval discharge could be reduced 18 percent from 1,000 cfs to 820 cfs as a result of the construction of the diversion. The effect of the diversion on the full spectrum of flood flows is seen to be very similar to the effect of the Capitol Drive detention reservoir.

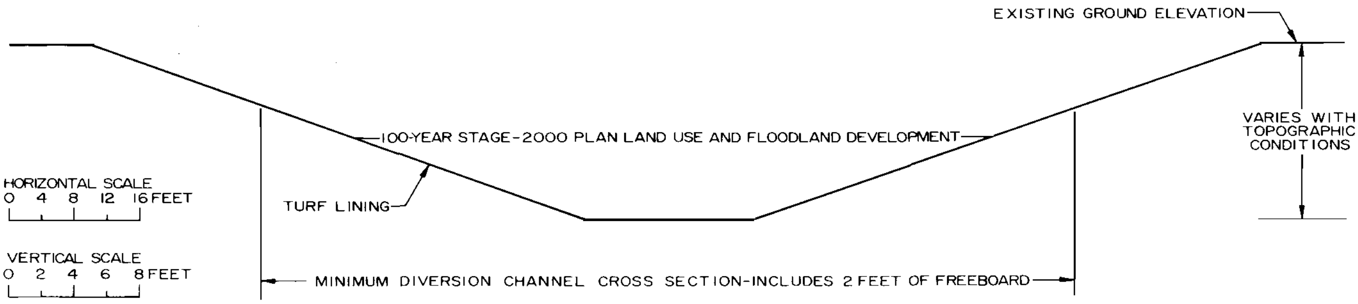
The model was then used to compute flood stage profiles through the flood-prone reaches for selected recurrence intervals. The resulting flood stage profiles were found to be lower than those without the diversion with the reduction in stage associated with the 100-year recurrence interval discharge ranging from zero to 1.2 feet with the largest stage increase occurring on the Pewaukee River just upstream of CTH J at Station 365500, which is located downstream of the point of diversion. The River diversion could be expected to effect an approximate 0.1 foot decrease in the 100-year recurrence interval flood stage profile under year 2000 plan land use-floodland development conditions on the Pewaukee River at CTH SS and 0.3 feet on the Pewaukee River at Oakton Avenue. The resulting stage-probability information was then used in the model to compute average annual monetary risks.

A design flow of 270 cfs was selected for the diversion. This flow is the 100-year recurrence interval discharge of the diversion under year 2000 conditions at its downstream confluence with the Pewaukee River. Hydraulic calculations indicate that a channel having a bottom width of about 10 feet, depth of 7 feet, including 2 feet of freeboard, with side slopes of one on three would be required to convey the design flow. A typical cross section of the channel is shown in Figure 11. A potential negative feature of turf-lined channels is their susceptibility to erosion damage. Even if turf channels are well maintained, flood flow velocities in excess of five feet per second may be expected to cause erosion problems. Hydraulic analyses of the turf-lined diversion channel, however, indicated that the 100-year recurrence interval flood flow under year 2000 plan conditions could be expected to produce a velocity of only about two feet per second due to the mild slope and, therefore, erosion would not be a serious problem.

The 850-foot-long portion of the diversion between Hickory Drive and the Chicago, Milwaukee, St. and Pacific Railroad crossing would be enclosed inasmuch as the Village's planned industrial parkway closely follows the alignment of the proposed diversion, necessitating the use of a closed conduit. Hydraulic calculations indicate that two parallel five foot by 10 foot box culverts would be required to convey the 100-year recurrence interval flood

Figure 11

TYPICAL CROSS SECTION OF THE PEWAUKEE RIVER DIVERSION CHANNEL IN THE VILLAGE OF PEWAUKEE



Source: SEWRPC.

flow through this reach. Shallow bedrock formations in this area would require blasting during the construction of the diversion. The attendant increased construction costs have been incorporated in the total cost of this alternative.

Construction of the diversion would require the demolition and replacement of existing bridges at the following three locations, listed in downstream order, in the Village of Pewaukee: the Chicago, Milwaukee, St. Paul and Pacific Railroad, Hickory Drive, and CTH SS. For the purposes of preliminary investigations, it was assumed that the Hickory Drive to CTH SS portion of the diversion would be replaced by a 300-foot-long section of conduit due to lateral limitations. In addition, a new bridge would have to be constructed at Capitol Drive (USH 190) inasmuch as there are presently no waterway openings at that location. The demolition and construction costs for all of the above structures would be charged to this alternative with the exception of the CTH SS portion of the proposed conduit, about 50 feet, which is recommended for replacement under the adopted jurisdictional highway system plan for Waukesha County.

The Wisconsin Department of Transportation has prepared preliminary plans for alteration of the STH 190-USH 16 interchange in the northwestern portion of the Village of Pewaukee. As shown on Map 9, the alignment of the diversion channel would cross STH 190 along the eastern end of the proposed interchange. The interchange, however, should not affect the proposed alignment of the diversion channel nor would it significantly alter the cost of the new hydraulic structures needed to carry the diversion channel beneath STH 190.

Earthen dikes or berms would be required along both sides of the diversion channel where the existing topography does not provide sufficient relief to contain the design flow. These earthen dikes, which would rise about three feet above the existing ground level, would be required along approximately 700 feet of the diversion channel as shown on Map 10.

The capital cost of the diversion is estimated at $1,223,900, consisting of $648,600 for channel construction and land acquisition, $568,000 for bridge demolition and construction, $3,900 for the diversion structure, and $3,400 for construction of earthen embankments. The average annual cost equivalent to the $1,223,900 capital cost of the diversion at a 6 percent interest rate and for a project life and amortization period of 50 years would be $77,600. Adding estimated operation and maintenance costs of $500 per year yields a total annual cost of $78,100.

The flood control benefits which could be expected to result from this expenditure would be a 28 percent reduction in average annual flood damages, from $169,800 to $122,000, to the residential and commercial areas along the Pewaukee River and Pewaukee Lake outlet in the Village of Pewaukee. Thus, the average annual benefit would approximate $47,800 in the Village of Pewaukee. The resulting benefit-cost ratio would be 0.61 and the annual excess of costs over benefits would be about $30,300. Therefore, the river diversion alternative is an economically unsound, although technically feasible, means of abating a portion of the flood problem within the Village of Pewaukee.

As already noted, the cost of the CTH SS crossing of the Pewaukee River was excluded from the above detailed cost analysis since it is recommended for replacement under the adopted jurisdictional highway system plan for Waukesha County. If the $40,000 capital cost of the CTH SS structure is assigned to this alternative, the total capital cost would be increased to $1,263,900 and the average annual amortization cost would be increased to $80,200. Adding estimated operation and maintenance expenditures of $500 per year yields a total annual cost of $80,700, $2,600 more than when the cost of the River crossing is excluded from the economic analysis. The average annual flood control benefit would remain at $47,800 and, therefore, the benefit-cost ratio would be reduced from 0.61 to 0.59, and the annual excess of costs over benefits would be increased from $30,300 to $32,900.

The principal negative noneconomic and nontechnical feature of the Pewaukee River diversion alternative is the possibility that flood-prone development may occur along the Pewaukee River downstream of the point of diversion.

A possible variation on the above-described Pewaukee River diversion was also considered. Under this variation floodwaters would be intercepted on the Pewaukee River upstream of the Village and conveyed by means of gravity flow in a diversion channel around the northern edge of the Village to Pewaukee Lake for temporary storage. This potential diversion of floodwaters from the Pewaukee River around the Village of Pewaukee to Pewaukee Lake was eliminated from further consideration for two reasons. First, to assure gravity flow from the Pewaukee River to Pewaukee Lake, the upstream end of the diversion would have to be located at least as far upstream as the CTH JF crossing of the Pewaukee River, located about 0.8 mile upstream of the point of diversion for the above-described Pewaukee River to Pewaukee River diversion alternative. Since the Pewaukee River to Pewaukee Lake diversion would control even less tributary area than the Pewaukee River to Pewaukee River diversion, the former would be less effective than the latter in reducing flood discharges, stages, and damage in the Village. Second, some floodwaters would be diverted to Pewaukee Lake for temporary storage, necessitating a measure such as modification of the outlet control structure to effect such storage while protecting areas in the Village immediately downstream of the lake.

Structure Floodproofing

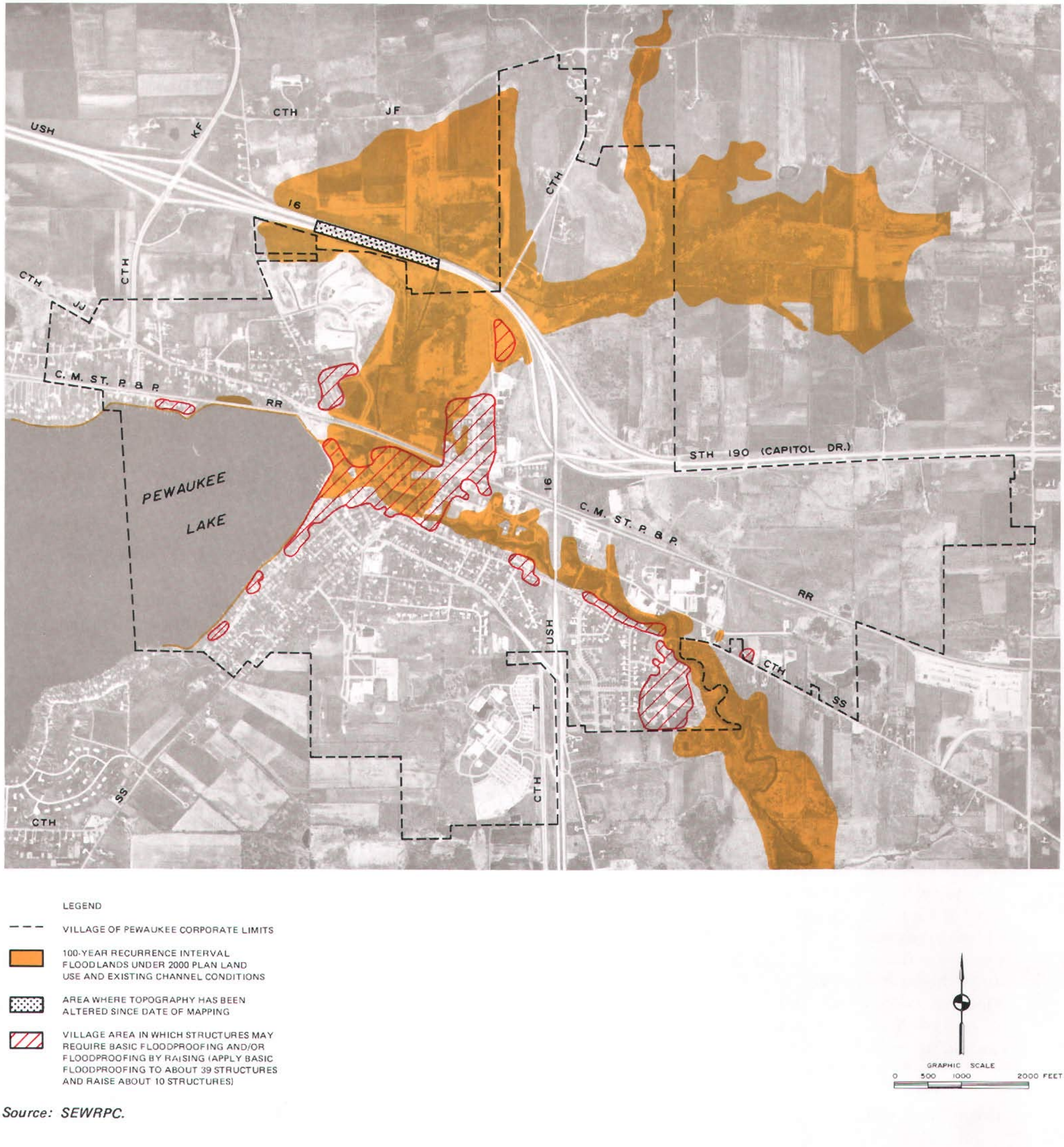
A floodproofing and removal alternative was developed and analyzed to determine if such a structure-by-structure approach would be a technically, economically, and environmentally acceptable solution to the flood problem in the Village of Pewaukee. As noted above, although floodproofing and removal are categorized as nonstructural measures, they were examined in conjunction with structural measures because they effectively complement structural measures in a technical sense and because they, like structural measures, are amenable to benefit-cost analysis. For purposes of this analysis, the 100-year recurrence interval flood event under year 2000 plan conditions was used as a basis for determining how many flood-prone structures would have to be floodproofed or removed.

In the case of residential structures in the primary flooding zone, basic floodproofing was assumed to be feasible if the design floodstage was below the first floor elevation. If the design flood stage was at or above the first floor elevation, floodproofing by structure elevation was assumed to the extent that it would be less costly than structure removal. Basic floodproofing was assumed to be feasible for all nonresidential structures within the primary flooding zone irrespective of flood stage, with the floodproofing cost for stages above the first floor being a function of the distance between the flood stage and the first floor elevation. For structures located in the secondary flooding zone, that is, outside of but immediately adjacent to the 100-year recurrence interval floodlands, it was assumed that floodproofing would be applied to those structures with basement floors below the elevation of the design flood stage. The total floodproofing cost so computed for the secondary flooding zone was then reduced by 0.50 to 0.90 to reflect the fact that not all buildings in that zone with basement floors set at an elevation below the design flood stage would in fact incur secondary flooding. The factor assigned to each flood-prone reach was the same as that used to compute flood damage in the secondary zone.

As shown on Map 11, the analyses indicated that about 10 structures would have to be floodproofed by raising them above the 100-year recurrence interval flood stage under this alternative and about 39 structures located in the primary and secondary flood zones would require some form of less extensive floodproofing. Future flood damage to private residences and commercial

Map 11

STRUCTURE FLOODPROOFING ALONG THE PEWAUKEE RIVER, PEWAUKEE LAKE OUTLET, AND PEWAUKEE LAKE IN THE VILLAGE OF PEWAUKEE



Source: SEWRPC.

structures within the Village of Pewaukee would be virtually eliminated by the floodproofing. Table 7 sets forth the approximate number of structures to be floodproofed and also summarizes the estimated costs and benefits.

Assuming that the aforementioned structure floodproofing measures would be fully implemented and utilizing an annual interest rate of 6 percent and a project life and amortization period of 50 years, the equivalent average annual cost is estimated at about $51,500, consisting entirely of the amortization of the $644,700 capital cost for basic floodproofing and $167,400 for floodproofing by raising. The average annual flood abatement benefit is estimated at about $169,800, yielding a benefit-cost ratio of 3.30 and an excess of annual benefits over costs of about $118,300. Therefore, the structure floodproofing alternative, as described herein, would be both technically and economically feasible within the Village of Pewaukee.

The principal noneconomic and nontechnical characteristics of the structure floodproofing alternative are presented in Table 7. The two positive features which are associated with the structure floodproofing alternative are: 1) provision of immediate partial relief to some riverine property owners through application of floodproofing; and 2) assignment of flood protection cost directly to beneficiaries.

The following three negative features are associated with the structure floodproofing alternative: 1) the likelihood that complete voluntary implementation of the floodproofing will not be achieved, therefore leaving the residual problem; 2) problems associated with overland flooding will remain in areas provided with floodproofing; and 3) the strong possibility that some floodproofing will be applied without adequate professional advice, resulting in structure damage and danger to occupants.

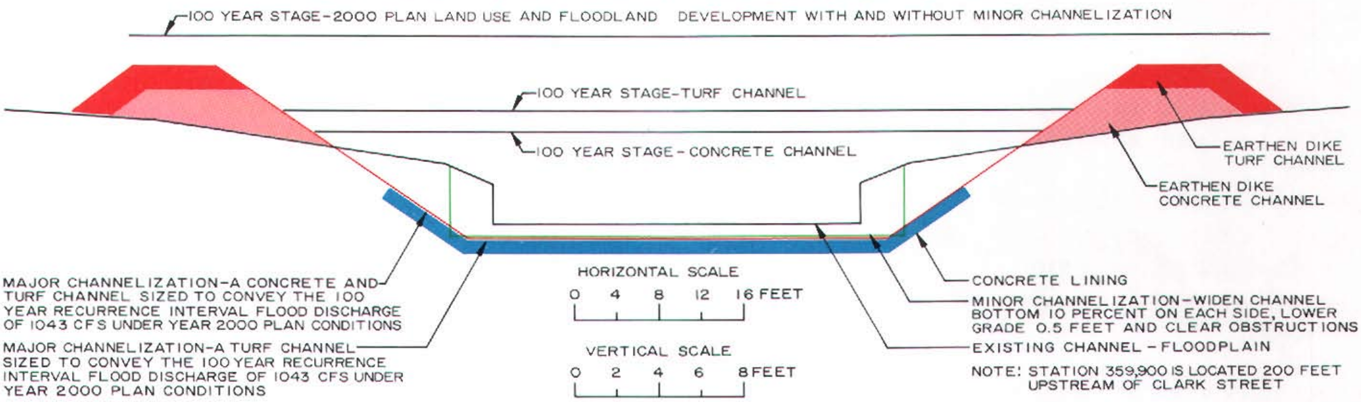
Minor Channel Modification

An often suggested method for resolving flood problems—but one usually ineffective insofar as major flood events are concerned—is to undertake a program of minor and selective channel clearing, deepening, widening, and shaping. This approach is intended to remove "obstructions" to flow with little effort and expense, thereby making the channel system itself more efficient so that flood flows may be conveyed at lower stages.

A minor channel clearing, deepening, widening, and shaping alternative was developed for a 2.4-mile-long reach of the Pewaukee River in the Village bounded at the downstream end by the Village limits at Station 351570 and at the upstream end by STH 16 at Station 364340 and the 0.1-mile-long farthest downstream portion of the Pewaukee Lake Outlet in the Village. Under this alternative and as illustrated in Figure 12, it was assumed that these reaches of the Pewaukee River and Pewaukee Lake Outlet in the Village of Pewaukee would be cleared of obstructions, deepened by about one-half foot and that the bottom width would be increased by 10 percent on each side. A schedule

Figure 12

CROSS SECTIONS CORRESPONDING TO EXISTING TOPOGRAPHIC CONDITIONS, MINOR CHANNELIZATION, AND MAJOR CHANNELIZATION AT STATION 359,900 ON THE PEWAUKEE RIVER IN THE VILLAGE OF PEWAUKEE



Source: SEWRPC.

of the physical characteristics of the minor channelization project and the attendant costs and benefits is set forth in Table 7.

The model was then used to compute flood stage profiles through the flood-prone reaches in the Village for selected recurrence intervals. The resulting 100-year recurrence interval flood stages were found to be up to 0.7 foot lower than those existing in the absence of the minor channel modification. The resulting stage-probability information was then used in the model to compute average annual monetary flood risks.

The capital cost of the minor channel modification alternative was estimated at $80,100. The average annual cost equivalent to the $80,100 capital cost of the minor channel modification at a 6 percent interest rate and for a project life of 50 years and amortization period of 50 years would be $5,100.

The flood control benefits which would be expected to result from this expenditure would be a 22 percent reduction in average annual flood damages from $169,800 to $133,000 to the residential and commercial areas along the Pewaukee River and the Pewaukee Lake Outlet in the Village of Pewaukee. Thus the average annual benefit would approximate $36,800 in the Village. The resulting benefit-cost ratio would be 7.25, and the annual excess of benefits over costs would be about $31,700. Therefore, the minor channel modification alternative, as described herein, would be both a technical and economic solution to part of the flood problem in the Village of Pewaukee.

There are no significant positive nontechnical and noneconomic considerations associated with this alternative. The most critical negative aspect of this alternative is that overland flooding and attendant problems would be largely unmitigated inasmuch as minor channel modification would cause only a slight decrease in stages of severe floods.

Major Channel Modification

Two major channel modification alternatives were developed and analyzed for the portion of the Pewaukee River and the Pewaukee Lake Outlet in the Village of Pewaukee in order to determine if such a structural measure would provide a technically feasible, economically sound, and environmentally acceptable solution to the Village's flood problem. The proposed channels were designed to pass the 100-year recurrence interval flood discharges under year 2000 land use plan conditions without overtopping.

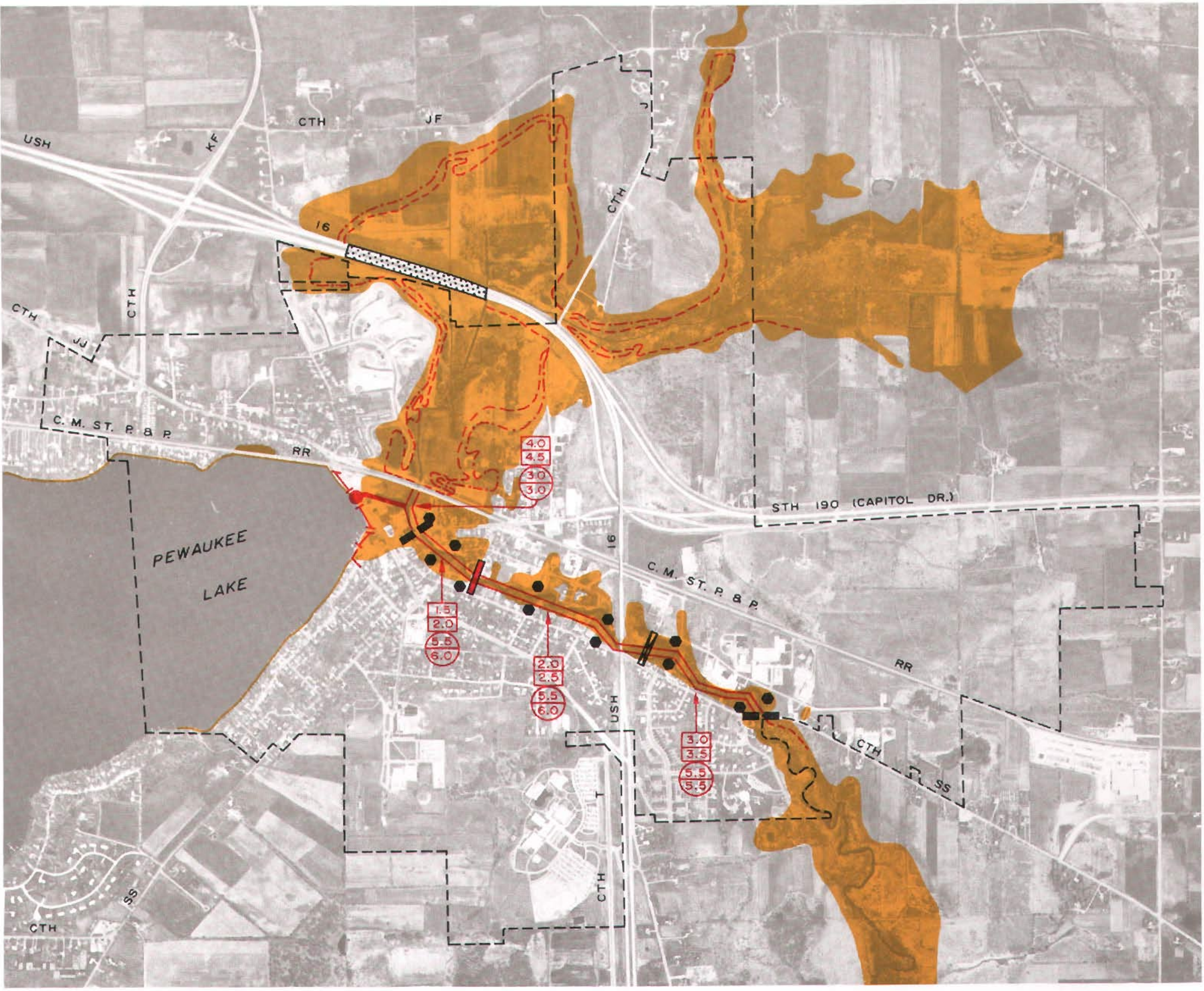
Concrete-Lined Channel with Supplemental Measures: The major concrete channelization alternative for the Pewaukee River in the Village of Pewaukee is shown on Map 12. A representative channel-floodplain cross section is shown in Figure 12. A schedule of the physical characteristics of the major concrete channel modifications and the attendant costs and benefits is set forth in Table 7. Under this alternative, channel modifications would be carried out over a total of about 1.9 miles of the Pewaukee River. Of the 1.9 miles of channel modification, the upstream 0.9 mile would consist of major channel modifications and the remaining 1.0 mile would consist of transition between the channelized cross section and the natural river cross section with the farthest downstream 0.6 mile of transition section consisting of minor channel bottom lowering. The improved channel would be located along or near the alignment of the Pewaukee River in the Village of Pewaukee, extending from the Village limits at the downstream end at Station 351570 to the Chicago, Milwaukee, St. Paul and Pacific Railroad at the upstream end at Station 361300.

Moving in a downstream direction, the channelization would lower the existing Pewaukee River channel grade by 1.0 foot at the Chicago, Milwaukee, St. Paul and Pacific Railroad crossing, about 0.4 foot at Oakton Avenue, 1.0 foot at Clark Street, 1.4 feet at the USH 16 crossing and about 0.8 foot at CTH SS, as shown in Figure 13. In addition, the channel invert between CTH SS and the Village corporate limits would have to be lowered in order to provide a transition between the channelization and natural channel profile. The width of the invert or bottom of the concrete channel within the Village of Pewaukee, as illustrated in Figure 12, would be 40 feet for the Pewaukee River with side slopes of one on three. The bottom and the side slopes, up to a 10-year recurrence interval flood stage, would be lined with concrete resulting in a total concrete width of about 50 feet.

The channelization would require the demolition and replacement of the existing bridges at the following three crossings of the Pewaukee River in the Village of Pewaukee, listed in downstream order: Oakton Avenue, Clark Street, and CTH SS. In addition, a private bridge at Station 356800 would be removed and not replaced and the waterway under the USH 16 bridge at Station 357100 would be altered. The cost of the Clark Street replacement was charged against the major concrete channelization alternative. The replacement

Map 12

MAJOR CHANNEL MODIFICATIONS ALONG THE PEWAUKEE RIVER AND PEWAUKEE LAKE OUTLET IN THE VILLAGE OF PEWAUKEE



LEGEND

VILLAGE OF PEWAUKEE CORPORATE LIMITS

100-YEAR RECURRENCE INTERVAL FLOODLANDS UNDER 2000 PLAN LAND USE AND EXISTING CHANNEL CONDITIONS

AREA WHERE TOPOGRAPHY HAS BEEN ALTERED SINCE DATE OF MAPPING

APPROXIMATE LATERAL EXTENT OF PROPOSED MAJOR TURF OR CONCRETE CHANNEL WITH SUPPLEMENTAL DIKE/FLOODWALL

5.5 / 6.0 APPROXIMATE DEPTH OF PROPOSED CONCRETE CHANNEL/APPROXIMATE DEPTH OF PROPOSED TURF CHANNEL IN FEET

1.5 / 2.0 APPROXIMATE HEIGHT OF PROPOSED DIKE OR FLOODWALL FOR CONCRETE CHANNEL/APPROXIMATE HEIGHT OF PROPOSED DIKE OR FLOODWALL FOR TURF CHANNEL IN FEET ABOVE EXISTING GROUND ELEVATION

APPROXIMATE LOCATION OF PROPOSED STORM WATER PUMPING STATION

PROPOSED BRIDGE REPLACEMENT (COSTS ASSIGNABLE TO THIS ALTERNATIVE)

PROPOSED BRIDGE REPLACEMENT (COSTS NOT ASSIGNABLE TO THIS ALTERNATIVE)

PROPOSED BRIDGE REMOVAL

APPROXIMATE LOCATION OF PROPOSED PEWAUKEE LAKE OUTLET CONDUIT

PROPOSED LAKE LEVEL CONTROL STRUCTURE

PROPOSED CONCRETE FLOODWALL

PROPOSED EARTHEN DIKE

100-YEAR RECURRENCE INTERVAL FLOOD LINE UNDER 2000 PLAN LAND USE CONDITIONS WITH PROPOSED CONCRETE CHANNEL (SAME AS WITH EXISTING CHANNEL CONDITIONS IF NOT SHOWN)

100-YEAR RECURRENCE INTERVAL FLOOD LINE UNDER 2000 PLAN LAND USE CONDITIONS WITH PROPOSED TURF CHANNEL (SAME AS WITH CONCRETE CHANNEL IF NOT SHOWN)

NOTE: BETWEEN CAPITOL DRIVE AND CTH SS THE 100-YEAR RECURRENCE INTERVAL FLOOD WOULD BE CONTAINED WITHIN THE PROPOSED MAJOR CHANNEL. BETWEEN PEWAUKEE LAKE AND THE PEWAUKEE RIVER THE 100-YEAR RECURRENCE INTERVAL FLOOD WOULD BE CONTAINED WITHIN THE PROPOSED CONDUIT.

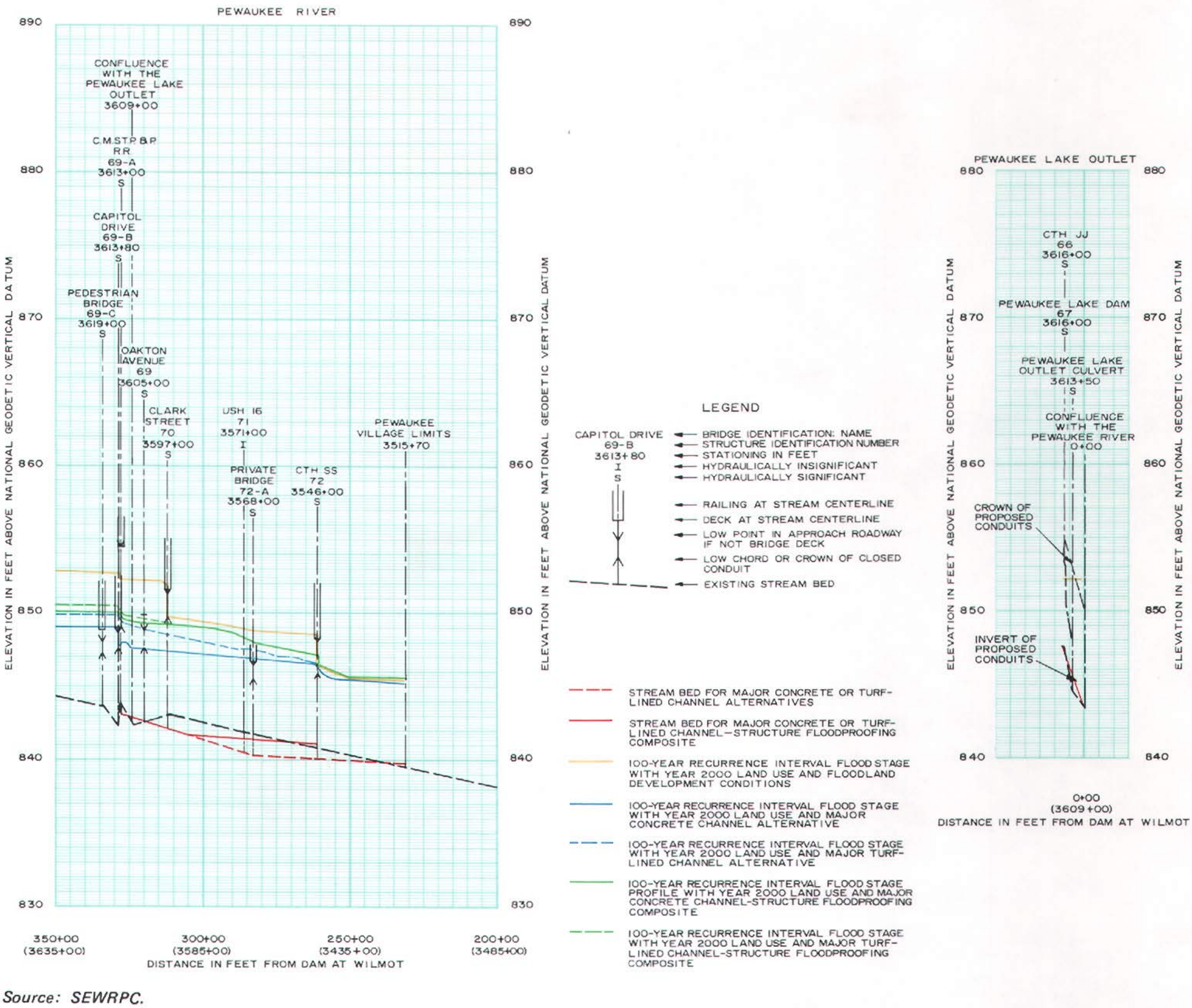
GRAPHIC SCALE

0 500 1000 2000 FEET

Source: SEWRPC.

Figure 13

FLOOD STAGE AND STREAM BED PROFILES FOR THE PEWAUKEE RIVER AND PEWAUKEE LAKE OUTLET IN THE VILLAGE OF PEWAUKEE WITH AND WITHOUT MAJOR CHANNELIZATION



Source: SEWRPC.

of the Oakton Avenue and CTH SS crossing is recommended under the adopted jurisdictional highway system plan for Waukesha County and, therefore, was not charged against the major concrete channelization alternative. The replacement of the USH 16 bridge is currently scheduled by the Wisconsin Department of Transportation and, therefore, alteration of the waterway was not charged against this alternative.

Earthen dikes or embankments, as shown in Figure 12, would be required along all of the proposed open channel. These earthen dikes, which would rise to an average of about 2.5 feet above the existing River bank level, are required because the longitudinal channel bottom slope of the Pewaukee River reach requiring protection is extremely flat—about three feet per mile—and because lateral excavation is restricted by existing development. Use of supplemental earthen dikes permits a shallower channel excavation through the reach requiring flood protection which, in turn, means that a shorter length of river downstream of the channel reach will be needed to affect a smooth transition from the lower channel bottom in the protected reach to the natural channel bottom downstream. More specifically, the supplemental earthen dike would permit termination of the channel modification at the farthest downstream limit of the Village of Pewaukee so as not to extend downstream south of the Village into the park lands recently acquired along the Pewaukee River by Waukesha County in the Town of Pewaukee.[8] It should be noted that narrow concrete floodwalls may be required in the place of earthen dikes at several locations due to existing structures and land uses which limit the lateral extent of land available along the Pewaukee River.

Because of the required earthen dikes on both sides of the channel, the major concrete channelization alternative would have to include provision for the construction of a minimum of 12 major storm water lift or pumping stations and backwater gates near the end of storm sewer outfalls or natural drainageways that are tributary to the Pewaukee River. These facilities would be required to prevent the movement of floodwaters from the river into the surrounding urban area via these storm sewers and drainage channels and to prevent the accumulation of lateral runoff behind the dikes and floodwalls creating local drainage problems.

In addition to the channelization of the Pewaukee River, preliminary economic analyses indicated that enclosing the 0.15-mile Pewaukee Lake Outlet in two or more parallel conduits would be less costly than a large open channel. This would be accomplished by reconstructing 0.05 mile of existing enclosed channel and constructing 0.10 mile of new channel enclosure. For purposes of this report, it was assumed that the conduits would be located along or near the alignment of the existing Pewaukee Lake Outlet channel from Station 360900 at the Pewaukee Outlet-Pewaukee River confluence to Station 361600 at the existing Pewaukee Lake dam. The conduits would have a total length of about 0.14 mile. The upstream invert would be at an elevation of about 848.5 feet above National Geodetic Vertical Datum and the downstream invert would be at an elevation of about 843.5 feet above National Geodetic Vertical Datum for a total drop and, therefore, available hydraulic head of 5.0 feet. Alternative routes for the Pewaukee Lake Outlet exist within the Village, such as the vacant corridor running parallel to Oakton Avenue from the southern edge of the Pewaukee Lake beach to the existing Pewaukee Lake Outlet-Pewaukee River confluence. The use of alternate routes, however, is not likely to significantly affect the total cost of the major channelization alternative.

A design flow of 1,000 cfs was selected for the Pewaukee Lake Outlet, the 100-year recurrence interval flood discharge of Pewaukee Lake under year 2000 plan conditions. Hydraulic calculations indicate that two conduits having diameters of approximately eight feet would be required to carry the design flow under gravity flow conditions using the available hydraulic head. Two elliptical conduits of equivalent pipe size were selected in order to minimize the aesthetic impact of the enclosure.

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[8] *In 1977 Waukesha County began to acquire land along the Pewaukee River reach bounded at the upstream end by the southern limits of the Village and at the downstream end by IH 94 as part of the Pewaukee River Parkway. See Waukesha County Park and Planning Commission, "Pewaukee River Parkway Environmental Assessment Statement," February 14, 1977, and "Amendment to Pewaukee River Parkway Environmental Assessment Statement," April 8, 1977.*

The existing Pewaukee Lake level control structure would require either modification in the form of a second parallel structure or replacement[9] in order to provide sufficient capacity to discharge the 100-year recurrence interval flood flow under 2000 plan conditions from Pewaukee Lake without affecting the 100-year recurrence interval lake stage of 854.6 feet above National Geodetic Vertical Datum. This design criterion was selected in order to prevent the occurrence of higher lake stages which could be expected, as discussed above, to produce increased flood damage to lake properties and also to prevent increased lake discharges which could be expected to increase flood damage along the reaches of the Pewaukee Lake Outlet and Pewaukee River downstream of Pewaukee Lake in the Village of Pewaukee.

In order to prevent flood damage caused by high lake levels along the W. Wisconsin Avenue and Park Avenue commercial corridor, an earthen dike-floodwall system would be required as shown on Map 12. The dikes and floodwalls would be located parallel to Wisconsin Avenue in the Village-owned beach area and would pass through privately owned boat launching and docking facilities south of the beach. These dikes and floodwalls, which would have a maximum height of 2.5 feet, could be constructed so as not to interfere with access to either the beach or the boating facilities. One practical approach would be to use earthen berms along Wisconsin Avenue which could be readily crossed by beach users and to use broad-based concrete or asphalt surfaced berms in the boat launching area to provide cars and boat trailers with easy access to the launching ramps.

It was assumed that possible sanitary sewer surcharging caused by overland flooding along the Pewaukee River in those areas not protected by the major concrete channelization alternative would be eliminated as part of the Village's infiltration/inflow removal program. For example, sanitary sewers located north of Capitol Drive within the 100-year recurrence interval floodplain would be protected from clearwater inflow by sealed manhole covers.

Assuming the aforementioned major concrete channelization project would be fully implemented and utilizing an interest rate of 6 percent and a project life and amortization period of 50 years, the average annual cost is estimated at about $333,600, consisting of the following: amortization of the $3,237,200 capital cost of the channel modifications, amortization of the $308,800 capital cost of dike and floodwall construction, amortization of the $96,000 capital cost of bridge demolition and replacement, amortization of the $294,500 capital cost of the lake level control structure and Pewaukee Lake Outlet enclosure, amortization of the $1,068,000 capital cost of construction of storm water pumping stations, and $16,100 in annual operation and maintenance costs. Assuming that the major concrete channelization alternative would completely eliminate all direct and indirect flood damage along the Pewaukee River in the Village of Pewaukee extending from CTH SS at Station 354600 to the Chicago, Milwaukee, St. Paul and Pacific Railroad at Station 361300, along the entire Pewaukee Lake Outlet and around Pewaukee Lake along the W. Wisconsin Avenue and Park Avenue commercial area in the Village, the average annual flood abatement benefit is estimated at about $143,100, yielding a benefit-cost ratio of 0.43 and an annual excess of costs over benefits of $190,500. Therefore, major channelization as described above, although technically practicable, is economically unsound in the Village of Pewaukee.

As already noted, the costs of the CTH SS and Oakton Avenue crossings of the Pewaukee River were excluded from the above detailed cost analysis since they are recommended for replacement under the adopted jurisdictional highway system plan for Waukesha County. If the $206,000 capital costs of the CTH SS and Oakton Avenue structures are assigned to this alternative, the total capital cost increases to $5,210,500 and the average annual amortization cost increases to $330,600. Adding estimated operation and maintenance expenditures of $16,100 per year yields a total annual cost of $346,700—$13,100 more than when the costs of the two river crossings are excluded from the economic analysis. The average annual flood control benefit would remain at $143,100 and, therefore, the benefit-cost ratio would be reduced

[9] *The Pewaukee Lake Outlet control structure was replaced in 1975. This action was not recommended in the adopted comprehensive plan for the Fox River watershed but was recommended by the Wisconsin Department of Natural Resources for fish and vegetation management, flood control, and low flow control purposes as set forth in the Department's report entitled: Pewaukee Lake, Waukesha County, Wisconsin, Lake Use Report No. FX-2, 1970.*

from 0.43 to 0.41 and the annual excess of costs over benefits would be increased from $190,500 to $203,600.

Two positive nontechnical and noneconomic features of the concrete-lined channel alternative are set forth in Table 7. First, this alternative would provide an opportunity to develop a water-oriented greenway along the Pewaukee River through the business-commercial area of the Village. The Pewaukee River and lands lying along it within the Village of Pewaukee have been defined as primary environmental corridor in the Commission's year 2000 land use plan. Although present encroachment onto the floodplains and into the channel of the Pewaukee River detracts substantially from the appearance of this area, the area could be restored to the corridor use by developing a continuous parkway from Capitol Drive at the upstream end to CTH SS at the downstream end. Because of the surrounding intensive business and commercial land uses, the parkway would necessarily have to have an urban character and would offer only limited outdoor recreational opportunities such as pleasure walking and adding beauty and "green" open space to the urban area. Channelization in this portion of the Village could provide the major focus or framework within which such an urban-oriented parkway could be developed. The channelized reach could be developed as an urban parkway with grassy areas, pleasure walks, ponds, and attractive plantings of trees and shrubs.

The second positive feature of the concrete-lined channel alternative is the elimination of overland flooding in the Village's business district. The concrete-lined channel and the supplemental dikes and floodwalls would contain the floodwaters, thus preventing the river and lake from "spilling" over their respective banks. This would diminish damage and disruption and enhance the development potential of the commercial area. Vacant land thus protected from inundation would be available for development, for example, the area bounded by the Pewaukee River, the Pewaukee Lake Outlet, and the Chicago, Milwaukee, St Paul and Pacific Railroad.

Turf-Lined Channel with Supplemental Measures: A second major channel modification alternative was analyzed for the Village of Pewaukee consisting of a completely turf-lined channel, as shown on Map 12, with a channel-floodplain cross section, as shown on Figure 12. The extent of the major turf channel improvements is the same as described above for the major concrete channel including supplementing the major channel modification with dikes and floodwalls, bridge demolition and replacement, enclosure of the Pewaukee Lake Outlet, a new lake level control structure, and storm water pumping stations. The physical characteristics of the major turf channel modifications, as set forth in Table 7, are the same as those of the major concrete channel modification with the exception of a turf lining replacing the concrete lining. The earthen dikes are an integral part of the turf channel and would rise an average of 3.0 feet above the existing River bank level as compared to 2.5 feet with the concrete channel. The earthen dike would permit termination of the channel modification at the farthest downstream limit of the Village of Pewaukee so as not to extend downstream south of the Village into parklands recently acquired along the Pewaukee River by Waukesha County in the Town of Waukesha. The increase in earthen dike size occurs because the turf bottom and sidewalls offer more resistance to flow than the combination of concrete and turf. Therefore, a given flood discharge will occur at a higher stage in the turf channel than in the concrete-lined channel. The Manning roughness coefficient, which is a quantitative measure of resistance to flow in an open channel, is about 0.035 for a turf channel and only about 0.017 for a concrete channel, indicating that the flow resistance of turf is approximately twice that of concrete.

A negative feature of turf-lined channels is a potential erosion problem. Even if turf channels are well maintained, flood flow velocities in excess of five feet per second may be expected to cause erosion problems. Hydraulic analyses, however, indicate that the 100-year recurrence interval flood flow under year 2000 plan conditions would produce a velocity in the turf channel of less than two feet per second because of the mild slope of the Pewaukee River and, therefore, erosion should not be a serious problem.

Assuming the aforementioned major turf channelization project would be fully implemented and utilizing an interest rate of 6 percent and a project life and amortization period of 50 years, the average annual cost is estimated at about $261,300, consisting of the following: amortization of the $2,079,000 capital cost of the channel modifications, amortization of the $308,800 capital cost of dike and floodwall construction, amortization of the $115,200 capital cost of the bridge demolition and replacement, amortization of the $294,500 capital cost of the lake level control structure and Pewaukee Lake Outlet conduits, amortization of the $1,068,000 capital cost of construction of storm water pumping stations, and $16,100 in annual operation and maintenance costs. Assuming that major turf channelization would completely eliminate all direct and indirect flood damages along the Pewaukee River in the Village of Pewaukee extending from CTH SS at Station 331300 along the entire Pewaukee Lake Outlet and around Pewaukee Lake along the W. Wisconsin Avenue and Park Avenue commercial area in the Village, the average annual flood abatement benefit is estimated at about $143,100, yielding a benefit-cost ratio of 0.55, and an annual excess of costs over benefits of $118,200. Therefore, major turf channelization as described above is an economically unsound, although technically practicable, solution to part of the flood problem in the Village of Pewaukee.

As already noted, the costs of the CTH SS and Oakton Avenue crossings of the Pewaukee River were excluded from the above detailed cost analysis since they are recommended for replacement under the adopted jurisdictional highway system plan for Waukesha County. If the $225,200 capital costs of the CTH SS and Oakton Avenue structures are assigned to this alternative, the total capital cost would be increased to $4,090,700 and the average annual amortization cost would be increased to $259,500. Adding estimated operation and maintenance expenditures of $16,100 per year would yield a total annual cost of $275,600—$14,300 more than when the costs of the two river crossings are excluded from the economic analysis. The average annual flood control benefit would remain at $143,100 and, therefore, the benefit-cost ratio would be reduced from 0.55 to 0.52 and the annual excess of costs over benefits would be increased from $118,200 to $132,500.

Two positive nontechnical and noneconomic features of the turf channel alternative are set forth in Table 7 and are identical to those associated with the concrete channel. The first significant positive feature of the turf channel is the opportunity to develop a water-oriented greenway along the Pewaukee River through the business-commercial area of the Village. The second positive feature is elimination of overland flooding in the Village business district, thereby enhancing the development of that area.

Dikes and Floodwalls

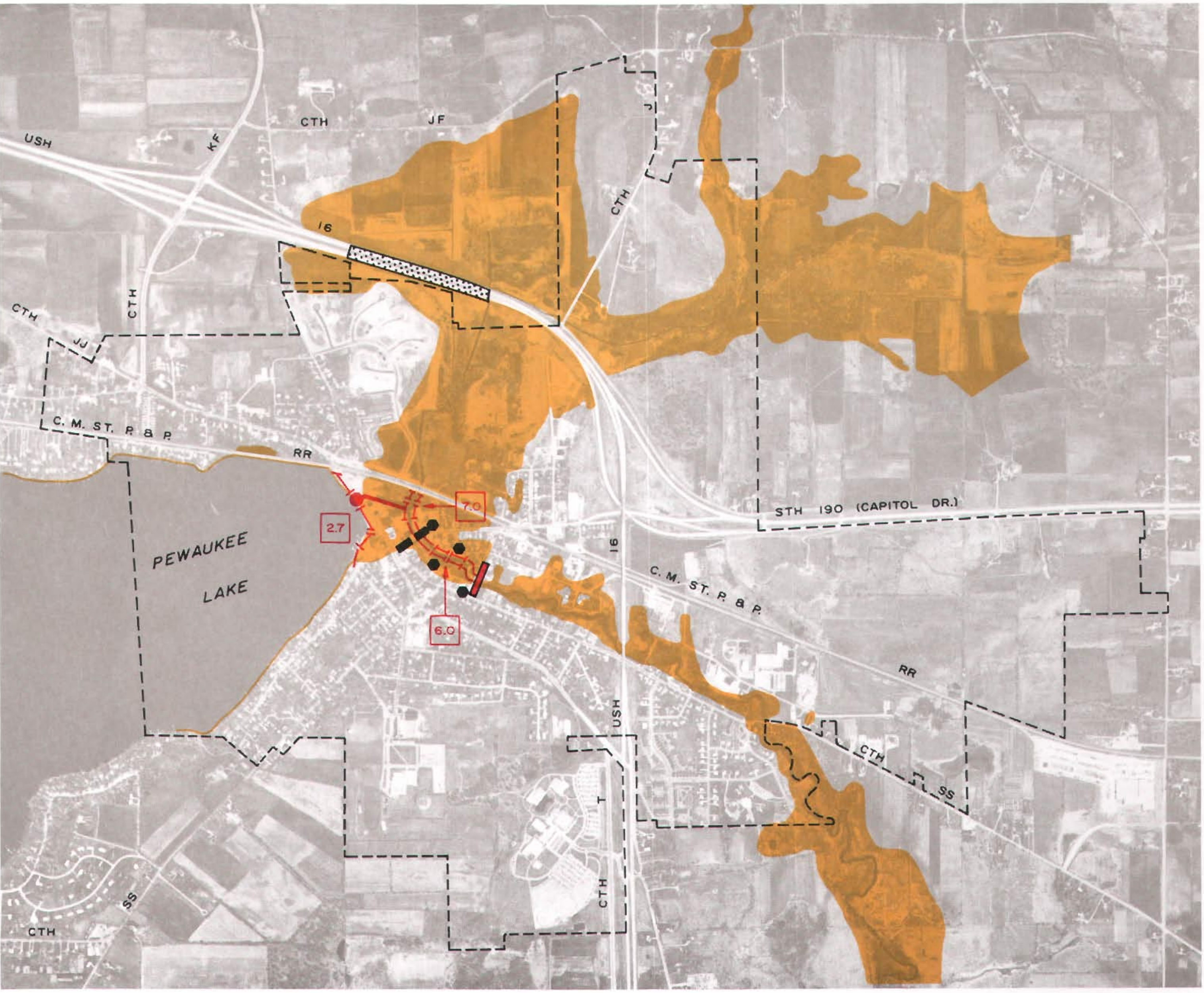
A dikes and floodwalls alternative was developed and analyzed for the lands subjected to flooding by the Pewaukee River in the reach extending from Clark Street at Station 359700 to the Chicago, Milwaukee, St. Paul and Pacific Railroad at Station 361300 and the Pewaukee Lake Outlet and Pewaukee Lake along the W. Wisconsin Avenue and Park Avenue commercial area in the Village of Pewaukee. The purpose of the alternative development and analysis was to determine if such a structural measure would provide a technically sound, economically viable, and environmentally acceptable solution to existing and probable future flood problems. The 100-year recurrence interval flood discharge under year 2000 land use plan conditions was used as the basis for a preliminary design of the dikes and floodwalls.

The dikes and floodwalls alternative for the Pewaukee River and Pewaukee Lake in the Village of Pewaukee is shown on Map 13. A schedule of the physical characteristics of the dikes and floodwalls and the attendant costs and benefits is presented in Table 7. Under this alternative, a total of about 0.79 mile of earthen dikes and concrete or sheet steel floodwalls would be constructed along both sides of the Pewaukee River extending from Clark Street at Station 359700 to the Chicago, Milwaukee, St. Paul and Pacific Railroad at Station 361300 and along 0.25 mile of Pewaukee Lake in the Village of Pewaukee. About 0.47 mile of earthen dike and about 0.32 mile of concrete or sheet steel floodwall would be required. In order to convey the design flood flow with a minimum free-board of two feet, the earthen dikes and concrete floodwalls would be extremely high in most locations with a maximum height above existing ground grade of about seven feet.

The dikes and floodwalls alternative would require the construction of new bridges at two crossings of the Pewaukee River in order to contain the floodwaters within the confines of the dikes and floodwalls. These new structures would be required at the following two crossings, listed in downstream order, of the Pewaukee River in the Village: Oakton Avenue and Clark Street. The replacement of the Oakton Avenue crossing is recommended under the adopted jurisdictional highway system plan for Waukesha County and therefore was not charged against the dikes and floodwalls alternative. Replacement of the Clark Street crossing was charged against the dikes and floodwalls alternative.

Map 13

DIKES AND FLOODWALLS ALONG THE PEWAUKEE RIVER AND PEWAUKEE LAKE IN THE VILLAGE OF PEWAUKEE



LEGEND

- – – VILLAGE OF PEWAUKEE CORPORATE LIMITS
- 100-YEAR RECURRENCE INTERVAL FLOODLANDS UNDER 2000 PLAN LAND USE AND EXISTING CHANNEL CONDITIONS
- AREA WHERE TOPOGRAPHY HAS BEEN ALTERED SINCE DATE OF MAPPING
- PROPOSED EARTHEN DIKE
- PROPOSED CONCRETE FLOODWALL
- 2.7 APPROXIMATE HEIGHT OF PROPOSED DIKE OR FLOODWALL IN FEET ABOVE EXISTING RIVER BANK ELEVATION
- APPROXIMATE LOCATION OF PROPOSED STORM WATER PUMPING STATION
- PROPOSED BRIDGE REPLACEMENT (COSTS ASSIGNABLE TO THIS ALTERNATIVE)
- PROPOSED BRIDGE REPLACEMENT (COSTS NOT ASSIGNABLE TO THIS ALTERNATIVE)
- APPROXIMATE LOCATION OF PROPOSED PEWAUKEE LAKE OUTLET CONDUIT
- PROPOSED LAKE LEVEL CONTROL STRUCTURE

NOTE: WITHIN THE STREAM REACH SUBJECT TO MAJOR CHANNEL WORK THE 100-YEAR RECURRENCE INTERVAL FLOOD WOULD BE CONTAINED WITHIN THE PROPOSED DIKES AND FLOODWALLS. BETWEEN PEWAUKEE LAKE AND THE PEWAUKEE RIVER THE 100-YEAR RECURRENCE INTERVAL FLOOD WOULD BE CONTAINED WITHIN THE PROPOSED CONDUIT. WITHIN THE STREAM REACHES UPSTREAM AND DOWNSTREAM OF THE STREAM REACH SUBJECT TO MAJOR CHANNEL WORK THE 100-YEAR RECURRENCE INTERVAL FLOOD WOULD BE THE SAME AS UNDER 2000 PLAN LAND USE AND EXISTING CHANNEL CONDITIONS.

GRAPHIC SCALE
0 500 1000 2000 FEET

Source: SEWRPC.

Modification of the existing Pewaukee Lake level control structure, enclosing the Pewaukee Lake Outlet, and installation of four storm water pumping stations as shown on Map 13 would also be required as subelements of the dikes and floodwalls alternative.

Assuming that the dikes and floodwalls project would be fully implemented and utilizing an annual interest rate of 6 percent and a project life and amortization period of 50 years, the average annual cost is estimated at $121,600 consisting of the following: amortization of the $1,093,900 capital cost of the dikes and floodwalls and the land necessary to construct them, amortization of the $96,000 capital cost of the new River crossings, amortization of the $356,000 capital cost of storm water backwater control and pumping facilities, amortization of the $294,500 capital cost of the lake level control structure and Pewaukee Lake Outlet enclosure, and $4,800 in annual operation and maintenance costs of dikes, floodwalls, and pumping facilities.

Assuming that the dikes-floodwalls system would completely eliminate all direct and indirect flood damages along the Pewaukee River extending from Clark Street at Station 359700 to the Chicago, Milwaukee, St. Paul and Pacific Railroad at Station 361300, along the entire Pewaukee Lake Outlet, and around Pewaukee Lake along the W. Wisconsin Avenue and Park Avenue commercial area in the Village of Pewaukee, the average annual flood abatement benefit is estimated at about $138,900, yielding a benefit-cost ratio of 1.14 and an annual excess of benefits over costs of about $17,300. Therefore, the Village of Pewaukee dikes and floodwalls alternative, as described herein, is an economically sound and technically feasible means of abating part of the flood problem in the Village of Pewaukee.

As already noted, the cost of the Oakton Avenue crossing of the Pewaukee River was excluded from the above detailed cost analysis since it is recommended for replacement under the adopted jurisdictional highway system plan for Waukesha County. If the $96,000 capital cost of the Oakton Avenue structure is assigned to this alternative, the total capital cost would be increased to $1,936,400 and the average annual amortization cost would be increased to $122,900. Adding estimated operation and maintenance expenditures of $4,800 per year would yield a total annual cost of $127,700—$6,100 more than when the cost of the river crossing is excluded from the economic analysis. The average annual flood control benefit would remain at $138,900 and, therefore, the benefit-cost ratio would be reduced from 1.14 to 1.09 and the annual excess of benefits over costs would be reduced from $17,300 to $11,200.

One positive nontechnical and noneconomic feature and one negative feature of the dikes-floodwalls alternative are set forth in Table 7. The positive feature of the dikes and floodwalls alternative is the elimination of overland flooding in the Village's business district, thereby enhancing the development potential of that area. The most significant negative feature of the dikes-floodwalls alternative is the aesthetic impact of the high dikes and floodwalls on riverine property owners and Village residents.

Bridge Culvert Alteration and
Replacement for Flood Control Purposes

The removal and possible replacement of selected bridges or culverts on the Pewaukee River within the Village of Pewaukee was examined as a potential means of significantly reducing flood problems in the reaches immediately upstream of these crossings. Bridges and culverts producing backwater in excess of 1.0 foot in the flood-prone reaches were selected for inclusion in the technical examination of this alternative. The three bridges or culverts that were identified consist of the CTH SS bridge at Station 354600, the Clark Street bridge at Station 359700, and the Oakton Avenue bridge at Station 360500. Assuming that the aforementioned bridges were altered or replaced, flood stage profiles were developed through the flood-prone reaches in the Village for selected recurrence intervals. The resulting flood stage profiles were found to be lower than those existing in the absence of the bridge and culvert alteration or replacement alternative with the decrease in the 100-year recurrence interval flood stage associated with the bridge and culvert alteration and replacement alternative ranging from 0.2 feet to 1.6 feet. The resulting stage-probability information was then used to compute average annual monetary risks. The cost of the demolition and reconstruction of only the Clark Street bridge is charged to this alternative. The replacement of the CTH SS and Oakton Avenue bridges was recommended under the adopted jurisdictional highway system plan for Waukesha County.

The capital cost of the bridge and culvert alteration and replacement alternative is estimated to be

$96,000, which consists of the demolition and replacement of the Clark Street bridge. The average annual cost equivalent to the $96,000 capital cost of the bridge and culvert alteration and replacement project at a 6 percent interest rate and for a project life and amortization period of 50 years would be $6,100.

The flood control benefits which would be expected to result from this expenditure would be a 24 percent reduction in average annual flood damages from $169,800 to $129,200 to the residential and commercial areas along the Pewaukee River and the Pewaukee Lake Outlet in the Village of Pewaukee. Thus the average annual benefit would approximate $40,600 in the Village. The resulting benefit-cost ratio would be 6.66, and the annual excess of benefits over costs would be about $34,500. Thus, the bridge and culvert alteration and replacement alternative is an economically sound, as well as technically practicable, means of abating a small portion of the flood problem in the Village of Pewaukee.

There are no significant positive nontechnical or noneconomic features associated with this alternative. The most important nontechnical and noneconomic feature is that overland flooding and attendant problems would be largely unaffected by this alternative.

As already noted, the costs of the CTH SS and Oakton Avenue crossings of the Pewaukee River were excluded from the above detailed cost analysis since they are recommended for replacement under the adopted jurisdictional highway system plan for Waukesha County. If the $206,000 capital costs of the CTH SS and Oakton Avenue structures are assigned to this alternative, the total capital cost would be increased to $302,000 and the average annual amortization cost would be increased to $19,200, $13,100 more than when the costs of the two River crossings are excluded from the economic analysis. The average annual flood control benefit would remain at $40,600 and, therefore, the benefit-cost ratio would be reduced from 6.66 to 2.11 and the annual excess of benefits over costs would be reduced from $34,500 to $21,400.

Concluding Statement: Assessment of Alternative Single Means Structural Flood Control Measures

Ten distinctly different, essentially single means primarily structural floodland management alternatives were examined as possible solutions to the flood problem that exists along the Pewaukee River, Pewaukee Lake, and Pewaukee Lake Outlet in the Village of Pewaukee. These 10 measures are: 1) storage in a detention reservoir at Capitol Drive, 2) retention storage on Pewaukee Lake, 3) lake diversion, 4) river diversion, 5) structure floodproofing, 6) minor channel modification, 7) major channel modification with a concrete-lined channel, 8) major channel modification with a turf-lined channel, 9) dikes and floodwalls, and 10) bridge and culvert alteration or replacement. In addition, an eleventh alternative, that of taking no action, is available to the public agencies concerned, and the flood damages attendant to this alternative provide an important basis for analyses of the potential benefits associated with each of the other alternatives.

The principal features of, and the costs and benefits associated with, each of the floodland management alternatives are summarized in Table 7 together with the major favorable and unfavorable nontechnical and noneconomic considerations likely to influence selection of the most desirable solution.

Excluding the "no action" approach, all of the above structural alternatives were found to be technically feasible. Of these 10 technically feasible alternatives, the following five were found to be economically feasible: lake storage, structure floodproofing, minor channel modifications, dikes and floodwalls, and bridge and culvert alteration or replacement, thus providing five separate technically and economically feasible partial or whole solutions to the flood problems along the Pewaukee River, Pewaukee Lake Outlet, and Pewaukee Lake in the Village of Pewaukee. Each of the 10 "action" alternatives is discussed below with respect to its desirability as essentially single means solutions to the Village's flood problem and for its possible use in combination with other primarily structural flood control measures.

Detention storage at the Capitol Drive site was eliminated from further consideration as either a single means flood control measure or for use in combination with other structural measures because it is uneconomic and resolves only a small portion of the flood problem.

Surface floodwater storage on Pewaukee Lake was eliminated from further consideration as an individual flood control measure because of higher lake stages which would be associated with this alternative during major flood events and would increase flood problems along the perimeter of Pewaukee Lake outside of the Village of Pewaukee, that is, within the Towns of Pewaukee and Delafield. Average annual monetary flood risks to the structures along Pewaukee Lake in the Towns of Pewaukee and Delafield could be expected to increase from $23,700 to $28,100, or by 19 percent, and from $13,900 to $20,600, or by 48 percent, respectively, if the lake storage alternative were implemented. Because of the favorable benefit-cost features with respect to resolution of flood problems within the Village of Pewaukee, Pewaukee Lake floodwater storage was considered for use in combination with other measures to develop a composite alternative that might yield a technically practicable and economically feasible solution to the flood problems within the Village of Pewaukee while minimizing adverse effects on flood problems around Pewaukee Lake in the Towns of Pewaukee and Delafield.

Lake diversion was eliminated from further consideration as either a single means flood control measure or for use in combination with other structural measures because it is uneconomic and because the entire alignment of the diversion lies outside of the Village of Pewaukee.

The river diversion alternative was eliminated from further consideration as either a single means solution to the Village's flood problem or for use in combination with other structural measures because it was uneconomic and would abate only about 28 percent of the problem.

Even though structure floodproofing and removal constitutes a technically and economically feasible floodland management alternative for the Village of Pewaukee, this alternative was eliminated from further consideration as a separate solution to flood problems for three important reasons. First, complete implementation of a voluntary structure floodproofing and removal program is unlikely and, with partial implementation, the Village of Pewaukee would be left with a significant residual problem whenever a major flood event occurs. Assuming that numerous individual owners of residential business property incur the necessary cost to implement floodproofing and further assuming that the floodproofing devices are adequately maintained, community officials may still be faced with the problem of reducing the flood threat to those structures that have not been voluntarily floodproofed. Second, even if a voluntary structure floodproofing program were completely carried out, the Village of Pewaukee would still be subjected to extensive overland flooding that would hamper routine access to and from some riverine area structures, would periodically close local streets to automobile traffic, would disrupt business activities, and would hinder the future development of the business district. Furthermore, some yard and street damages and cleanup costs would remain with the structure floodproofing and removal alternative, and sanitary and storm sewers would continue to experience surcharging. Third, some floodproofing is very likely to be applied without adequate professional advice, and, as a result, structure damage is likely to occur and once again Village officials are likely to be asked to assist in the resolution of the problem. Although eliminated from further consideration as a single means solution to Village of Pewaukee flood problems, floodproofing was retained for possible use as a supplement to other structural measures because of its favorable benefit-cost features.

Although both the minor channel modification and the bridge and culvert alteration or replacement alternatives exhibit very favorable benefit-cost ratios, these alternatives would abate only about 22 percent and 24 percent, respectively, of the flood problem in the Village of Pewaukee as measured by reduction in average annual flood damages. Therefore, neither the minor channel modification and the bridge and culvert alteration or replacement alternatives are viable single means solutions to the flood problem in the Village of Pewaukee. Because of their favorable economic features, however, these two alternatives were retained for development of a composite alternative.

Although economic, the dikes-floodwalls alternative was eliminated from further consideration as a single means solution to the Village's flood problem because a residual problem would remain and because of the undesirable aesthetic impact of the structures. The dikes and floodwalls would be extremely high in most locations with a maximum height above existing ground grade of about 7.0 feet. Dikes and floodwalls were retained for possible use in combination with other measures.

Because of their unfavorable benefit-cost features, the concrete-lined and turf-lined major channelization alternatives were eliminated from further consideration as single means flood control measures. These alternatives were retained for possible use in combination with other structural measures for two reasons: they substantially reduce overland flooding in the business district of the Village, thereby enhancing the development potential of that area, and they provide an opportunity for development of water-oriented greenway through the Village.

In summary, all available primarily structural flood control alternatives were eliminated from further consideration as single means solution to the Village of Pewaukee flood problem. The principal value of screening single means structural flood control measures is that seven measures were determined to have potential for consideration in developing a series of alternatives consisting of various combinations of structural measures. The selected seven measures are: 1) storage on Pewaukee Lake, 2) structure floodproofing, 3) minor channel modification, 4) major concrete-lined channel, 5) major turf-lined channel, 6) dikes and floodwalls, and 7) bridge and culvert alteration or replacement. The technical, economic, and environmental impact of those composite alternatives is described below. Figure 14 summarizes, in graphic form, the above process by which the single means structural flood control alternatives were compared, reduced in number, and used to synthesize composite alternatives.

ALTERNATIVE COMPOSITE STRUCTURAL FLOOD CONTROL MEASURES

After careful consideration of the single means structural flood control alternatives described above, five composite alternatives, formed by combining single means alternatives, were analyzed. The composite alternatives, which are discussed in greater detail below, consist of: 1) a minor channel modification-bridge and culvert alternative or replacement composite; 2) a major concrete-lined channel and structure floodproofing composite; 3) a major turf-lined channel and structure floodproofing composite; 4) a lake storage-major turf-lined channel-structure floodproofing composite; and 5) a dike and floodwall-structure floodproofing composite. The purpose of developing and analyzing these composite alternatives was to move one step closer to identifying the optimum solution to the existing and future flood problems within the Village of Pewaukee.

Minor Channel Modification-Bridge and Culvert Alteration or Replacement Composite

As discussed previously, both the minor channel modification alternative and the bridge and culvert alteration or replacement alternative are economically feasible means of abating part of the flood problem in the Village of Pewaukee in that each would yield benefits in excess of costs. However, use of either of these measures would result in a substantial residual average annual flood damage—78 percent in the case of minor channel modification and 76 percent in the case of bridge and culvert alteration or replacement. An alternative consisting of a combination of these two alternatives was analyzed to determine if the composite would be not only economic but would also substantially reduce the average annual monetary flood risk.

The physical characteristics and attendant costs and benefits of the composite minor channel modification-bridge and culvert alteration or replacement alternative are set forth in Table 8. The minor channel modification and the bridge and culvert alteration or replacement components of this alternative would be identical to those of the corresponding single means alternatives described previously.

Flood stage profiles for the flood-prone reaches in the Village of Pewaukee were computed for selected recurrence intervals assuming the combination of minor channel modification and bridge and culvert alteration or replacement. The resulting 100-year recurrence interval flood stage profile ranged from zero feet to about 0.5 foot lower than those existing with either single means alternative with the largest stage decrease occurring upstream of Oakton Avenue. The resulting stage-probability information was then used to compute average annual monetary risks.

The average annual cost of the composite minor channel modification-bridge and culvert alteration or replacement alternative, calculated using an annual interest rate of 6 percent and a project life and amortization period of 50 years, is estimated at about $11,200 consisting of amortization of the $80,100 capital cost of channel cleaning and amortization of the $96,000 capital cost of bridge replacement.

The flood control benefits which would be expected to result from this expenditure would be a 42 percent reduction in average annual flood damages from $169,800 to $98,100 in the Village of Pewaukee along the Pewaukee River and Pewaukee Lake Outlet. Thus, the average annual benefit would approximate $71,700 in the Village. The

Figure 14

EVALUATION OF SINGLE MEANS AND COMPOSITE STRUCTURAL FLOOD CONTROL ALTERNATIVES FOR THE VILLAGE OF PEWAUKEE

STEP 1: SINGLE MEANS STRUCTURAL FLOOD CONTROL ALTERNATIVES[a]	(1) NO ACTION	(2) DETENTION STORAGE AT CAPITOL DIRVE	(3) RETENTION STORAGE ON PEWAUKEE LAKE	(4) LAKE DIVERSION	(5) RIVER DIVERSION	(6) STRUCTURE FLOODPROOFING	(7) MINOR CHANNEL MODIFICATION	(8) MAJOR CHANNEL MODIFICATION–CONCRETE	(9) MAJOR CHANNEL MODIFICATION–TURF	(10) DIKES AND FLOODWALLS	(11) BRIDGE AND CULVERT ALTERATION OR REPLACEMENT
TECHNICALLY FEASIBLE?	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
ECONOMICALLY FEASIBLE?	NO	NO	YES	NO	NO	YES	YES	NO	NO	YES	YES
PERCENT OF PROBLEM REMAINING	100	70	65	--	72	0	78	16	16	18	76
OTHER POSITIVE FACTORS	--	● OPEN SPACE RETENTION	--	--	--	● IMMEDIATE PARTIAL RELIEF ● COSTS BORNE BY BENEFICIARIES	--	● GREENWAY DEVELOPMENT ● ELIMINATION OF OVERLAND FLOODING IN BUSINESS AREA	● GREENWAY DEVELOPMENT ● ELIMINATION OF OVERLAND FLOODING IN BUSINESS AREA	● ELIMINATION OF OVERLAND FLOODING IN BUSINESS AREA	--
OTHER NEGATIVE FACTORS	--	● MAY ENCOURAGE DOWNSTREAM FLOODPRONE DEVELOPMENT ● EXTENDS OUTSIDE OF VILLAGE LIMITS	● ENCOURAGE DOWNSTREAM FLOODPRONE DEVELOPMENT ● CREATES OR AGGRAVATES FLOOD PROBLEMS FOR SHORELINE PROPERTY IN THE TOWNS OF PEWAUKEE AND DELAFIELD	● ENTIRELY OUTSIDE OF VILLAGE LIMITS	● ENCOURAGE DOWNSTREAM FLOODPRONE DEVELOPMENT	● COMPLETE VOLUNTARY FLOODPROOFING IS UNLIKELY ● OVERLAND FLOODING REMAINS ● POSSIBLE INADEQUATE FLOODPROOFING TECHNIQUES	● OVERLAND FLOODING REMAINS	--	--	● AESTHETIC IMPACT	--
RETAIN AS A SINGLE PURPOSE ALTERNATIVE?	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
RETAIN FOR COMBINATION WITH OTHER ALTERNATIVES?	NO	NO	YES	NO	NO	YES	YES	YES	YES	YES	YES

STEP 2: COMPOSITE STRUCTURAL FLOOD CONTROL ALTERNATIVES[b]	LAKE STORAGE–MAJOR CHANNEL MODIFICATION–STRUCTUE FLOODPROOFING	MINOR CHANNEL MODIFICATION–BRIDGE AND CULVERT ALTERATION OR REPLACEMENT	MAJOR CONCRETE-LINED CHANNEL-STRUCTURE FLOODPROOFING	MAJOR TURF CHANNEL-STRUCTURE FLOODPROOFING	DIKES AND FLOODWALLS-STRUCTURE FLOODPROOFING
TECHNICALLY FEASIBLE?	YES	YES	YES	YES	YES
ECONOMICALLY FEASIBLE?	YES	YES	NO	YES	YES
PERCENT OF PROBLEM REMAINING	0	58	0	0	0
OTHER POSITIVE FACTORS	● IMMEDIATE PARTIAL RELIEF BY FLOODPROOFING ● FLOODPROOFING COSTS BORNE BY BENEFICIARIES ● GREENWAY DEVELOPMENT ● ELIMINATION OF OVERLAND FLOODING IN BUSINESS AREA	--	● IMMEDIATE PARTIAL RELIEF BY FLOODPROOFING ● FLOODPROOFING COSTS BORNE BY BENEFICIARIES ● GREENWAY DEVELOPMENT ● ELIMINATION OF OVERLAND FLOODING IN BUSINESS AREA	● IMMEDIATE PARTIAL RELIEF BY FLOODPROOFING ● FLOODPROOFING COSTS BORNE BY BENEFICIARIES ● GREENWAY DEVELOPMENT ● ELIMINATION OF OVERLAND FLOODING IN BUSINESS AREA	● IMMEDIATE PARTIAL RELIEF BY FLOODPROOFING ● FLOODPROOFING COSTS BORNE BY BENEFICIARIES ● ELIMINATION OF OVERLAND FLOODING IN BUSINESS AREA
OTHER NEGATIVE FACTORS	● COMPLETE VOLUNTARY FLOODPROOFING IS UNLIKELY ● OVERLAND FLOODING IN FLOODPROOFING AREAS ● POSSIBLE INADEQUATE FLOODPROOFING TECHNIQUES ● NEED FOR INTERCOMMUNITY COORDINATION ● ENCOURAGE DOWNSTREAM FLOODPRONE DEVELOPMENT	● OVERLAND FLOODING REMAINS	● COMPLETE VOLUNTARY FLOODPROOFING IS UNLIKELY ● OVERLAND FLOODING IN FLOODPROOFING AREAS ● POSSIBLE INADEQUATE FLOODPROOFING TECHNIQUES	● COMPLETE VOLUNTARY FLOODPROOFING IS UNLIKELY ● OVERLAND FLOODING IN FLOODPROOFING AREAS ● POSSIBLE INADEQUATE FLOODPROOFING TECHNIQUES	● COMPLETE VOLUNTARY FLOODPROOFING IS UNLIKELY ● OVERLAND FLOODING IN FLOODPROOFING AREAS ● POSSIBLE INADEQUATE FLOODPROOFING TECHNIQUES ● AESTHETIC IMPACT
RETAIN FOR FURTHER CONSIDERATION?	NO	NO	NO	YES	NO

STEP 3: RECOMMENDED STRUCTURAL FLOOD CONTROL ALTERNATIVE: MAJOR TURF CHANNEL MODIFICATION-STRUCTURE FLOODPROOFING

[a] *Refer to Table 7 for additional information about each single means structural flood control alternative.*

[b] *Refer to Table 8 for additional information about each composite structural flood control alternative.*

Source: SEWRPC.

Table 8

PRINCIPAL FEATURES AND COSTS AND BENEFITS OF COMPOSITE STRUCTURAL FLOODLAND MANAGEMENT MEASURES FOR THE VILLAGE OF PEWAUKEE

Alternative			Technically Feasible	Economic Analysis[a]					Residual Flood Damages		Annual Benefit Minus Annual Cost (in $1,000)	Benefit Cost Ratio	Economically Feasible	Nontechnical and Noneconomic Considerations		Recommended
Number	Name	Description		Capital Cost (in $1,000)	Annual Amortization of Capital Cost (in $1,000)	Annual Operation and Maintenance Cost (in $1,000)	Total Annual Cost (in $1,000)	Annual Benefit (in $1,000)	Residual Average Annual Monetary Flood Risk (in $1,000)	Percent of Total Annual Monetary Flood Risk				Positive	Negative	
1	Minor Channel Modification[b] Bridge and Culvert Alteration or Replacement Composite	2.6 Miles of Minor Channel Cleanout Replace 3 Stream crossings	Yes	Channel Cleaning 80.1 Bridges 96.0 Total 176.1	11.2	--	11.2	71.7	98.1	58	60.5	6.41	Yes	--	● Overland flooding and attendant problems remain	No
2	Major Concrete-Lined Channel-Structure Floodproofing Composite	0.43 Mile of Major Channelization Replace 3 Stream Crossings Enclose the Lake Outlet 0.19 Mile of Dike 0.06 Mile of Floodwall Install 4 Storm Water Pumping Stations Basic Floodproofing: 17 Residential and 3 Commerical and Other Structures Elevate 5 Residential Structures	Yes	Channelization 1,387.5 Bridges 96.0 Lake Outlet Structure 294.5 Dike 250.6 Floodwall 58.2 Pumping Stations 356.0[c] Floodproofing (basic 213.9 Floodproofing (elevating) 82.8 Total 2,739.4	173.8	5.9	179.7	169.8	0.0	0	- 9.9	0.94	No	● Floodproofing component would provide immediate partial flood relief at discretion of property owners ● With floodproofing component some costs could be borne by beneficiaries ● Opportunity to develop water oriented greenway along the Pewaukee River through the business-commercial area of the Village ● Eliminate overland flooding in the Village business area	● Complete, voluntary implementation of flood-proofing unlikely and therefore left with a residual flood problem ● Overland flooding and some attendant problems remain with floodproofing ● Some floodproofing is likely to be applied without adequate professional advice and, as a result, structure damage may occur	No
3	Major Turf Channel-Structure Floodproofing Composite	0.43 Mile of Major Channelization Replace 3 Stream Crossings Enclose the Lake Outlet 0.19 mile of Dike 0.06 Mile of Floodwall Install 4 Storm Water Pumping Stations Basic Floodproofing: 17 Residential and 3 Commercial and Other Structures Elevate 5 Residential Structures	Yes	Channelization 1,028.9 Bridges 115.2 Lake Outlet Structure 294.5 Dike 250.6 Floodwall 58.2 Pumping Stations 356.0[c] Floodproofing (basic) 213.9 Floodproofing (elevating) 82.8 Total 2,400.1	152.3	5.9	158.2	169.8	0.0	0	11.6	1.07	Yes	● Floodproofing component would provide immediate partial flood relief at discretion of property owners ● With floodproofing component some costs could be borne by beneficiaries ● Opportunity to develop water oriented greenway along the Pewaukee River through the business-commercial area of the Village ● Eliminate overland flooding in the Village business area	● Complete, voluntary *implementation* of flood-proofing unlikely and therefore left with a residual flood problem ● Overland flooding and some attendant problems remain with floodproofing ● Some floodproofing is likely to be applied without adequate profes-sional advice and, as a result, structure damage may occur	Yes
4	Lake Storage-Major Turf Channel-Structure Floodproofing Composite	0.43 Mile of Major Channelization Replace 3 Stream Crossings Enclose the Lake Outlet 0.19 Mile of Dike 0.06 Mile of Floodwall Install 4 Storm Water Pumping Stations Basic Floodproofing: 27 Residential and 5 Commercial and Other Structures Elevate 13 Resi-dential Structures	Yes	Channelization 975.4 Bridges 115.2 Lake Outlet Structure 72.0 Dike 250.6 Floodwall 58.2 Pumping Stations 356.0[c] Floodproofing (basic) 192.9 Floodproofing (elevating) 247.8 Total 2,268.3	143.9	5.1	149.0	207.4	0.0	0	58.4	1.39	Yes	● Floodproofing component would provide immediate partial flood relief at discretion of property owners ● With floodproofing component some costs could be borne by beneficiaries ● Opportunity to develop water oriented greenway along the Pewaukee River through the business-commercial area of the Village ● Eliminate overland flooding in the Village business area	● Complete, voluntary imple-mentation of floodproofing unlikely and therefore left with a residual flood problem ● Overland flooding and some attendant problems remain with floodproofing ● Some floodproofing is likely to be applied without adequate professional advice and, as a result, structure damage may occur ● Necessary coordination between the Village of Pewaukee and the Towns of Delafield and Pewaukee ● May encourage downstream flood-prone development	No
5	Dikes and Floodwalls-Structure Floodproofing Composite	0.48 Mile of Dike 0.32 Mile of Floodwall Replace 2 Stream Crossings Enclose the Lake Outlet Install 4 Storm *Water Pumping* Stations Basic Floodproofing: 17 Residential and 3 Commercial and Other Structures Elevate 5 Residential Structures	Yes	Dikes 571.4 Floodwalls 522.5 Bridges 96.0 Lake Outlet Structure 294.5 Pumping Stations 356.0[c] Floodproofing (basic) 213.9 Floodproofing (elevating) 82.8 Total 2,137.1	135.6	4.8	140.4	169.8	0.0	0	29.4	1.21	Yes	● Floodproofing component would provide immediate partial flood relief at discretion of property owners ● With floodproofing component some costs could be borne by beneficiaries ● Eliminate overland flooding in the Village business area	● Complete, voluntary implementation of flood-proofing unlikely and therefore left with a residual flood problem ● Overland flooding and some attendant problems remain with floodproofing ● Some floodproofing is likely to be applied without adequate professional advice and, as a result, structure damage may occur ● Aesthetic impact of the dikes and floodwalls on riverine property owners and village residents	No

[a] *Economic analyses are based on an annual interest rate of 6 percent and assume a 50-year amortization and project life.*

[b] *Assumes minor channel modification will be necessary every five years.*

[c] *Present worth cost based on 25-year economic life.*

Source: SEWRPC.

resulting benefit-cost ratio would be 6.41 and the annual excess of benefits over costs would be about $60,500. Thus, the minor channel modification-bridge and culvert alteration or replacement composite is an economically sound, as well as technically feasible, means of abating part of the flood problem in the Village of Pewaukee.

Assuming complete implementation of the minor channel modification-bridge and culvert alteration or replacement composite, the annual average monetary flood risk remaining would be $98,100, or 58 percent of the total annual average monetary flood risk in the Village. Because of this large residual flood risk, the minor channel modification-bridge and culvert alteration or replacement composite was eliminated from further consideration as a viable floodland management alternative for the Village of Pewaukee.

There are no significant positive nontechnical or noneconomic considerations associated with this alternative. The most important nontechnical and noneconomic negative feature of this alternative is that overland flooding and attendant problems would be largely unaffected.

As already noted, the costs of the CTH SS and Oakton Avenue crossings of the Pewaukee River were excluded from the above detailed cost analysis since they are recommended for replacement under the adopted jurisdictional highway system plan for Waukesha County. If the $206,000 capital costs of the CTH SS and Oakton Avenue structures are assigned to this alternative, the total capital cost would be increased to $382,100 and the average annual amortization cost would be increased to $24,200. Adding estimated operation and maintenance expenditures of $500 per year would yield a total annual cost of $24,200—$13,000 more than when the costs of the two river crossings are excluded from the economic analysis. The average annual flood control benefit would remain at $71,700 and, therefore, the benefit-cost ratio would be reduced from 6.41 to 2.96 and the annual excess of benefits over costs would be reduced from $60,500 to $47,500.

Major Concrete Channel-
Structure Floodproofing Composite

The major concrete-lined channel is an uneconomic means for resolution of flood problems in the Village of Pewaukee. A major concrete-lined channel and structure floodproofing composite was developed and analyzed in order to use the very favorable benefit-cost features of structure floodproofing and also utilize the most favorable features of the major concrete-lined channel, namely, the elimination of extensive overland flooding in the business area of the Village and the opportunity for the development of a greenway along the Pewaukee River. A graphical representation of the major concrete channel-structure floodproofing composite is shown on Map 14, and the physical characteristics and attendant costs and benefits are presented in Table 8.

The length of the concrete-lined channel component of this alternative is significantly less than that contained in the major concrete-lined channel alternative discussed above. The shorter concrete channel length was selected in order to minimize the channel modification costs but still eliminate the overland flooding in the Village's business district, thereby enhancing the development potential of that area. The improved channel would be located along or near the alignment of the Pewaukee River in the Village of Pewaukee extending from CTH SS at the downstream end at Station 354600 to the Chicago, Milwaukee, St. Paul and Pacific Railroad at the upstream end at Station 361300. Under this alternative, channel modifications would be carried out over a total of 1.27 miles of the Pewaukee River. Of the 1.27 miles of channel modification, only the upstream 0.30 mile would consist of major channel modifications. The remaining 0.97 mile would consist of transition between the channelized cross section and the natural River cross section with the farthest downstream 0.84 mile of transition section consisting only of minor channel bottom lowering.

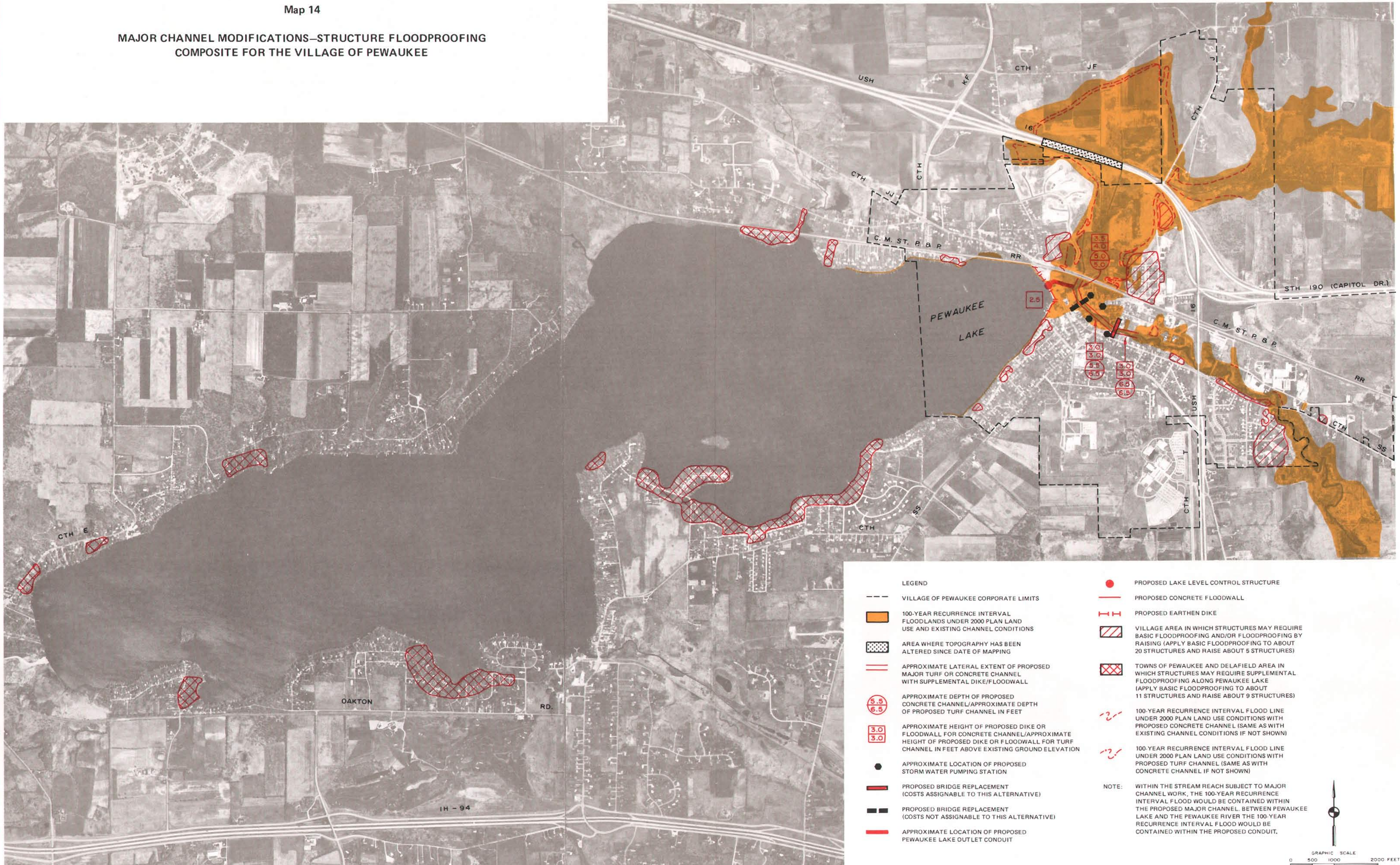
Moving in a downstream direction, the channelization would lower the existing Pewaukee River channel grade by 1.0 feet at the Chicago, Milwaukee, St. Paul and Pacific Railroad crossing, about 0.4 foot at Oakton Avenue and about 1.0 foot at Clark Street, as shown in Figure 13. In addition, the channel invert between a point about 700 feet downstream of Clark Street and CTH SS would be lowered in order to provide a transition between the channelization and the natural channel profile. Therefore, channel improvements would terminate within the Village at CTH SS so as not to extend downstream along the Pewaukee River into the parklands recently acquired by Waukesha County in the Town of Pewaukee. The width of the invert or bottom of the concrete channel along the Pewaukee River would be 40 feet as illustrated in Figure 12, with side slopes of one on three. The bottom and side slopes up to a 10-year recurrence interval flood stage would be lined with concrete, resulting in a total concrete width of about 55 feet.

Because of the shortened channelization, a total of only four storm water pumping stations, as shown on Map 14, would be required. The supplemental dikes and floodwalls would rise an average of 3.0 feet above the existing river bank elevation. A representative channel-floodplain cross section is shown in Figure 15 to illustrate the vertical and horizontal extent of the proposed channel modifications and supplemental dikes relative to existing topographic features. Bridge demolition and replacement, lake level control structure, and enclosure of the Pewaukee Lake Outlet are identical to those contained in the original major concrete-lined channel alternative described previously.

The structure floodproofing component would require the floodproofing of about 25 residential and commercial structures along the Pewaukee

Map 14

MAJOR CHANNEL MODIFICATIONS–STRUCTURE FLOODPROOFING COMPOSITE FOR THE VILLAGE OF PEWAUKEE



Source: SEWRPC.

River, Pewaukee Lake Outlet, and Pewaukee Lake in the Village of Pewaukee, as compared to the floodproofing of about 49 structures under the previously examined structure floodproofing alternative. This floodproofing would be required to supplement the major concrete channel modifications inasmuch as the channelization does not provide protection along the Pewaukee River and Pewaukee Lake outside of the channelized reaches.

The annual cost of the major concrete-lined channel-structure floodproofing composite, utilizing an annual interest rate of 6 percent and a project life and amortization period of 50 years, is estimated at $179,700, which consists of the following: amortization of the $1,387,500 capital cost of the channel modifications, amortization of the $308,800 capital cost of dikes and floodwalls construction, amortization of the $356,000 capital cost of storm water pumping stations, amortization of the $96,000 capital cost of bridge demolition and replacement, amortization of the $294,500 capital cost of the lake level control structure and Pewaukee Lake Outlet enclosure, amortization of the $213,900 capital cost of basic floodproofing and $82,800 for floodproofing by elevating, and $5,900 in annual operation and maintenance costs.

Assuming that the concrete-lined channel-structure floodproofing composite would completely eliminate all direct and indirect flood damages along the Pewaukee River, Pewaukee Lake Outlet, and Pewaukee Lake in the Village of Pewaukee, the average annual flood abatement benefit is estimated at about $169,800, yielding a benefit-cost ratio of 0.94 and an excess of annual costs over benefits of $9,900. The concrete-lined channel-structure floodproofing composite, as described herein, is a technically feasible although slightly uneconomic means of abating the flood problem within the Village of Pewaukee.

As already noted, the costs of the CTH SS and Oakton Avenue crossings of the Pewaukee River were excluded from the above-detailed cost analysis since they are recommended for replacement under the adopted jurisdictional highway system plan for Waukesha County. If the $206,000 capital cost of the CTH SS and Oakton Avenue structures are assigned to this alternative, the total capital cost would be increased to $2,945,400 and the average annual amortization cost would be increased to $186,900. Adding estimated operation and maintenance expenditures of $5,900 per year would yield a total annual cost of $192,800—$13,100 more than when the costs of the two River crossings are excluded from the economic analysis. The average annual flood control benefit would remain at $169,800 and, therefore, the benefit-cost ratio would be reduced from 0.94 to 0.88 and the annual excess of costs over benefits would be increased from $9,900 to $23,000.

As shown in Table 8, this composite alternative would exhibit the various positive and negative features of the several alternatives used to synthesize it. Positive features include the opportunity to develop a water-oriented greenway along the Pewaukee River through the Village and elimination of overland flooding in the business area and the resulting enhancement of the development potential of that area. Vacant land thus protected from inundation would be available for development—for example, the area bounded by the Pewaukee River, the Pewaukee Lake Outlet, and the Chicago, Milwaukee, St. Paul and Pacific Railroad. Positive features associated with the floodproofing component of this alternative are immediate partial relief at the discretion of the property owner and assumption, by the beneficiaries, of the costs of flood protection. Negative features of this channelization-floodproofing alternative are associated with the floodproofing component and have been discussed above in conjunction with the river diversion-floodproofing alternative.

A variation on the major concrete-lined channel-structure floodproofing composite was considered under which an enclosed concrete conduit would be used along the Pewaukee River in place of the concrete-lined channel. More specifically, five parallel concrete box structures 10 feet wide by five feet deep would be located along or near the alignment of the Pewaukee River in the Village of Pewaukee extending from the Chicago, Milwaukee, St. Paul and Pacific Railroad right of way at the upstream end to a point approximately 700 feet downstream of Clark Street at the downstream end. The 2,250-foot-long enclosed underground conduit would carry all flows up to and including the 100-year recurrence interval discharge. As was the case with the concrete-lined channel, the concrete conduit would be supplemented with storm water pumping stations, bridge replacement, a lake level control structure, enclosure of the Pewaukee Lake Outlet, and structure floodproofing.

Because of the significantly higher cost of the enclosed concrete conduit than the concrete-lined channel, the total capital cost of a concrete conduit-structure floodproofing composite would be approximately $1,200,000 more, or about 44 percent more, than the $2,739,500 capital cost of the concrete-lined channel-structure floodproofing composite. An enclosed concrete conduit to convey the Pewaukee River accordingly was eliminated from further consideration.

A possible supplement to the concrete channel-structure floodproofing composite was considered in which floodproofing would be applied primarily to residential structures located around the perimeter of Pewaukee Lake in the Towns of Pewaukee and Delafield. As indicated in Table 4, the estimated average annual flood damage to lake structures in the Towns of Pewaukee and Delafield is, respectively, $23,700 and $13,900, for a total of $37,600. The concrete channel-structure floodproofing alternative would not affect Pewaukee Lake stages—and therefore flood damage in the Towns of Pewaukee and Delafield. However, the incremental cost and benefits of floodproofing lake structures in the two towns were determined and added to the costs and benefits of the concrete channel-structure floodproofing alternative to permit an economic comparison of the resulting augmented alternative to the lake storage-major channelization-structure floodproofing alternative discussed below.

Criteria and procedures used to determine the need for and nature of floodproofing are similar to those described above for the single means structure floodproofing alternative. As shown on Map 14, the analyses indicated that about nine structures located in the primary flood zone would have to be floodproofed by elevating them above the 100-year recurrence interval flood stage, and about 11 structures located in the primary and secondary flood zones would require some form of less extensive floodproofing. Future flood damage to private residences and commercial structures along Pewaukee Lake in the Towns of Pewaukee and Delafield would be virtually eliminated by the floodproofing.

Assuming that the aforementioned structure floodproofing measures along Pewaukee Lake in the two towns would be fully implemented and utilizing an annual interest rate of 6 percent and project life and amortization period of 50 years, the equivalent average annual cost is estimated at about $11,000, consisting entirely of the amortization of the $25,800 capital cost for basic floodproofing and $146,800 for floodproofing by elevating structures. The average annual flood abatement benefit is estimated at about $37,600, yielding a benefit-cost ratio of 3.42 and an excess of annual benefits over costs of about $26,600. Therefore, floodproofing, as described herein, would be both technically and economically feasible for structures located on the perimeter of Pewaukee Lake in the Towns of Pewaukee and Delafield.

Assuming that the aforementioned structure floodproofing measures along Pewaukee Lake in the two towns would be integrated into the concrete channel-structure floodproofing alternative and utilizing an annual interest rate of 6 percent and a project life and amortization period of 50 years, the equivalent average annual cost is estimated at $190,600. The average annual flood abatement is estimated at $207,400, yielding a benefit-cost ratio of 1.09 and an excess of annual benefits over costs of about $16,800. The concrete channel-structure floodproofing alternative developed for the Village of Pewaukee alone has a benefit-cost ratio of 0.94 and an excess of annual costs over benefits of $9,900. Therefore, if that alternative is augmented with structure floodproofing around Pewaukee Lake in the Towns of Pewaukee and Delafield, the alternative would become economic in that the benefit-cost ratio would be increased to 1.09 and there would be a $16,800 excess of benefits over costs per year.

Major Turf Channel-Structure Floodproofing Composite

The major turf channel was determined to be an uneconomic alternative for resolution of flood problems in the Village of Pewaukee. A composite major turf channel-structure floodproofing alternative was developed and analyzed in order to use the very favorable benefit-cost features of structure floodproofing to supplement the most favorable feature of the major turf-lined channel, namely elimination of extensive overland flooding in the business area of the Village and the opportunity to develop a greenway along the Pewaukee River. Furthermore, inasmuch as the major concrete channel-structure floodproofing alternative was, as discussed above, determined to be slightly uneconomic—the benefit-cost ratio was 0.94—the major turf channel-structure floodproofing composite had the potential for being economic inasmuch as a turf lining would be used in place of the more costly concrete lining. The potential desirability of a turf channel was further enhanced by the earlier analysis of expected velocities during flood events which indicated that erosion of the turf would not be a serious problem because of the mild slope of the Pewaukee River.

A graphical representation of the major turf channel-structure floodproofing composite is shown on Map 14 and the physical characteristics as well as the attendant costs and benefits of the major turf channel-structure floodproofing composite are presented in Table 8. The channel profile for this alternative is shown in Figure 13. The length, bottom grade, and width of the channel composite are identical to that of the channel component of the concrete-lined channel-structure floodproofing composite.

The supplemental dikes and floodwalls would rise an average of 3.5 feet above the existing river bank elevation. A representative channel-floodplain cross section is shown in Figure 15 to illustrate the vertical and horizontal extent of the proposed channel modifications and supplemental dikes relative to existing topographic conditions. Bridge demolition and reconstruction, lake level control structure, and enclosure of the Pewaukee Lake Outlet are identical to those contained in the original major turf-lined channel alternative. Because of the shorter length of the turf-lined channel, a total of only four storm water pumping stations would be required.

The structure floodproofing component would require the floodproofing of about 25 residential and commercial structures along the Pewaukee River, Pewaukee Lake Outlet, and Pewaukee Lake in the Village of Pewaukee, as compared to the floodproofing of about 49 structures under the previously examined structure floodprcofing alternative. This floodproofing would be required to supplement the major turf channel modifications inasmuch as the channelization does not afford protection along the Pewaukee River and Pewaukee Lake outside of the channelized reaches.

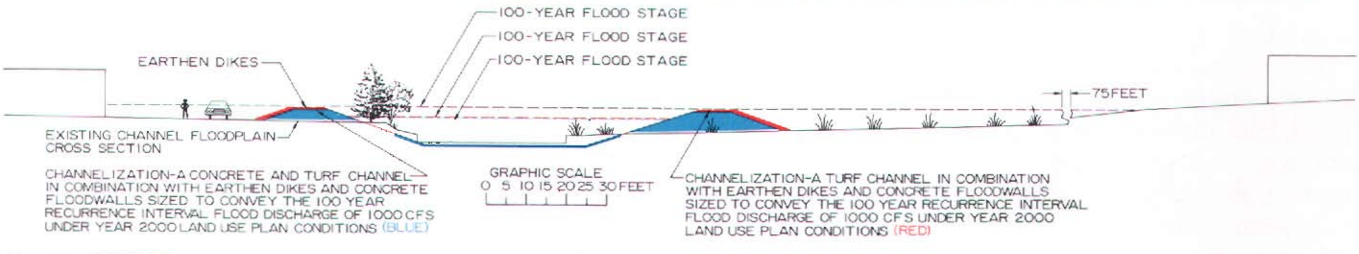
The annual cost of the major turf channel-structure floodproofing composite, utilizing an annual interest rate of 6 percent and a project life and amortization period of 50 years, is estimated at $158,200, which consists of the following: amortization of the $1,028,900 capital cost of the channel modifications, amortization of the $308,800 capital cost of dikes and floodwalls construction, amortization of the $115,200 capital cost of bridge demolition and replacement, amortization of the $294,500 capital cost of the lake level control structure and Pewaukee Lake Outlet enclosure, amortization of the $356,000 capital cost of construction of storm water pumping stations, amortization of the $213,900 capital cost of basic floodproofing and $82,800 for floodproofing by elevating, and $5,900 in annual operation and maintenance costs.

The total capital cost of the major turf channel-structure floodproofing composite was estimated at $2,400,100, or 12 percent less than the $2,739,400 capital cost of the major concrete channel-structure floodproofing composite, with the cost reduction primarily attributable to the use of a turf lining in place of the more costly concrete lining.

Assuming that the major turf channel-structure floodproofing composite would completely eliminate all direct and indirect flood damages along the Pewaukee River, Pewaukee Lake Outlet, and Pewaukee Lake in the Village of Pewaukee, the average annual flood abatement benefit is estimated at about $169,800, yielding a benefit-cost ratio of 1.07 and an annual excess of benefits over cost of about $11,600. Therefore, the major turf channel-structure floodproofing composite, as described herein, is both technically sound and economically feasible.

Figure 15

CROSS SECTION CORRESPONDING TO EXISTING TOPOGRAPHIC CONDITIONS, CHANNELIZATION, AND SUPPLEMENTAL DIKES AT STATION 360,100 ON THE PEWAUKEE RIVER IN THE VILLAGE OF PEWAUKEE



Source: SEWRPC.

As already noted, the costs of the CTH SS and Oakton Avenue crossings of the Pewaukee River were excluded from the above detailed cost analysis since they are recommended for replacement under the adopted jurisdictional highway system plan for Waukesha County. If the $225,200 capital cost of the CTH SS and Oakton Avenue structures are assigned to this alternative, the total capital cost would be increased to $2,625,300, and the average annual amortization cost would be increased to $166,600. Adding estimated operation and maintenance expenditures of $5,900 per year would yield a total annual cost of $172,500—$14,300 more than when the costs of the two river crossings are excluded from the economic analysis. The average annual flood control benefit would remain at $169,800 and, therefore, the benefit-cost ratio would be reduced from 1.07 to 0.98 and the annual $11,600 excess of benefits over costs would become an annual $2,700 excess of costs over benefits.

As shown in Table 8, this composite alternative would exhibit the positive and negative features of the several alternatives used to synthesize it. These features are identical to those of the previously discussed concrete-lined channel and structure floodproofing alternative.

As was the case with the concrete channel-structure floodproofing alternative, a possible supplement to the turf channel-structure floodproofing composite was considered in which floodproofing would be applied to primarily residential structures located on the perimeter of Pewaukee Lake in the Towns of Pewaukee and Delafield. The incremental cost and benefits of floodproofing lake structures in the two towns were determined and added to the costs and benefits of the turf channel-structure floodproofing alternative to permit an economic comparison of the resulting augmented alternative to the lake storage-major channelization-structure floodproofing alternative discussed below.

As shown on Map 14, the analyses indicated that about nine structures located in the primary flood zones would have to be floodproofed by elevating them above the 100-year recurrence interval flood stage, and about 11 structures located in the primary and secondary flood zones would require some less extensive form of floodproofing. Future flood damage to private residences and commercial structures along Pewaukee Lake in the Towns of Pewaukee and Delafield would be virtually eliminated by the floodproofing.

Assuming that the aforementioned structure floodproofing measures around Pewaukee Lake in the two towns would be fully implemented and utilizing an annual interest rate of 6 percent and a project life and amortization period of 50 years, the equivalent average annual cost is estimated at about $11,000. This average annual cost consists entirely of the amortization of the $25,800 capital cost for basic floodproofing and $146,800 for floodproofing by elevating structures. The average annual flood abatement benefit is estimated at about $37,600, yielding a benefit-cost ratio of 3.42 and an excess of annual benefits over costs of about $26,600. Therefore, floodproofing, as described herein, would be both technically and economically feasible for structures located on the perimeter of Pewaukee Lake in the Towns of Pewaukee and Delafield.

Assuming that the aforementioned structure floodproofing measures along Pewaukee Lake in the two towns would be integrated into the turf channel-structure floodproofing alternative and utilizing an annual interest rate of 6 percent and a project life and amortization period of 50 years, the equivalent average annual cost is estimated at $169,100. The average annual flood abatement is estimated at $207,400, yielding a benefit-cost ratio of 1.23 and an excess of annual benefits over costs of about $38,300. The turf channel-structure floodproofing alternative developed for the Village of Pewaukee has a benefit-cost ratio of 1.07 and an excess of annual benefits over costs of $11,600. If floodproofing in the Towns of Pewaukee and Delafield is included, the alternative becomes more economic in that the benefit-cost ratio increases to 1.23 and the excess of annual benefits over costs increases to $38,300.

Lake Storage-Major Turf Channel-Structure Floodproofing Composite

Although the storage of floodwaters on Pewaukee Lake, as described earlier, is a technically practicable and economically feasible structural floodland management measure for the Village of Pewaukee, it would resolve only a small part—about 25 percent—of the flood problem; equally important, it would aggravate flood problems around the perimeter of Pewaukee Lake in the Towns of Pewaukee and Delafield. Therefore, an alternative consisting of lake storage in combination with a major turf channel along the Pewaukee River in the Village and supplemented with structure floodproofing in the Village and along Pewaukee Lake in the Towns of Pewaukee and Delafield was developed and subjected to technical and economic analysis. The lake storage-major turf channel-structure floodproofing composite is shown on Map 15 and the physical characteristics and attendant costs and benefits are presented in Table 8.

The lake storage component of this alternative would be identical to that in the single means lake storage alternative consisting of about 1,300 feet of earthen dike and concrete floodland along the eastern shoreline in the Village of Pewaukee. The channel modification component of this alternative would be identical to that described above for the major turf channel-structure floodproofing composite except that the earthen dikes and concrete floodwalls paralleling the turf channel in the lake storage-channel modification-structure floodproofing composite would be about one foot lower than the dikes and floodwalls required for the turf channel-structure floodproofing alternative. A reduction in dike-floodwall heights is possible because the 100-year recurrence interval design discharge for the former is less than the 100-year design discharge for the latter—610 cfs at the downstream village limits for the former versus 1,040 cfs for the latter—reflecting the effects of the upstream storage. A turf-lined channel, as opposed to a concrete channel, was incorporated into the lake storage-major channelization-structure floodproofing alternative since the above technical and economic analyses of the two channel types indicated that each was technically practicable whereas the turf channel would be less costly.

The pumping station and bridge replacement components of this composite alternative are identical to those of the turf channel-structure floodproofing composite. More specifically, the lake storage-major channelization-structure floodproofing alternative would require four storm water pumping stations along the Pewaukee River and demolition and replacement of the existing Oakton Avenue, Clark Street, and CTH SS bridges over the Pewaukee River. The Pewaukee Lake Outlet control structure would be unchanged from its existing condition but the downstream 0.1 mile portion of the Pewaukee Lake Outlet, which is presently an open channel, would be enclosed.

The structure floodproofing component of this composite alternative would require: 1) the basic floodproofing of about 19 residential and commercial structures and the floodproofing by raising of about one residential structure within the Village along the Pewaukee River and Pewaukee Lake, 2) the basic floodproofing of 10 structures and the floodproofing by raising of about six structures around the perimeter of Pewaukee Lake in the Town of Pewaukee, and 3) the basic floodproofing of about three structures and the raising of about six structures in the Town of Delafield. Floodproofing in Towns of Pewaukee and Delafield is needed to mitigate existing flood problems and to prevent damage due to higher stages expected on Pewaukee Lake as a result of its being used for temporary storage of flood water.

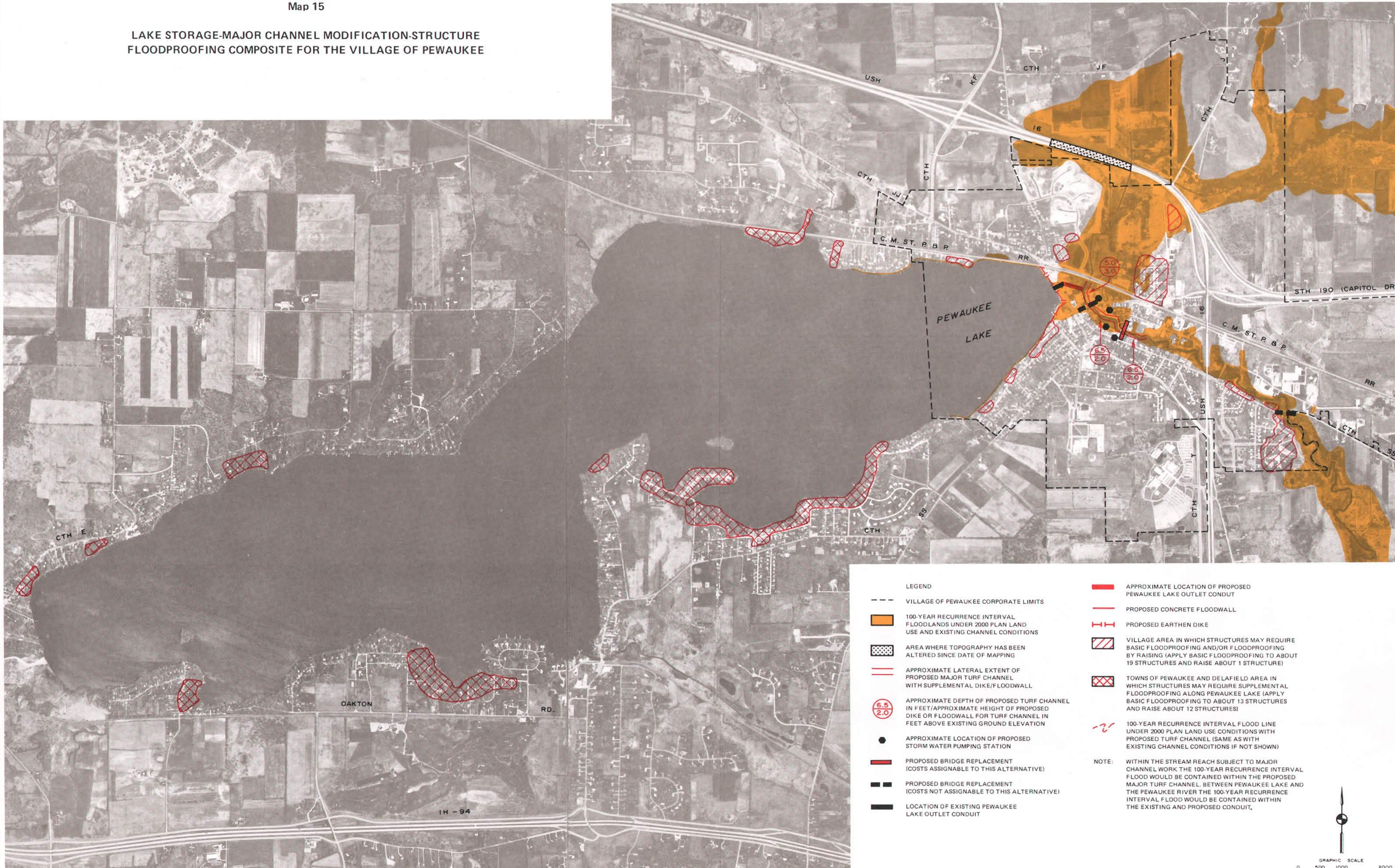
The annual cost of the lake storage-major channelization-structure floodproofing composite, utilizing an annual interest rate of 6 percent and a project life and amortization period of 50 years, is estimated at $149,000, which consists of the following: amortization of the $975,400 capital cost of the channel modifications and supplemental dikes and floodwalls, amortization of the $72,200 capital cost of Pewaukee Lake Outlet enclosure, amortization of the $250,600 capital cost of earthen dikes and $58,200 capital cost of concrete floodwalls along the eastern edge of Pewaukee Lake in the Village, amortization of the $356,000 capital cost of storm water pumping stations, amortization of the $115,200 capital cost of the Clark Street bridge demolition and replacement, amortization of the $192,900 capital cost of basic floodproofing and $247,800 for floodproofing by elevating, and $5,100 in annual operation and maintenance costs.

Assuming that the lake storage-major channelization-structure floodproofing composite would completely eliminate all direct and indirect flood damages along the Pewaukee River, the Pewaukee Lake Outlet, and Pewaukee Lake in the Village of Pewaukee and the Towns of Pewaukee and Delafield, the average annual flood abatement benefit is estimated at about $207,400, yielding a benefit-cost ratio of 1.39 and an annual excess of benefits over costs of $58,400. The lake storage-channelization-structure floodproofing composite, as described herein, is a technically practicable and economically feasible means of abating the flood problem within the Village and along Pewaukee Lake in the Towns of Pewaukee and Delafield.

The costs of the CTH SS and Oakton Avenue crossings of the Pewaukee River were excluded

Map 15

LAKE STORAGE-MAJOR CHANNEL MODIFICATION-STRUCTURE FLOODPROOFING COMPOSITE FOR THE VILLAGE OF PEWAUKEE



Source: SEWRPC.

from the above detailed cost analysis since they are recommended for replacement under the adopted jurisdictional highway system plan for Waukesha County. If the $225,200 capital cost of the CTH SS and Oakton Avenue structures is assigned to this alternative, the total capital cost would be increased to $2,493,500 and the average annual amortization cost would be increased to $158,200. Adding estimated operation and maintenance expenditures of $5,100 per year would yield a total annual cost of $163,300—$14,300 more than when the costs of the two river crossings are excluded from the economic analysis. The average annual flood control benefit would remain at $207,400 and, therefore, the benefit-cost ratio would be reduced from 1.39 to 1.27 and the annual $58,400 excess of benefits over cost would decrease to $44,100.

As shown in Table 8, this composite alternative would exhibit the various positive and negative features of the several alternatives used to synthesize it. Positive features include the opportunity to develop a water-oriented greenway along the Pewaukee River through the Village and elimination of overland flooding in the business area and the resulting enhancement of the development potential of that area. Positive features associated with the floodproofing component of this alternative are immediate partial relief at the discretion of the property owner and assumption, by the beneficiaries, of the cost of flood protection. Negative features of this composite alternative associated with the floodproofing component have been discussed above in conjunction with the river diversion-floodproofing alternative. Other negative features of the lake storage-channelization-structure floodproofing composite include the need for coordination between the Village of Pewaukee and the Towns of Pewaukee and Delafield for successful implementation of the alternative and the possibility that upstream floodwater control may lead to unwise downstream floodprone development.

Dikes and Floodwalls-Structure Floodproofing Composite

The dikes and floodwalls alternative described above was determined to be a technically practicable and economically feasible floodland management measure but left a residual average annual flood damage of 18 percent of the total average annual flood damage. Therefore, a composite dikes and floodwalls-structure floodproofing composite was developed and analyzed in order to use the very favorable benefit-cost features of the structure floodproofing to supplement the favorable economic aspects of a dikes-floodwalls system.

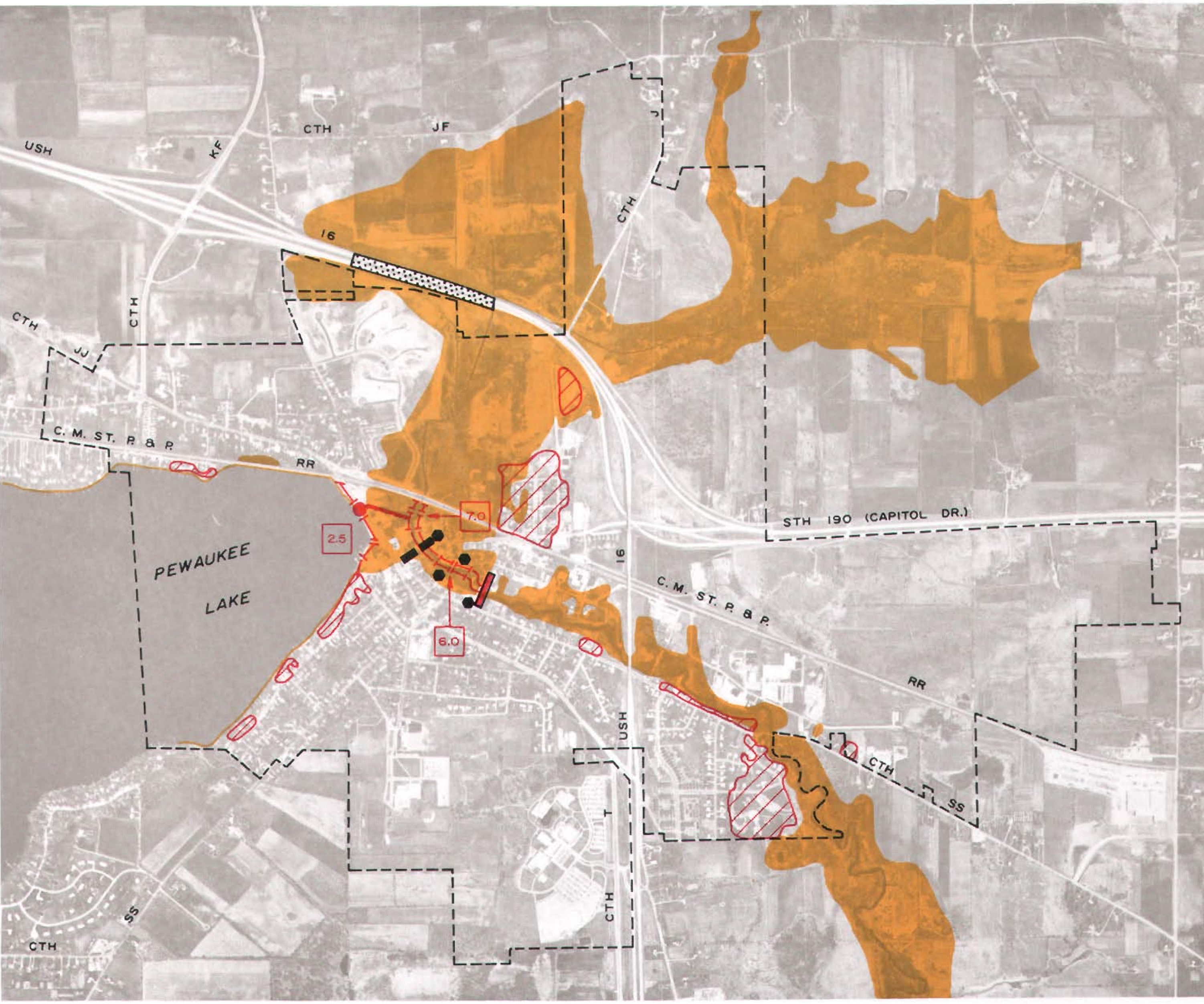
A graphical representation of the dikes and floodwalls-structure floodproofing composite is shown graphically on Map 16 and the physical characteristics and attendant costs and benefits of this composite are presented in Table 8. The dikes and floodwalls component of this alternative would be identical to that contained in the dikes-floodwalls alternative discussed above including: necessary replacement of river crossings, backwater control and pumping facilities, lake level control structure modifications, and Pewaukee Lake Outlet enclosure. The structure floodproofing component would require the floodproofing of about 25 residential and commercial structures along the Pewaukee River, Pewaukee Lake Outlet, and Pewaukee Lake in the Village of Pewaukee as compared to the floodproofing of about 49 structures under the previously examined structure floodproofing-removal alternative. This floodproofing would be required to supplement the dikes and floodwalls inasmuch as the dikes and floodwalls do not afford protection along the Pewaukee River and Pewaukee Lake outside of the immediate location of the dikes and floodwalls.

The total capital cost of the dikes and floodwalls-structure floodproofing composite is estimated at $2,137,100, composed of $1,093,900 for dikes and floodwalls construction and land acquisition, $96,000 for new river crossings, $356,000 for backwater control and pumping facilities, $294,500 for construction of a new lake level control structure and Pewaukee Lake Outlet enclosure, $213,900 for basic floodproofing, and $82,800 for floodproofing by elevating. The average annual cost equivalent to the $2,137,100 capital cost of the dikes and floodwalls-structure floodproofing composite at a 6 percent interest rate and for a project life and amortization period of 50 years would be $135,600. Adding estimated operation and maintenance costs of $4,800 per year yields a total annual cost of $140,400.

Assuming that the dikes and floodwalls-structure floodproofing composite would completely eliminate all direct and indirect flood damage along the Pewaukee River, Pewaukee Lake Outlet, and Pewaukee Lake in the Village of Pewaukee, the average annual flood abatement benefit is estimated at about $169,800, yielding a benefit-cost ratio of 1.21 and an annual excess of benefits over

Map 16

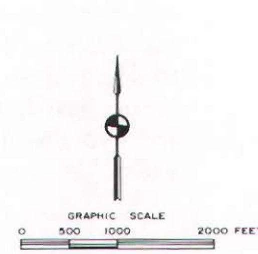
DIKES AND FLOODWALLS-STRUCTURE FLOODPROOFING COMPOSITE FOR THE VILLAGE OF PEWAUKEE



LEGEND

- VILLAGE OF PEWAUKEE CORPORATE LIMITS
- 100-YEAR RECURRENCE INTERVAL FLOODLANDS UNDER 2000 PLAN LAND USE AND EXISTING CHANNEL CONDITIONS
- AREA WHERE TOPOGRAPHY HAS BEEN ALTERED SINCE DATE OF MAPPING
- PROPOSED EARTHEN DIKE
- PROPOSED CONCRETE FLOODWALL
- 2.5 APPROXIMATE HEIGHT OF PROPOSED DIKE OR FLOODWALL IN FEET ABOVE EXISTING GROUND ELEVATION
- APPROXIMATE LOCATION OF PROPOSED STORM WATER PUMPING STATION
- PROPOSED BRIDGE REPLACEMENT (COSTS ASSIGNABLE TO THIS ALTERNATIVE)
- PROPOSED BRIDGE REPLACEMENT (COSTS NOT ASSIGNABLE TO THIS ALTERNATIVE)
- APPROXIMATE LOCATION OF PROPOSED PEWAUKEE LAKE OUTLET CONDUIT
- PROPOSED LAKE LEVEL CONTROL STRUCTURE
- VILLAGE AREA IN WHICH STRUCTURES MAY REQUIRE BASIC FLOODPROOFING AND/OR FLOODPROOFING BY RAISING (APPLY BASIC FLOODPROOFING TO ABOUT 20 STRUCTURES AND RAISE ABOUT 5 STRUCTURES)

NOTE: WITHIN THE STREAM REACH SUBJECT TO MAJOR CHANNEL WORK THE 100-YEAR RECURRENCE INTERVAL FLOOD WOULD BE CONTAINED WITHIN THE PROPOSED DIKES AND FLOODWALLS. BETWEEN PEWAUKEE LAKE AND THE PEWAUKEE RIVER THE 100-YEAR RECURRENCE INTERVAL FLOOD WOULD BE CONTAINED WITHIN THE PROPOSED CONDUIT. WITHIN THE STREAM REACHES UPSTREAM AND DOWNSTREAM OF THE STREAM REACH SUBJECT TO MAJOR CHANNEL WORK THE 100-YEAR RECURRENCE INTERVAL FLOOD WOULD BE THE SAME AS UNDER 2000 PLAN LAND USE AND EXISTING CHANNEL CONDITIONS.



Source: *SEWRPC.*

costs of about $29,400. Therefore, the dikes and floodwalls-structure floodproofing composite is an economically sound as well as technically practicable means of abating the flood problem in the Village of Pewaukee.

As already noted, the cost of the Oakton Avenue crossing of the Pewaukee River was excluded from the above detailed cost analysis since it is recommended for replacement under the adopted jurisdictional highway system plan for Waukesha County. If the $96,000 capital cost of the Oakton Avenue structure is assigned to this alternative, the total capital cost would be increased to $2,233,100 and the average annual amortization cost would be increased to $141,700. Adding estimated operation and maintenance expenditures of $4,800 per year would yield a total annual cost of $146,500—$6,100 more than when the cost of the river crossing is excluded from the economic analysis. The average annual flood control benefit would remain at $146,500 and, therefore, the benefit-cost ratio would be reduced from 1.21 to 1.16 and the annual excess of benefits over cost would be reduced from $29,400 to $23,300.

As shown in Table 8, this composite alternative would exhibit the various positive and negative features of the several alternatives used to synthesize it. The three principal positive noneconomic and nontechnical characteristics of this dikes and floodwalls-structure floodproofing alternative include: 1) provision of immediate partial flood relief to some riverine property owners through application of floodproofing; 2) assignment of flood protection cost directly to beneficiaries via the floodproofing portion of the alternative; and 3) the elimination of overland flooding in the Village's business district and, therefore, enhancement of the development potential of that area.

The following four negative features are associated with the composite alternative: 1) the likelihood that complete voluntary implementation of the floodproofing component will not be achieved, therefore leaving a residual flood problem; 2) the problems associated with overland flooding which will remain in the areas provided with floodproofing; 3) the strong possibility that some floodproofing will be applied without adequate professional advice, resulting in structure damage and danger to occupants; and 4) the aesthetic impact of the dikes and floodwalls on riverine property owners and Village residents.

RECOMMENDED STRUCTURAL FLOOD CONTROL MEASURES

Five distinctly different composite structural floodland management alternatives were examined as possible solutions to the flood problem that exists along the Pewaukee River, Pewaukee Lake, and the Pewaukee Lake Outlet in the Village of Pewaukee and, in the case of alternatives 2, 3, and 4 along Pewaukee Lake in the Towns of Pewaukee and Delafield. These alternatives were: 1) minor channel modification-bridge and culvert alteration or replacement, 2) lake storage-major channelization structure floodproofing, 3) concrete-lined channel-structure floodproofing, 4) turf-lined channel-structure floodproofing, and 5) dikes and floodwalls-structure floodproofing. In addition, a sixth alternative, that of taking no action, is available to the public agencies concerned, and the flood damages attendant to this alternative provide an important basis for analysis of the potential benefits associated with each of the other alternatives.

The principal features of, and the cost and benefits associated with, each of the five composite floodland management alternatives are summarized in Table 8 together with the major favorable and unfavorable nontechnical and noneconomic considerations likely to influence selection of the most desirable composite solution or solutions. Figure 14 summarizes in graphic form the process by which the five composite alternatives were developed by combining the more viable single means structural flood control alternatives.

All five composite structural flood control alternatives were found to be technically feasible. In addition, all but one of the five composite structural flood control alternatives were found to be economically viable. The exception was the concrete-lined channel and structure floodproofing composite which has a benefit cost ratio of 0.94—slightly less than unity. Although the five alternatives were found to be technically practicable and all were found to be economically feasible or almost so, consideration of noneconomic and nontechnical factors associated with the five alternatives revealed significant differences in both the likelihood and desirability of implementation in the Village of Pewaukee.

The minor channel modification-bridge and culvert alteration or replacement composite was eliminated from further consideration because this composite alternative would provide only a partial solution to the Village of Pewaukee—only about 40 percent of the average annual flood damages would be mitigated.

The major concrete channel-structure floodproofing composite was eliminated from further consideration. This alternative would cost more than the similar turf channel-structure floodproofing composite while not having any significant technical or nontechnical advantages.

The dikes and floodwalls-structure floodproofing composite alternative was eliminated from further consideration primarily because of the aesthetic impacts of the dikes and floodwalls. The height of the dikes and floodwalls would render them extremely unsightly to some owners or tenants of residential and commercial property in the central portion of the Village and to visitors to that area. The crest of the dikes and floodwalls along the Pewaukee River would be as much as 7.0 feet above the existing ground grade at the bank of the Pewaukee River. These massive structures would dominate the local environment and form a significant visual barrier.

Upon elimination of the above three composite alternatives, two composite alternatives remain: the major turf channel-structure floodproofing composite and the lake storage-turf channel-structure floodproofing composite. From the perspective of flood control effectiveness within the Village of Pewaukee, there is no difference between these two alternatives—either approach may be expected to control floods up to and including the 100-year recurrence interval event. From the perspective of the continued viability of the Village business area, there is no difference between these two alternatives—either would eliminate overland flooding in the business district as well as in the contiguous residential area and thereby enhance the developmental potential of the business district. From the perspective of environmental amenities in the Village, there is no difference between these two alternatives—either would provide an opportunity to develop a water-oriented greenway along the Pewaukee River through the Village thereby substantially improving the aesthetic quality of the center portion of the Village. From the perspective of cost to the Village, there is no significant difference between these two alternatives—the entire $158,200 annual cost of the turf channel-structure floodproofing composite would have to be borne by the Village or its residents, and the entire $149,000 annual cost of the lake storage-turf channel-structure floodproofing composite would also have to be borne by the Village. Even through about 10 percent of the costs would be expended for structure floodproofing along Pewaukee Lake in the Towns of Pewaukee and Delafield, the entire cost of the lake storage-turf channel-structure floodproofing composite would probably have to be borne by the Village since the required floodproofing is due in part to higher lake stages associated with the temporary storage of floodwater.

The principal physical difference between the turf channel-structure floodproofing composite and the lake storage-turf channel-structure floodproofing composite from the perspective of the Village of Pewaukee is that the latter would permit slightly lower—about one foot—supplemental dikes and floodwalls along Pewaukee Lake. The principal implementation-oriented difference between the two alternatives from the perspective of the Village is that the lake storage-turf channel-structure floodproofing alternative would require a coordinated effort by the Village of Pewaukee and the Towns of Pewaukee and Delafield, whereas the turf channel-structure floodproofing alternative could be implemented by the Village. Ease of implementation of the turf channel-structure floodproofing alternative offsets the small economic advantage of the lake storage-turf channel-structure floodproofing alternative.

Therefore, it is recommended that the major turf channel-structure floodproofing alternative be adopted and implemented to solve existing and potential flood problems along the Pewaukee River, the Pewaukee Lake Outlet, and Pewaukee Lake in the Village of Pewaukee. In addition to providing essentially complete relief from flood damages within the Village of Pewaukee, this approach would help to accomplish two desirable related objectives. First, the turf channel-structure floodproofing composite would eliminate overland flooding in the Village business district—as well as the contiguous residential areas—and thereby enhance the development potential of the central business district. Second, the composite would provide an opportunity to develop a water-oriented greenway along the Pewaukee River through the business-commercial area, thereby improving the aesthetic character of the center portion of the Village.

This recommendation is directed to the Village of Pewaukee and does not include floodproofing of structures located on the periphery of Pewaukee Lake in the Towns of Pewaukee and Delafield. However, this recommendation to the Village does not preclude structure floodproofing around Pewaukee Lake outside of the Village. Officials of the Towns of Pewaukee and Delafield may wish to pursue this recommendation since preliminary analyses conducted under this floodland management study indicate that structure floodproofing would be technically practicable and economically feasible.

RECOMMENDED NONSTRUCTURAL FLOODLAND MANAGEMENT MEASURES

Of the 10 available nonstructural floodland management measures set forth in Table 5 and discussed earlier in this chapter, three are particularly effective for minimizing aggravation of existing flood problems and for preventing development of future flood problems. These three preventive measures are: 1) reservation of floodlands for recreational and related open space uses through such measures as private use or public acquisition of the land or of an easement; 2) floodland use regulation as accomplished through zoning, land subdivision, sanitary, and building ordinances; and 3) regulation of land use outside of the floodlands which could also be accomplished through zoning, land subdivision, and sanitary and building ordinances. These three primary nonstructural floodland management measures are directed toward some form of control over the use of land as that use may either aggravate existing flood problems or create new ones. On their application to the Village of Pewaukee, the above nonstructural preventive measures are discussed below in two categories: land use controls within the floodlands and land use controls outside of the floodlands.

Five of the nonstructural floodland management measures set forth in Table 5 also are discussed below as they relate to the Village of Pewaukee. These five measures are federal flood insurance, lending institution policies, realtor policies, community utility policies, and emergency programs. Although none of these measures alone is well suited to significantly reducing existing flood problems, a combination of these measures properly applied to a community may be instrumental in preventing the aggravation of existing flood problems or the development of future flood hazards; may help to alleviate the monetary flood loss incurred by owners of existing flood-prone property, as accomplished by participation in the flood insurance program; and, through emergency measures, may substantially reduce the threat to the life and health of residents of flood-prone areas. The remaining two of the 10 available nonstructural measures—floodproofing and removal—were discussed above in conjunction with structural measures.

Land Use Control Within Floodlands

Encouragement of Recreational and Related Open Space Uses: Substantial reduction in floodwater storage and conveyance associated with floodland fill and development may be expected to produce significant increases in downstream flood flows, stages, and areas of inundation, thereby seriously aggravating existing flood problems or creating new ones. It is recommended, therefore, that the use of floodland areas for outdoor recreation and related open space activities be emphasized and carried out to minimize the aggravation of existing flood problems and the development of new flood problems. Examples of floodland areas within the Village well suited for open space uses include some undeveloped floodplain fringe areas west of the reach of the Pewaukee River bounded at the downstream end by Capitol Drive and at the upstream end by USH 16. It is important to note that, in keeping with the adopted comprehensive plan for the Fox River watershed, hydrologic-hydraulic analyses carried out under this floodland management planning study assume no significant additional fill and development in the floodlands of the Pewaukee River subwatershed.

Floodland Regulations and the Wisconsin Floodplain Management Program: Wisconsin Statutes require that all counties, cities, and villages with existing or potential flood hazards adopt reasonable and effective floodland regulations in accordance with the floodplain management program administered by the Wisconsin Department of Natural Resources. On February 7, 1977, the Village of Pewaukee adopted floodland zoning regulations as a result of the Floodland Information Report for the Pewaukee River. The adopted floodland regulations divide the delineated 100-year recurrence interval floodlands of the Pewaukee River-Pewaukee Lake Outlet and Pewaukee Lake throughout the Village into three distinct regulatory areas—floodway overlay district, floodplain overlay district, and conservancy zoning district.[10] In addi-

[10] *SEWRPC Community Assistance Planning Report No. 11, Floodland Information Report for the Pewaukee River, Chapter IX, "Floodland Regulations," October 1976, 43 pp.*

tion to meeting minimum hydrologic-hydraulic standards established by the State of Wisconsin floodplain management program,[11] these regulations are intended to preserve the essentially open character of the floodlands while recognizing the existing and proposed land uses within the floodlands and contiguous areas as recommended in the adopted comprehensive plan for the Fox River watershed.

The eventual implementation of structural flood control works recommended in this report probably will necessitate adjustment of the Village's floodland regulations within and immediately downstream of those reaches along the Pewaukee River, Pewaukee Lake Outlet, and Pewaukee Lake in which structural flood control works are recommended. For example, construction of major channel works along the Pewaukee River in the Village would markedly reduce the lateral extent of the floodplain and, therefore, of the area requiring floodplain regulations. The need to alter floodplain regulations as a result of structural flood control works is reflected in the water control facility development objectives, principles, and standards adopted by the SEWRPC under the Commission's comprehensive watershed planning program. These standards state that the construction of structural flood control works shall be deemed to change the limits and extent of associated floodways and floodplains but that no such changes shall become effective until such time as the structural flood control works are actually constructed and operative. In summary, the Village of Pewaukee has adopted and is administering reasonable and effective floodland regulations. These regulations, however, are subject to revision upon adoption and implementation of the recommendations set forth in this study.

Land Use Controls Outside of the Floodlands

Changing land use outside of the floodlands can have a significant impact on flood flows and stages. For example, conversion of rural areas having little impervious area into urban land uses with relatively large impervious area may be expected to increase flood flows and stages.

Many factors enter into the design of a land use plan for the Region and for the subwatershed including relating new development sensibly to soil capabilities, to long established and planned utility systems, and to the natural resource base of the subwatershed and the allocation of sufficient land to each of the various major land use categories. The land use plan is also a key element in a floodland management plan for the subwatershed, and it should be emphasized that the recommended structural and nonstructural floodland management measures for the Village of Pewaukee assume implementation of the year 2000 watershed land use plan. Failure to recognize the impact of land use on flood problems and, accordingly, to control the manner in which incremental urbanization occurs in the Pewaukee River subwatershed could negate many of the positive flood mitigation aspects of many of the other nonstructural floodland management measures as well as the structural measures recommended for the Village.

Federal Flood Insurance

While the federal flood insurance program does not solve flood problems or mitigate flood damages, it does provide a means for distributing monetary flood losses in the form of an annual flood insurance premium and, in those situations where the insurance premiums are subsidized, the federal flood insurance program also provides a way of reducing monetary flood losses to the owner. As noted earlier in this chapter, the Village of Pewaukee has been participating in the first or emergency phase of the Federal Flood Insurance Program since March 1975, enabling all Village residents to acquire subsidized flood insurance for protection of residential and other structures and their contents.

It is recommended that the Village request the U. S. Department of Housing and Urban Development, in cooperation with the Wisconsin Department of Natural Resources, to authorize the conduct of insurance rate studies in the Village, and it is further recommended that the contractors retained by the U. S. Department of Housing and Urban Development to conduct the flood insurance rate studies make maximum use of the flood hazard data set forth in Floodland Information Report for the Pewaukee River and in this report. Completion of these flood insurance rate studies will enable residents of the Village of Pewaukee to obtain additional flood insurance coverage at actuarially determined rates. Such coverage should be maintained by property owners in the Village until such time as implementation of recommended flood control measures mitigate flood problems and eliminate the need for flood insurance.

[11] *As of September 15, 1977, the Village of Pewaukee floodland zoning regulations had been reviewed by the Wisconsin Department of Natural Resources staff and given preliminary approval.*

Lending Institution Policies

As a result of the Federal Flood Insurance Program, private lending institutions in the southeastern Wisconsin area have generally assumed the responsibility for determining whether or not a property is in a flood-prone area and, if so, they require the purchase of flood insurance before granting a mortgage for a structure on the property. It is recommended that lending institutions continue to determine the flood-prone status of properties prior to the granting of a mortgage, irrespective of the requirements of the Federal Flood Insurance Program.

Realtor Policies

As noted earlier in this chapter, an executive order by the Governor of Wisconsin in 1973 strongly urges that real estate brokers, salesmen, and their agents inform potential property purchasers of any flood hazards which may exist at the site. It is recommended that this program be continued inasmuch as the property purchaser, particularly a potential buyer of a residence, is not likely to be aware of the threat to life and property posed by an event as rare as a major flood.

Community Utility Policies

As discussed earlier in this chapter, local communities may adopt policies on the extension of certain public utilities and facilities such as sanitary sewers, water mains, and streets in recognition of the likely influence of the location and size or capacity of such utilities and facilities on the location of new urban development. It is recommended that the policies of governmental units and agencies having responsibility for such utilities and facilities within the Village of Pewaukee be formulated so that the size, location, and use of those utilities and facilities are consistent with the flood-prone status of riverine areas. More particularly, it is recommended that these utility and facility policies be designed to complement the floodland regulations adopted by the Village and the floodland management recommendations set forth in this report.

Emergency Programs

An emergency program to minimize the damage and disruption associated with flooding normally consists of a variety of devices and techniques that are tailored to the flood hazard characteristics of individual communities. It is recommended, therefore, that the Village develop procedures to provide floodland residents and other property owners with information about potential flooding. It is suggested that such measures as the following be considered: monitoring of National Weather Service flash flood watch bulletins and flash flood warning bulletins during periods when rainfall or snowmelt are occurring or are anticipated, patrolling riverine areas to note when bankful conditions are imminent, emergency messages broadcast to community residents over radio and television, use of police patrol cars or other vehicles equipped with public address systems, and use of warning sirens having a special pattern to indicate that flooding is occurring, especially during nighttime hours.

While emergency measures like those recommended above may alleviate some damage to property in flood-prone areas by providing property owners with time to prepare for the flood stage, their most significant benefit is to provide a way to reduce the threat to the life and health of residents of flood-prone areas, particularly during nighttime hours when residents of riverine areas may not be aware of rising flood waters. None of the other floodland management alternatives available to the Village is directed explicitly to the protection of the inhabitants of existing flood-prone areas.

MISCELLANEOUS FLOODLAND MANAGEMENT CONSIDERATIONS

Influence of the Fox River on Flood Stages in the Village of Pewaukee

Village officials have expressed concern over the possible increase in flood stages on the Pewaukee River in the Village of Pewaukee resulting from the operation of the Barstow Street Dam on the Fox River in the City of Waukesha. The Barstow Street Dam is located about 2.2 miles downstream of the Fox River-Pewaukee River confluence which, in turn, is located 4.4 miles downstream of the farthest downstream limit of the Village of Pewaukee. As part of the floodland management study, a hydraulic analysis was conducted to determine the sensitivity of flood stages along the Pewaukee River in the Village to flood stages on the Fox River at the Fox River-Pewaukee River confluence. The concept underlying this analysis was that if extreme changes in Fox River flood stages at the confluence of the Fox and Pewaukee Rivers do not affect flood stages along the Pewaukee River in the Village of Pewaukee, then stage changes on the Fox River brought about by the operation of the Barstow Street Dam also would not affect flood stages along the Pewaukee River in the Village of Pewaukee.

The regulatory 100-year recurrence interval flood flow under year 2000 plan land use conditions was selected for the purpose of this analysis. A series of backwater computations was conducted to obtain 100-year recurrence interval flood stage profiles along the Pewaukee River upstream of the Fox River-Pewaukee River confluence corresponding to various flood stages at the confluence as developed under the Commission's Fox River watershed planning program. Simulated stages on the Fox River at the confluence range from a low of 818.0 feet above National Geodetic Vertical Datum, which is two feet below the 100-year recurrence interval flood stage on the Fox River at that location, to a high of 826.0 feet above National Geodetic Vertical Datum which is six feet above the 100-year recurrence interval stage on the Fox River at the confluence.

As set forth in Table 9, the hydraulic analysis indicates that flood stages on the Pewaukee River in the Village of Pewaukee are not affected by the extreme water level fluctuations occurring on the Fox River at the confluence of the Fox and Pewaukee Rivers. Therefore, flood stages on the Pewaukee River in the Village of Pewaukee are not affected by water level changes caused by operation of the Barstow Street Dam located about 2.2 miles downstream of the Fox-Pewaukee River confluence in the City of Waukesha.

Watershedwide Effects of Recommended Structural Flood Control Measures

The recommended floodland management plan for the Village of Pewaukee includes the following primarily structural flood control measures, as shown on Map 14, for the abatement of the existing, and for the avoidance of new, flood problems within the Village of Pewaukee.

- The construction of 0.43 mile of major channel improvements—consisting of 0.43 mile of a concrete- or turf-lined channel with supplemental dikes and floodwalls designed to convey the 100-year recurrence interval flood flow under year 2000 plan conditions—and attendant necessary bridge and culvert modifications along the Pewaukee River from 700 feet downstream of Clark Street to the Chicago, Milwaukee, St. Paul and Pacific Railroad bridge.

- The reconstruction of 0.05 mile and the construction of 0.10 mile of new channel improvements along the Pewaukee Lake Outlet—consisting of enclosing the outlet in several conduits designed to convey the 100-year recurrence interval flood flow under 2000 plan conditions.

Table 9

EFFECT OF THE FOX RIVER ON FLOOD STAGES ON THE PEWAUKEE RIVER IN THE VILLAGE OF PEWAUKEE UNDER YEAR 2000 PLAN LAND USE CONDITIONS

Location			Reference Stages	Stages Corresponding to a 2 Foot Rise at the Confluence		Stages Corresponding to a 4 Foot Rise at the Confluence		Stages Corresponding to a 6 Foot Rise at the Confluence		Stages Corresponding to a 2 Foot Drop at the Confluence	
River Station[a]	Structure Name or Other Location Identification	Structure Number	100-Year Flood Stage Profile[b] National Geodetic Vertical Datum	National Geodetic Vertical Datum	Increase Relative to Reference Stage (feet)	National Geodetic Vertical Datum	Increase Relative to Reference Stage (feet)	National Geodetic Vertical Datum	Increase Relative to Reference Stage (feet)	National Geodetic Vertical Datum	Increase Relative to Reference Stage (feet)
328500	Fox River Pewaukee River Confluence	--	820.0	822.0	2	824.0	4	826.0	6	818.0	-2
351570	Downstream Pewaukee Village Limits	--	845.5	845.5	0	845.5	0	845.5	0	845.5	0
354600	CTH SS	72	848.5	848.5	0	848.5	0	848.5	0	848.5	0
359700	Clark Street	70	851.6	851.6	0	851.6	0	851.6	0	851.6	0

[a] *Stationing in feet along the stream system referenced to the Wilmot Dam on the main stem of the Fox River in Kenosha County.*

[b] *Stages corresponding to structure locations are immediately upstream of the structure.*

Source: SEWRPC.

- The construction of 0.25 mile of dikes and floodwalls along the eastern extremity of Pewaukee Lake.

- The construction of four backwater control gates and storm water pumping stations along the Pewaukee River.

- The floodproofing of approximately 20 residential and commercial structures by basic floodproofing techniques and five residential structures by raising.

Earlier sections of this chapter discussed the hydrologic-hydraulic consequences that extensive floodland development in the subwatershed may have, whether through floodland fill up to the channel limits or through stream channelization. These consequences may be in the form of markedly increased flood flows, flood stages, and, therefore, flood damages. Therefore, concern exists over the expected long-term impact of the recommended structural flood control measures on downstream flood flows, flood stages, and flood damages. Moreover, analysis of the expected effect of recommended structural flood control measures on flood flows and stages is required by the adopted water control facility development objectives and standards, particularly the standard which states that the upstream and downstream effect of structural flood control works and flood discharges and stages shall be determined and, if the flood control works significantly increase upstream or downstream discharges or stages, such works shall be used only in conjunction with complementary facilities for the storage and movement of the incremental floodwaters through the watershed stream system.

The recommended structural flood control measures for the Village of Pewaukee would be expected to have insignificant effects on downstream flood flows, flood stages, and flood damages for the following two reasons:

- Only about 0.5 mile of the 6.1 miles, or 8 percent, of the Pewaukee River and Pewaukee Lake Outlet upstream of the Village of Pewaukee southern limits and only about 0.5 mile of the 10.5 miles, or 5 percent, of the Pewaukee River and Pewaukee Lake Outlet upstream of the Pewaukee River-Fox River confluence are recommended for major channel modifications.

- Minimal potential floodwater storage would be affected inasmuch as existing land uses have already greatly encroached into the floodlands of the Pewaukee River and Pewaukee Lake Outlet reaches for which major channel modifications are recommended.

In order to verify the above qualitative evaluation of the expected downstream effect of channel modifications, a quantitative analysis was conducted with the simulation model. The April 1973 flood event, which had an estimated recurrence interval of 50 years on the Pewaukee River at the downstream corporate limits of the Village and at the Pewaukee River-Fox River confluence, was simulated for the year 2000 planned land use condition and two channel conditions. The first channel condition was the existing channel-floodplain configuration along the Pewaukee River and Pewaukee Lake Outlet within the Village and the second channel condition was the channel and floodplain as they would exist if the recommended major turf-lined channel measure was implemented. Under existing channel-floodplain conditions and year 2000 planned land use, the peak discharge on the Pewaukee River at the downstream limits of the Village of Pewaukee was 770 cfs whereas the peak discharge on the Pewaukee River at the Pewaukee River-Fox River confluence was 830 cfs. Assuming implementation of the turf-lined channel measure, no difference in flood flows would occur at these two locations. Therefore, the recommended structural flood control measures for the Village of Pewaukee would have no significant effect on downstream flood flows, stages, and damage.

In addition, the recommended structural flood control measures for the Village of Pewaukee would be expected to have insignificant adverse effects on upstream flood flows, flood stages, and flood damages for the following two reasons:

- Backwater computations indicate that flood stages on the Pewaukee River upstream of the proposed channel modifications will not increase and, in fact, the flood stages decrease due to the increased efficiency of the channel and the replacement of existing bridges which create significant backwater.

- The Pewaukee Lake level control structure and outlet would be designed to convey the 100-year recurrence interval flood discharge without increasing or decreasing flood stages on Pewaukee Lake.

Chapter IV

PLAN IMPLEMENTATION

INTRODUCTION

The foregoing chapter of this report sets forth a recommended solution to existing and potential flood problems along the Pewaukee River, the Pewaukee Lake Outlet, and Pewaukee Lake in the Village of Pewaukee. Briefly stated, these recommendations are as follows:

1. Construction of a turf-lined channel along the Pewaukee River within the Village, enclosure of the Pewaukee Lake Outlet, and placement of an earthen dike-concrete floodwall along the eastern edge of Pewaukee Lake.

2. Floodproofing of selected residential and commercial structures in the Village of Pewaukee.

3. Reservation of remaining floodlands for recreational and related open space uses and for floodwater storage and conveyance purposes.

4. Vigorous administration of the floodland zoning regulations and revision of regulations upon completion of recommended structural flood control works.

5. Regulation of land outside of the floodlands in the Pewaukee River subwatershed in conformance with the SEWRPC year 2000 land use plan.

6. Conduct of a flood insurance rate study under the National Flood Insurance Program to provide an opportunity for additional flood insurance coverage to Village residents.

7. Continuation of the procedures by which real estate brokers, salesmen, and their agents inform potential purchasers of property of any flood hazards which may exist at the site and by which lending institutions determine the flood-prone status of properties prior to granting of mortgages or other financial assistance.

8. Adoption of utility and facility policies and procedures to assure that the size, location, and the use of those utilities and facilities is consistent with the flood-prone status of riverine areas.

9. Development of emergency procedures to provide floodland residents and other property owners with information about impending flooding.

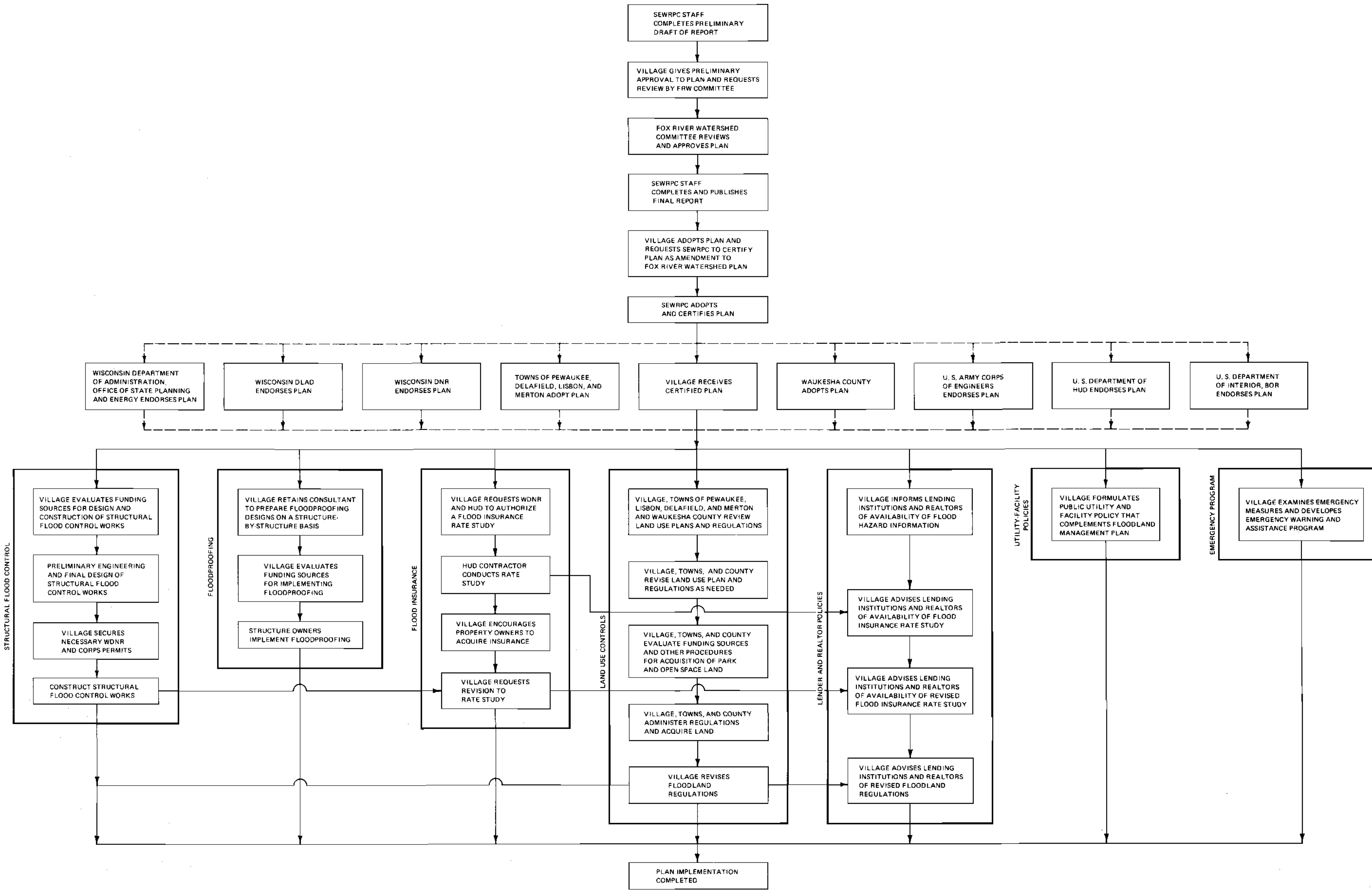
While the recommended floodland management plan for the Village of Pewaukee is designed to resolve existing and future flood problems within the Village, the plan is not complete in the practical sense until the steps required to implement the plan—that is, to convert the plan into action policies and programs—are specified. This chapter, therefore, is presented as a guide for use in implementation of the floodland management plan for the Village. It outlines the sequential actions which must be taken by the Village of Pewaukee in cooperation with other units and agencies of government in order to implement the recommended floodland management plan. Financial and technical assistance programs available in implementation of the watershed plan also are discussed.

SEQUENTIAL IMPLEMENTATION PROCESS

Although local, state, and federal units and agencies of government may all eventually be involved in successful implementation of the recommended floodland management plan for the Village of Pewaukee, primary responsibility for initiating the plan implementation process and for maintaining continuity in the process through completion resides with the Village. Figure 16 sets forth a suggested implementation process that 1) establishes the leadership role of the Village, 2) identifies other local, state, and federal units and agencies of governments which may or will be involved in the implementation process, and 3) establishes a sequential procedure by which each of the structural and nonstructural subelements of the recommended plan may be implemented. The steps in the

Figure 16

IMPLEMENTATION PROCESS FOR THE RECOMMENDED FLOODLAND MANAGEMENT PLAN FOR THE VILLAGE OF PEWAUKEE



Source: SEWRPC.

recommended sequential implementation process are discussed below with the order of the discussion generally following the sequence set forth in Figure 16.

Plan Review, Adoption, and Endorsement

Local and Regional Agencies: The plan review, adoption, and endorsement process was initiated by the Village's review of the draft of the report in September 1977. The Village Board approved the preliminary draft of the report on December 5, 1977, and the Village Planning Commission gave its approval on January 5, 1978. The floodland management plan for the Village of Pewaukee was recommended for approval by the Fox River Watershed Committee on February 20, 1978. After this recommendation, the SEWRPC staff completed and published the final report.

It is recommended that the plan be adopted by the Plan Commission of the Village of Pewaukee as part of the master plan for the Village by resolution pursuant to Section 62.23(3)(b) of the Wisconsin Statutes and be certified to the Village Board for adoption by the Board. After Village Board adoption, it is suggested that the Village request the Regional Planning Commission to adopt the plan and certify it as an amendment to the previously adopted Fox River watershed plan.

Upon adoption of the plan by the Southeastern Wisconsin Regional Planning Commission, in accordance with Section 66.945(10) of the Wisconsin Statutes as an amendment to the adopted Fox River watershed plan, the Commission will transmit a certified copy of the resolution adopting the plan, together with the plan itself, to local, areawide, state, and federal agencies having potential plan implementation functions.

It is recommended that, upon receipt of the certified plan, the plan commissions of the Towns of Pewaukee, Delafield, Lisbon, and Merton adopt the plan as it affects them, by resolution pursuant to Section 62.23(3)(b) of the Wisconsin Statutes, and certify such adoption to the town boards for adoption by the boards.

It is recommended that the Waukesha County Board also formally adopt the recommended floodland management plan for the Village of Pewaukee as an amendment to the adopted Fox River watershed plan after a report and recommendations by the County Park and Planning Commission.

State Level Agencies: It is recommended that the Wisconsin Natural Resources Board endorse the recommended floodland management plan as an amendment to the Fox River watershed plan and direct its staff in the Wisconsin Department of Natural Resources to integrate the recommended plan into its broad range of agency responsibilities. In particular, it is recommended that the Board, through its staff, coordinate the recommended floodland management plan for the Village of Pewaukee with its activities relating to floodland zoning, water regulatory powers, the National Flood Insurance Program, and the Outdoor Recreation Aids Program (ORAP).

It is recommended that the Wisconsin Department of Local Affairs and Development endorse the recommended floodland management plan for the Village of Pewaukee and integrate the plan into its activities for the provision of technical assistance to the Village of Pewaukee, for reviewing subdivision plats, and for administering federal urban planning grants.

It is recommended that the Wisconsin Department of Administration, Office of State Planning and Energy, endorse the recommended floodland management plan for the Village of Pewaukee and integrate the plan into its activities for reviewing applications for federal and state loans, grants, and other aids in accordance with Circular A-95 published by the U. S. Office of Management and Budget.

Federal Level Agencies: It is recommended that the U. S. Department of Housing and Urban Development endorse the recommended floodland management plan for the Village of Pewaukee and utilize such plan in its administration and granting of federal aids for community development and in the administration of the National Flood Insurance Program.

It is recommended that the U. S. Department of the Army, Corps of Engineers, formally acknowledge the recommended floodland management plan for the Village of Pewaukee and integrate it into the water resources study currently being prepared by the Corps of Engineers for the Fox River watershed in Wisconsin and Illinois. It is further recommended that the Corps of Engineers cooperate with the Village of Pewaukee and other local, state, and federal units and agencies of government concerned in any requests for financial or technical assistance in the review, design, and construction phases of the structural elements of the recommended plan.

It is recommended that the U. S. Department of the Interior, Bureau of Outdoor Recreation, formally acknowledge the recommended floodland management plan for the Village of Pewaukee and utilize the plan recommendations in its administration and granting of federal aids under the Land and Water Conservation Fund Act (LAWCON).

Structural Flood Control Measures

The structural element of the recommended floodland management plan for the Village of Pewaukee consists of a turf-lined channel along the Pewaukee River, enclosure of the Pewaukee Lake Outlet, and placement of an earthen dike-concrete floodwall along the eastern edge of Pewaukee Lake. As indicated in Figure 16, this structural flood control element could be accomplished in a four-step procedure.

As step one, the Village would evaluate funding sources for both the design and construction of the structural flood control works. The Village could use revenue raised through the local property tax to carry out all or portions of the recommended structural flood control element. In addition, the Village is authorized to borrow money and issue municipal obligations.

Some financial assistance may also be available through the U. S. Department of the Army, Corps of Engineers in that the Corps can conduct planning studies and construct flood control facilities as authorized by Congress. In addition, under Section 205 of the Flood Control Act of 1948, as amended, the Corps is authorized to contribute to the review, design, and construction phases of selected projects, provided that the maximum Corps of Engineers first cost is $2 million or less. If the project is funded by the Corps under the first approach, that is, specific Congressional authorization, the total elapsed time from inception through construction would be in excess of 10 years. If the project is funded by the Corps under Section 205 authorization, the total elapsed time would be about five years. While the flood control subelements contained in the recommended floodland management plan for the Village of Pewaukee could be implemented largely through existing local agencies or units of government, the potential exists for the Corps of Engineers to play a very important role in implementation of the floodland management plan provided that the Village requests the Corps or Congress to fund the review of the recommended structural flood control elements. The potential for Corps of Engineers participation is enhanced by the fact that the Corps is currently conducting a water resources study for the Fox River watershed in Wisconsin and Illinois into which the recommended floodland management plan for the Village of Pewaukee could be integrated.

Some funding may be available under the community development block grants program authorized under Title I of the Housing and Community Development Act of 1974, Public Law 93.383, administered by the U. S. Department of Housing and Urban Development. This program consolidates former community development-type categorical programs and provides grants to communities for the acquisition and development of land for park and open spaces, for urban beautification, and for sewer and water facilities.

The second step in implementation of the recommended structural flood control works is preliminary engineering and final design of the structural flood control works based on the findings of the systems planning work as reported herein. The final design could include a functional and aesthetic urban-oriented greenway along both the Pewaukee River and the shore of Pewaukee Lake through provision of such amenities as paved walks, benches, decorative lighting, grassy areas, flower beds, shrubs, bushes, trees, and fountains. Depending on the source of funding and the extent to which the federal government may be involved, the preliminary engineering and final design of the structural flood control works and supplemental greenway could be conducted in whole or in part by the U. S. Army Corps of Engineers or by a consulting firm retained by the Village.[1]

Upon completion of the preliminary engineering and final design, the third step in the process leading to implementation of the structural flood control element would be the responsibility of the Village and would involve securing necessary

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[1] *For a detailed discussion of the distinction between systems planning, preliminary engineering, and final design, refer to SEWRPC Planning Report No. 26, A Comprehensive Plan for the Menomonee River Watershed, Volume Two, Alternative Plans and Recommended Plan, October 1976, pp. 308-311.*

permits for construction from the Wisconsin Department of Natural Resources and the Army Corps of Engineers. Construction of the structural flood control works would be the fourth and final step in the implementation process.

Structure Floodproofing

The plan recommends that basic floodproofing be applied to about 20 residential and commercial structures within the Village and that additionally about five structures be floodproofed by elevating. As indicated in Figure 15, this floodproofing recommendation could be accomplished through a three-step procedure.

Under the first step, the Village would retain a civil engineering consultant specializing in structural design and analysis to perform a floodproofing analysis and prepare, as needed, based on that analysis, floodproofing plans on a structure-by-structure basis in the Village. The report of the consultant would identify those structures requiring floodproofing measures and would provide a detailed final design of the optimum mix of measures for each such structure.

Upon completion of the engineering report on structure floodproofing, the Village would initiate the second step in which alternative funding sources for implementation of the required floodproofing measures would be evaluated. While the Village would incur the costs of the engineering report, the cost of applying the floodproofing measures could be the responsibility of structure owners. Funds also possibly could be made available under the community development block grants program of the U. S. Department of Housing and Urban Development or through the Corps of Engineers under either of the two Corps participation programs discussed above.

The third and final step in implementing the floodproofing recommendations would be for structure owners to apply the floodproofing recommendations to the structures identified in the consultant's report in the manner specified in the consultant's final design for each structure.

Flood Insurance Rate Study

The recommended floodland management plan for the Village of Pewaukee includes the conduct of a flood insurance rate study to provide owners and residents of flood-prone structures with additional protection in the form of more insurance coverage. As indicated in Figure 16, implementation of the flood insurance rate study could be accomplished through a four-step procedure.

As the first step in the process, the Village would request that the Wisconsin Department of Natural Resources and U. S. Department of Housing and Urban Development authorize and fund a flood insurance rate study for the Village using the hydrologic-hydraulic information developed under this floodland management planning study and the preceding floodland information report. The actual conduct of the flood insurance rate study by a contractor selected and funded by the U. S. Department of Housing and Urban Development would be the second step in the process.

As the third step in the process, which would be initiated by the Village upon receipt of the completed flood insurance study, the Village would inform residents of flood-prone areas of availability of additional flood insurance and encourage them to acquire such insurance. The fourth step in the process would be initiated upon completion of construction of the flood control works and would involve revising the flood insurance rate study to reflect the expected substantial reduction in flood hazards.

Land Use Controls Within and Outside of the Floodlands of the Pewaukee River Subwatershed

The floodland management plan for the Village of Pewaukee recommends that appropriate controls be applied to land use both within and outside of the floodlands of the Pewaukee River subwatershed to assure that future urban development occurs in conformance with the year 2000 land use plan. As indicated in Figure 16, this could be accomplished as a five-step procedure.

As the first step in the procedure, the Village of Pewaukee; the Towns of Pewaukee, Delafield, Lisbon, and Merton; and Waukesha County would review detailed land use plans and land use regulations in the Pewaukee River subwatershed. As a second step in this process, the Village of Pewaukee, the four Towns, and the County would revise land use plans and regulations as needed to assure implementation of the adopted land use plan for the Pewaukee River subwatershed.

Under the third step in this process, the Village, the four Towns, and Waukesha County would evaluate alternative sources of funding and other procedures for acquisition of park and open space lands in the Pewaukee River subwatershed in conformance with the land use plan.[2,3] Several federal grant programs are available to state and local units of government, and one state program is available to local units of government for financing the parkland acquisition and development. The state Outdoor Recreation Aids Program (ORAP) administered by the Wisconsin Department of Natural Resources provides grants to local units of government in amounts up to 50 percent of the cost of acquiring and developing recreational land and rights-in-land to be used for local park and open space systems. Such state funds can also be used to help match federal funds. The community development block grants program of the U. S. Department of Housing and Urban Development can also provide funds for the acquisition and development of land for park and open spaces. The federal Land and Water Conservation Fund Act (LAWCON) administered by the U. S. Department of Interior, Bureau of Outdoor Recreation, through the Wisconsin Department of Natural Resources, provides grants to state and local units of government in amounts up to 50 percent of the cost of acquisition and improvement of outdoor recreation areas. Another means to reserve lands for park and open space purposes is to encourage or require developers of large tracts of lands to dedicate portions of the tracts to a local governmental unit or agency for public maintenance and use.

The fourth step in implementing the land use controls recommendations for the Pewaukee River subwatershed is vigorous administration of the land use controls coupled with acquisition of land for park and open space uses by the various means identified above. As the fifth and final step in implementation of land use controls, it will be necessary for the Village to revise its floodland regulations upon completion of the structural flood control works so as to reflect the significantly reduced size of the regulatory area.

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[2] *SEWRPC Planning Report No. 25, A Regional Land Use Plan and A Regional Transportation Plan for Southeastern Wisconsin—2000, Volume Two, Alternative and Recommended Plan, 1978.*

[3] *SEWRPC Planning Report No. 27, A Regional Park and Open Space Plan for Southeastern Wisconsin—2000, November 1977.*

Lending Institution and Realtor Policies

The floodland management plan for the Village of Pewaukee recommends that lending institutions continue to determine the flood-prone status of properties prior to granting of mortgages or other financial assistance and that real estate brokers, salesmen, and their agents continue to inform potential purchasers of property of any flood hazard which may exist at the site. As indicated in Figure 16, the first step by which the Village can help to implement this recommendation is to inform lending institutions and realtors of the availability of flood hazard information as set forth in this report and in the preceding floodland information report. Second, the Village should advise lenders and realtors of the availability of the flood insurance rate study report when it is completed.

In addition, and upon completion of the structural flood control works, the Village should provide the lending institutions and realtors with copies of the revised flood insurance rate study and the revised floodland regulations, as the third and fourth steps in this implementation process, so that the lending institutions and realtors may act in accordance with actual remaining flood hazards.

Community Utility and Facility Policies

The floodland management plan for the Village of Pewaukee recommends that policies for public utilities and facilities—for example, sanitary sewer, water supply, and streets—be designed to complement the floodland management recommendations. The Village can implement this recommendation by carefully reviewing all utility and facility proposals brought before it to assure that they are in conformance with the structural and nonstructural elements of the recommended floodland management plan.

Emergency Program

The floodland management plan for the Village of Pewaukee recommends that the Village develop procedures to provide floodland residents and other property owners with information about impending floods or floods already in progress and assistance during such events. The Village can implement this recommendation by developing a program based on such measures as: installation of remote upstream stage sensors and alarms, patrolling riverine areas to note when bankful conditions are imminent, monitoring of National Weather Service flash flood watch and warning bulletins during periods when rainfall or snowmelt are occurring or are anticipated, broadcasting emergency messages to community residents over radio and television, use of police patrol cars or other vehicles equipped with public address systems, use of a siren warning system employing a special pattern to indicate that flooding is occurring, preplanned road closures and evacuation of residents, and mobilization of portable pumping equipment to relieve the surcharge of sanitary sewers.

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Chapter V

SUMMARY

INTRODUCTION

The purpose of this report is to set forth a recommended floodland management plan for lands lying along the Pewaukee River, the Pewaukee Lake Outlet, and Pewaukee Lake within the Village of Pewaukee, Waukesha County, Wisconsin. More specifically, this report presents alternative floodland management plan subelements; provides a comparative evaluation of the technical, economic, and environmental features of each alternative; recommends a floodland management plan for the Village of Pewaukee consisting of various structural and nonstructural measures; and sets forth a plan implementation program.

This report was prepared by the Southeastern Wisconsin Regional Planning Commission (SEWRPC) in response to a formal request received on September 22, 1976, from the Village Board of the Village of Pewaukee. This floodland management study for the Village of Pewaukee, although essentially single purpose in nature—being intended to resolve existing and to prevent the development of new flood problems in the Village—was conducted within the context of and is fully coordinated with the Commission's comprehensive regional planning program including the adopted comprehensive plan for the Fox River watershed.

STUDY FINDINGS

The Village of Pewaukee has experienced at least one major flood—that of April 21-22, 1973—and a series of lesser flood events—those of September 19, 1972; April 1, 1960; and June 26, 1940. The maximum flood of record—the April 1973 event—is estimated to have had a recurrence interval of approximately 50 years, and therefore, was significantly less severe than the 100-year recurrence interval flood specified for floodland regulation purposes by the Wisconsin Department of Natural Resources and recommended to be used by the Commission as the design flood for floodland management purposes.

The 100-year recurrence interval floodlands along the Pewaukee River, Pewaukee Lake Outlet, and Pewaukee Lake within the Village of Pewaukee encompass a total area of about 0.43 square mile, or about 14.5 percent of the 2.9-square-mile area of the Village. Approximately 0.15 square mile, or 35 percent of the 0.43 square mile of floodlands along the Pewaukee River, Pewaukee Lake Outlet, and Pewaukee Lake within the Village, are in various urban uses incompatible with the flood-prone nature of these lands. The large areal extent of flood-prone land within the Village of Pewaukee and the extensive amount of existing urban development within those flood-prone areas is of concern to the Village in terms of its present and future development and was the primary purpose for undertaking this floodland management planning study.

A personal interview survey was conducted under this study to further refine the identification of flood-prone areas within the Village; determine the manner by which floodwaters enter or could enter structures in flood-prone areas; provide information needed for computation of monetary flood risks; and provide information useful in the formulation of alternative flood control measures. The personal interview survey coupled with other historic flood information indicated that areas which have experienced significant flood or flood-related problems in the Village include areas along the 0.3 mile reach of the Pewaukee River extending from Clark Street upstream to the Chicago, Milwaukee, St. Paul and Pacific Railroad and areas along the perimeter of Pewaukee Lake. The personal interview survey indicated that Pewaukee Lake residents in the Towns of Pewaukee and Delafield have also experienced flood problems. The survey also indicated that flooding of basements or crawl spaces as a result of seepage through walls or floors was the most serious problem reported with the owners or tenants of one-third of the structures surveyed reporting having experienced this type of problem one or more times.

Average annual flood risks expressed in dollars for year 2000 plan land use conditions were computed for selected reaches to provide a monetary value that could be used in the calculation of benefits and costs of alternative floodland management plan elements. Average annual flood risks along the Pewaukee River, Pewaukee Lake Outlet, and Pewaukee Lake in the Village of Pewaukee for year 2000 plan land use and floodland development conditions are estimated at $132,500, $2,900, and $34,400, respectively, for a total average annual flood risk of $169,800. If a 100-year recurrence interval flood were to occur simultaneously along the Pewaukee River, Pewaukee Lake Outlet, and Pewaukee Lake in the Village of Pewaukee, total flood damages in the Village could be expected to reach $875,300. Average annual flood risks along Pewaukee Lake in the Town of Pewaukee and the Town of Delafield for year 2000 plan land use and floodland development conditions are estimated at $23,700 and $13,900, respectively, for a total of $37,600. If a 100-year recurrence interval flood were to occur on Pewaukee Lake, the total damages in the Towns of Pewaukee and Delafield could be expected to reach $67,400.

The techniques of floodland management may be broadly subdivided into two categories: structural measures and nonstructural measures. Structural measures include floodwater storage facilities such as reservoirs and impoundments, diversions, floodwater containment facilities such as earthen dikes and concrete floodwalls, floodwater conveyance facilities such as major channel modifications, and bridge and culvert modifications or replacement. Nonstructural measures include reservation of floodlands for recreational and open space uses, floodland use regulations, land use controls outside of the floodlands, structure floodproofing, structure removal, flood insurance, lending institution policies, realtor policies, community utility policies, and emergency programs.

An initial series of 10 primarily single means, structural flood control measures was developed for all or for selected flood-prone areas in the Village. These 10 measures are: 1) storage utilizing a detention reservoir at Capitol Drive, 2) storage utilizing Pewaukee Lake, 3) lake diversion, 4) river diversion, 5) structure floodproofing, 6) minor channel modification, 7) major channel modification with a concrete-lined channel, 8) major channel modification with a turf-lined channel, 9) dikes and floodwalls, and 10) bridge and culvert alteration or replacement. In addition, an eleventh alternative, that of taking no action, is available, the flood damages attendant to that alternative providing a basis for the calculation of potential benefits associated with each of the other alternatives. Each structural flood control alternative was subjected to a technical, economic, and environmental impact analysis.

All 10 individual structural flood control measures were eliminated from further consideration as good solutions to the Village of Pewaukee flood problem. The principal value of screening primarily single means, structural flood control measures was the finding that seven had potential for development of a series of alternatives consisting of various combinations of structural measures. The seven measures were: storage utilizing Pewaukee Lake; structure floodproofing; minor channel modification; major concrete-lined channel; major turf-lined channel; dikes and floodwalls; and bridge and culvert alteration or replacement.

Five distinctly different composite structural floodland management alternatives were then synthesized and subjected to technical, economic, and environmental impact analyses with the intent of identifying an optimum combination of structural floodland management measures. The five composite measures were: minor channel modification-bridge and culvert alteration or replacement, concrete-lined channel-structure floodproofing, turf-lined channel-structure floodproofing, lake storage-major channelization-structure floodproofing, and dikes and floodwalls-structure floodproofing. Based on analyses of these alternatives, the structural flood control measure recommended for resolution of existing and forecast flood problems along the Pewaukee River, Pewaukee Lake Outlet, and Pewaukee Lake in the Village of Pewaukee is the turf-lined channel-structure floodproofing composite. More specifically, major components of the recommended structural flood control measure are: 1) a turf-lined channel supplemented with low earthen dikes and concrete floodwalls along the Pewaukee River reach bounded at the upstream end by the Chicago, Milwaukee, St. Paul and Pacific Railroad and at the downstream end by CTH SS, with the downstream two-thirds consisting only of minor channel bottom lowering; 2) modification of the lake level control structure and enclosure of the Pewaukee Lake Outlet; 3) low earthen dikes and concrete floodwalls along the eastern shore of Pewaukee Lake; and 4) floodproofing of about 25 residential and commercial structures.

Nonstructural measures were then examined to identify those approaches most likely to effectively supplement the recommended structural floodland management measure. The three principal nonstructural floodland management measures recommended for the Village of Pewaukee are: reservation of floodlands for recreational and related open space uses through measures such as private use or public acquisition of land or of an easement; vigorous administration of the floodland zoning regulations adopted by the Village of Pewaukee on February 7, 1977, including adjustment of the Village's floodland regulations within and immediately downstream of those reaches along the Pewaukee River, Pewaukee Lake Outlet, and Pewaukee Lake after recommended structural flood control works are implemented; and regulation of land use development outside of the floodlands through zoning, land subdivision, sanitary, and building ordinances. Five additional supplementary nonstructural floodland management measures recommended for implementation in the Village of Pewaukee are: continued participation in the National Flood Insurance Program through conduct of a flood insurance rate study to provide opportunity for additional flood insurance coverage to Village residents; determination of the flood-prone status of properties by lending institutions prior to granting of mortgages or other financial assistance; continuation of the program whereby real estate brokers, salesmen, and their agents inform potential purchasers of property of any flood hazards which may exist at the site; adoption of utility and facility policies and procedures to assure that the size, location, and use of those utilities and facilities is consistent with the flood-prone status of riverine areas; and development of procedures to provide floodland residents and other property owners with information about impending flooding.

Two supplemental hydrologic-hydraulic analyses were conducted to investigate possible adverse intermunicipal hydrologic-hydraulic affects. The first investigation addressed the concern expressed by Village officials over the possible increase in flood stages on the Pewaukee River in the Village of Pewaukee resulting from operation of the Barstow Street Dam on the Fox River in the City of Waukesha. The Barstow Street Dam is located about 6.6 miles downstream of the farthest downstream limit of the Village of Pewaukee. The investigation indicated that flood stages on the Pewaukee River in the Village of Pewaukee are not affected by water level changes caused by operation of the Barstow Street Dam in the City of Waukesha.

The second hydrologic-hydraulic analysis addressed the protentially adverse effects of recommended structural flood control measures in the Village of Pewaukee on upstream or downstream flood flows, flood stages, and flood damages. The analyses clearly indicated that the recommended control measures for the Village of Pewaukee would have no significant adverse effect on either upstream or downstream flood flows, flood stages, and flood damages.

While the recommended floodland management plan for the Village of Pewaukee is designed to resolve existing and future flood problems within the Village, the plan is not complete in the practical sense until the steps required to implement the plan—that is, to convert the plan into action policies and programs—are specified. Accordingly, a plan implementation procedure was developed that outlines the actions which must be taken by the Village of Pewaukee in cooperation with other units and agencies of government in order to implement the recommended floodland management plan. More specifically, the plan implementation process: 1) establishes the leadership role of the Village, 2) identifies other local, state, and federal units and agencies of government which may or will be involved in the implementation process, and 3) establishes a sequential procedure whereby each of the structural and nonstructural subelements of the recommended plan may be implemented. In addition, financial and technical assistance that may be available in implementation of the watershed plan are identified.