83D CONGRESS
2d Session

SENATE

DOCUMENT
No. 98

KALAMAZOO RIVER, MICH., BATTLE CREEK AND VICINITY

LETTER

FROM

THE SECRETARY OF THE ARMY

TRANSMITTING

A LETTER FROM THE CHIEF OF ENGINEERS, UNITED STATES ARMY, DATED NOVEMBER 15, 1951, SUBMITTING A REPORT, TOGETHER WITH ACCOMPANYING PAPERS AND ILLUSTRATIONS, ON A SURVEY OF KALAMAZOO RIVER, MICH., WITH PARTICULAR REFERENCE TO BATTLE CREEK, MICH., AND VICINITY. THIS REPORT IS SUBMITTED UNDER THE AUTHORITY FOR A REVIEW OF REPORT ON THE KALAMAZOO RIVER, MICH., WITH A VIEW TO DETERMINING WHETHER FLOOD CONTROL IMPROVEMENTS ALONG THAT STREAM ARE ADVISABLE AT THIS TIME, WITH PARTICULAR REFERENCE TO KALAMAZOO AND BATTLE CREEK, MICH., AND VICINITIES, REQUESTED BY A RESOLUTION OF THE COMMITTEE ON PUBLIC WORKS, UNITED STATES SENATE, ADOPTED ON JUNE 24, 1947

FEBRUARY 9, (legislative day, FEBRUARY 8), 1954.—Referred to the Committee on Public Works and ordered to be printed with three illustrations

UNITED STATES
GOVERNMENT PRINTING OFFICE
42947 WASHINGTON : 1954

CONTENTS

LIST OF APPENDIXES MADE IN CONNECTION WITH THE REPORT OF THE DISTRICT ENGINEER

(Not printed)

LIST OF ILLUSTRATIONS MADE IN CONNECTION WITH THE REPORT OF THE DISTRICT ENGINEER

(Sheet 4 not printed)

LETTER OF TRANSMITTAL

DEPARTMENT OF THE ARMY,
Washington 25, D. C., February 8, 1954.

Hon. EDWARD MARTIN,
Chairman, Committee on Public Works,
United States Senate, Washington, D. C.

DEAR MR. CHAIRMAN: I am transmitting herewith a report dated November 15, 1951, from the Chief of Engineers, United States Army, together with accompanying papers and illustrations, on a survey of Kalamazoo River, Mich., with particular reference to Battle Creek, Mich., and vicinity. This report is submitted under the authority for a review of report on the Kalamazoo River, Mich., with a view to determining whether flood-control improvements along that stream are advisable at this time, with particular reference to Kalamazoo and Battle Creek, Mich., and vicinities, requested by resolution of the Committee on Public Works, United States Senate, adopted on June 24, 1947.

In accordance with section 1 of Public Law 534, 78th Congress, and Public Law 732, 79th Congress, the views of the State of Michigan are set forth in the enclosed communication, together with the views of the Department of the Interior in accordance with Public Law 732, 79th Congress. The views of the Public Health Service are also enclosed.

Although the Bureau of the Budget advises that, subject to changes given in the letter of the Assistant Secretary of the Army (materiel) dated February 4, 1954, a copy of which is transmitted with these papers, there is no objection to the submission of the report to the Congress, it states that no commitment can be made at this time as to when any estimate of appropriation would be submitted for construction of the project, if authorized by the Congress, since this would be governed by the President's budgetary objectives as determined by the then prevailing fiscal situation. The complete views of the Bureau of the Budget are contained in the attached copy of its letter.

Sincerely yours,

ROBERT T. STEVENS,
Secretary of the Army.

LETTER TO THE BUREAU OF THE BUDGET

DEPARTMENT OF THE ARMY,
Washington 25, D. C., February 4, 1954.

Hon. JOSEPH M. DODGE,
Director, Bureau of the Budget.

DEAR MR. DODGE: In accordance with section 4 of Executive Order No. 9384 dated October 4, 1943, there is submitted a copy of the report of the Chief of Engineers, together with accompanying

papers and illustrations, on a survey of Kalamazoo River, Mich., with particular reference to Battle Creek, Mich., and vicinity. This report is submitted under the authority for a review of report on the Kalamazoo River, Mich., with a view to determining whether flood-control improvements along that stream are advisable at this time, with particular reference to Kalamazoo and Battle Creek, Mich., and vicinities, requested by a resolution of the Committee on Public Works, United States Senate, adopted on June 24, 1947.

The Chief of Engineers informs me that members of his staff and the Bureau's staff have recently discussed the treatment of local cooperation in connection with this proposed flood-control project. At the request of a member of your staff, the report has been reexamined using Bureau of the Budget Circular A–47, dated December 31, 1952, as a guide in determining the amount of local cooperation that would be required due to the land enhancement benefits credited to the project. He informs me that after careful consideration of the reports of the reporting officers, the Board of Engineers for Rivers and Harbors, and certain data recently made available on this matter that in order to conform to present policies a cash contribution would be required in addition to the usual items of local cooperation.

With regard to the flood-control benefits derived for the project, the report of the district engineer refers to the benefits from prevention of direct and indirect damages. At the time the report was prepared, it was the practice of the Corps of Engineers to classify the primary benefits in this manner. Actually the indirect damages given in the report are additional costs incurred in the flood area because normal operations are not possible and include such items as flood fighting, evacuation, rehabilitation, loss of earnings and profits, and increased cost of operations. Benefits which result from reducing these damages should not be confused with so-called secondary benefits which have been discussed among the Federal agencies, particularly the Subcommittee on Benefits and Costs.

The matter of land-enhancement benefits as presented in the report has been reexamined and it has been determined that the amount of $5,000 derived for enhancement of building value realized through ability to use basements should be deleted. A further analysis of this item indicates that the cost involved in converting basements into higher use would be approximately equal to the enhancement benefits. The remaining land–enhancement benefits amounting to $55,100 are derived from increased utilization of land by filling low areas and a section of the open channel, and increase in land values realized by removal of the flood hazard. Of the total estimated benefits credited to the project amounting to $324,400, $269,300 or 83 percent are flood control, and $55,100 or 17 percent are land enhancement.

It should be noted that the accompanying report, which was prepared prior to issuance of Circular A–47, would require local interests to furnish all lands, easements, and rights-of-way and to make certain bridge and utility alterations, at an estimated cost of $2,267,000. However, in accordance with current policies on local cooperation, costs for the land-enhancement portion of the project should be shared equally between the United States and local interests. On this basis, 17 percent of the estimated project cost in the report, or $956,000, should be allocated to enhancement; of this amount $571,000 would be for labor and materials and $385,000 would be lands, easements,

rights-of-way, and relocations. Of the total amount allocated to enhancement, the total non-Federal responsibility would be $478,000. Since $385,000 of this share would be in the form of lands and relocations, the remainder, or $93,000, at report price levels, should be a cash contribution.

The above information is being submitted along with the report in accordance with the request of a member of your staff. It should be understood that the matter of a local cash contribution has not been fully discussed with local interests; however, the attached letter dated February 3, 1954, from Frank C. Wagner, mayor of Battle Creek, indicates local willingness to pay the city's share of the cost. Deducting a cash contribution of $93,000, at report price levels, the estimated first cost of the project to the Federal Government would be $3,272,000.

Information is requested as to the relationship of the proposed report to the program of the President. A proposed draft of a letter transmitting this report to Congress is enclosed.

Sincerely yours,

JOHN SLEZAK,
Assistant Secretary of the Army (materiel).

COMMENTS OF THE MAYOR OF THE CITY OF BATTLE CREEK, MICH.

CITY OF BATTLE CREEK, MICH.,
OFFICE OF THE MAYOR,
February 3, 1954.

The Honorable ROBERT T. STEVENS,
The Secretary of the Army,
Pentagon Building, Washington, D. C.

DEAR MR. STEVENS: I have been informed by the Corps of Engineers that the contribution of the city of Battle Creek may have to be increased over the amount originally set forth in the flood plan, by approximately $100,000.

This is to advise you that if such an increase is required by the applicable laws and regulations, the city of Battle Creek will make this further and additional local contribution.

Sincerely yours,

FRANK C. WAGNER,
Mayor of the City of Battle Creek, Mich.

COMMENTS OF THE BUREAU OF THE BUDGET

EXECUTIVE OFFICE OF THE PRESIDENT,
BUREAU OF THE BUDGET,
Washington 25, D. C., February 8, 1954.

The honorable the SECRETARY OF THE ARMY.

MY DEAR MR. SECRETARY: This will acknowledge receipt of Assistant Secretary Slezak's letter of February 4, 1954, submitting the proposed report of the Chief of Engineers on a survey of Kalamazoo River, Mich., with particular reference to Battle Creek, Mich., and

vicinity. The report was authorized by a resolution of the Senate Public Works Committee adopted June 24, 1947.

In his report the Chief of Engineers recommends improvement of Kalamazoo River and its tributary, Battle Creek, for flood control at and in the vicinity of Battle Creek by a Kalamazoo River cutoff and channel rectification on Battle Creek and Kalamazoo River at a total estimated cost of $5,632,000, of which $3,365,000 would be Federal cost for construction and $2,267,000 would be non-Federal cost for lands, easements, new highway bridges, and miscellaneous utility and other alterations. Based on estimated annual benefits of $329,400 and annual carrying charges of $264,460, the benefit-cost ratio is stated to be 1.24.

Mr. Slezak indicates in his letter of February 4, 1954, that on the basis of current policies on local cooperation due to land-enhancement benefits, a cash contribution of $93,000 would be required of local interests in addition to items of cooperation specified in the report of the Chief of Engineers. This cash contribution would reduce the United States share in project construction cost to $3,272,000. It is noted that the mayor of the city of Battle Creek has indicated the city's willingness to meet this share of project cost.

In the report, $107,100 of the total flood-control benefits of $269,300 credited to the proposed improvements are classed as indirect benefits. The report does not explain completely the derivation of the estimated indirect flood damage. However, it describes the kind of benefits which make up the indirect total. This description leads to the belief that benefits classed as "indirect" in the report are incorrectly labeled since they represent the direct benefits from preventing flood damages which are not of a physical nature. Mr. Slezak clarifies this point by indicating in his letter that the indirect damages specified in the report are additional costs incurred in the flood area because normal operations are not possible and include such nonphysical items as flood fighting, evacuation, rehabilitation, loss of earnings and profits, and increased cost of operations.

It appears that on the basis of the local cooperation outlined above, including the cash contribution of $93,000, authorization of the project as a Federal improvement would be justified. I am, therefore, authorized by the Director of the Bureau of the Budget to advise you that there would be no objection to the submission of the report as amended by Mr. Slezak's letter of February 4, 1954, to the Congress. No commitment, however, can be made at this time as to when any estimate of appropriation would be submitted for construction of the project, if authorized by the Congress, since this would be governed by the President's budgetary objectives as determined by the then prevailing fiscal situation.

Sincerely yours,

CARL H. SCHWARTZ, Jr.,
Chief, Resources and Civil Works Division,

COMMENTS OF THE STATE OF MICHIGAN

STATE OF MICHIGAN,
OFFICE OF THE GOVERNOR,
Lansing, November 6, 1951.

Brig. Gen. C. H. CHORPENING,
Assistant Chief of Engineers for Civil Works,
Department of the Army, Washington, D. C.

DEAR GENERAL CHORPENING: We are glad to acknowledge your letter of October 17 to Governor Williams regarding the proposed report of the Chief of Engineers on a review of report on Kalamazoo River, Mich., with particular reference to Battle Creek and vicinity.

It appears that the flood-control report and recommendations entitled, "Kalamazoo River, Mich., at Kalamazoo, Battle Creek, and Vicinities," has been heretofore acted upon by the State agencies concerned on the basis of separate projects.

A resolution of the water resources commission dated January 26, 1950, dealing with the project at Kalamazoo was conveyed to us under date of October 18, 1950. Copies of that letter and resolution were transmitted to the Board of Engineers at Washington, the division engineer at Chicago, and district engineer at Milwaukee.

With respect to the approval of the original project at Battle Creek, we were informed of commission approval on June 20, 1950, by letter dated June 26, to which was attached copy of a letter dated February 6, 1950, to the district engineer at Milwaukee.

The current report upon which the Governor's action is awaited deals, apparently, with your restudy of the Battle Creek project to permit its accomplishment in two stages, as requested by city officials when they appeared before the Board of Engineers at Washington on October 23, 1950.

We are glad to know you have been able to accede to the city's request and suspect the necessary details of that change will eventually be worked out between the city and the Milwaukee district engineer.

In accordance with the above, the Governor is glad to place his approval upon the consolidated projects, as set forth in the title of the latest report, submitted last July, which will permit both projects now to be considered by the Secretary of the Army and in due course be transmitted by him for attention of the Congress.

Sincerely,

LAWRENCE L. FARRELL,
Executive Secretary.

COMMENTS OF THE DEPARTMENT OF THE INTERIOR

UNITED STATES DEPARTMENT OF THE INTERIOR,
OFFICE OF THE SECRETARY,
Washington 25, D. C., October 9, 1951.

Lt. Gen. LEWIS A. PICK,
Chief of Engineers,
Department of the Army, Washington 25, D. C.

MY DEAR GENERAL PICK: By letter dated July 5, 1951 (ENGWD), you transmitted for the information and comments of the Department copies of your proposed report on a review of report on Kalamazoo River, Mich., together with the reports of the Board of Engineers for Rivers and Harbors, and of the district and division engineers.

The district engineer finds that a flood problem exists along the Kalamazoo River, Mich., and its tributary Battle Creek, at the city of Battle Creek and vicinity, and that floods considerably larger than any that have occurred are probable. He finds that the most practical plan of flood protection would provide for a wider, deeper, and straighter Battle Creek channel from above the Union Street Bridge in the city of Battle Creek downstream to its confluence with the Kalamazoo River; diversion of the constricted existing Kalamazoo River channel below the Monroe Street Dam away from and south of the congested downtown area, thence back to the existing channel and Battle Creek downstream from the Washington Avenue Bridge; and widening, deepening, and straightening the Kalamazoo River channel downstream from this confluence to below the Fort Custer Waterworks Bridge. He also finds that the improvements designed to safely pass floods equivalent to 11,000 cubic feet per second downstream from the confluence of Battle Creek and the Kalamazoo River will eliminate 84 percent of the flood damages in the area and that the cost of the work will be less than the benefits to be derived therefrom. He, therefore, recommends that a flood-control project at Battle Creek, Mich., and vicinity be constructed at an estimated Federal first cost of $3,296,000 subject to certain specified conditions of local cooperation. The division engineer and the Board of Engineers for Rivers and Harbors concur in the views of the district engineer.

The Fish and Wildlife Service of this Department is satisfied with the consideration given to fish and wildlife during the course of investigation and preparation of project plans, and concurs in this favorable report.

Other interests of the Department will not be affected by the recommendations in your report. I am, therefore, pleased to advise you that this Department concurs in the findings set forth in your report. Opportunity for such review is appreciated.

Sincerely yours,

WILLIAM E. WARNE,
Acting Secretary of the Interior.

COMMENTS OF THE PUBLIC HEALTH SERVICE

FEDERAL SECURITY AGENCY,
PUBLIC HEALTH SERVICE,
Washington 25, D. C., September 24, 1951.

Maj. Gen. LEWIS A. PICK,
Chief of Engineers,
Department of the Army,
Washington 25, D. C.

DEAR GENERAL PICK: Pursuant to the policies and procedures established by the Federal Inter-Agency River Basin Committee, we have reviewed the preliminary report furnished by your Department entitled, "Survey report on the Kalamazoo River, Mich., at Kalamazoo, Battle Creek, and vicinities."

We find nothing in this report which conflicts with our water pollution control policy.

Sincerely yours,

M. D. HOLLIS,
Chief Sanitary Engineering Officer, PHS,
FSA Member, Federal Inter-Agency River Basin Committee.

KALAMAZOO RIVER, MICH., BATTLE CREEK AND VICINITY

REPORT OF THE CHIEF OF ENGINEERS, UNITED STATES ARMY

DEPARTMENT OF THE ARMY,
OFFICE OF THE CHIEF OF ENGINEERS,
Washington 25, D. C., November 15, 1951.

Subject: Kalamazoo River, Mich., Battle Creek and vicinity.
To: The Secretary of the Army.

1. I submit herewith for transmission to Congress the report of the Board of Engineers for Rivers and Harbors in response to resolution of the Committee on Public Works of the United States Senate, adopted June 24, 1947, requesting the Board to review the report on the Kalamazoo River, Mich., contained in House Document No. 224, 72d Congress, 1st session, with a view to determining whether flood-control improvements along that stream are advisable at this time, with particular reference to Kalamazoo and Battle Creek, Mich., and vicinities. An interim report covering the local flood problem at Kalamazoo and vicinity was submitted by the Board to the Chief of Engineers on March 3, 1950. This report, dealing with the flood problem at Battle Creek, Mich., and vicinity, is the final report to be made in response to the resolution.

2. After full consideration of the reports secured from the district and division engineers, and after affording local interests full opportunity to be heard, the Board recommends improvement of Kalamazoo River and its tributary, Battle Creek, for flood control, at and in the vicinity of Battle Creek, Mich., by a Kalamazoo River cutoff and channel rectification on Battle Creek and Kalamazoo River, generally in accordance with the plan of the district engineer and with such modifications thereof as in the discretion of the Chief of Engineers may be advisable, at an estimated first cost to the United States of $3,365,000 for construction, provided that no money shall be expended on the construction by the United States until responsible local interests have given assurances satisfactory to the Secretary of the Army that they will (*a*) provide without cost to the United States all lands, easements, and rights-of-way necessary for the construction of the project; (*b*) hold and save the United States free from damages due to the construction works; (*c*) maintain and operate all the works after completion, including supervision of maintenance and operation of the existing Monroe Street Dam and headrace on the Kalamazoo River, in accordance with regulations prescribed by the Secretary of the Army; (*d*) prescribe and enforce regulations designed to prevent encroachments on the rights-of-way and improved channels; (*e*) construct new highway bridges across the new Kalamazoo River cutoff; and (*f*) make all changes and additions to streets, water mains, electric power lines, sewers, and other utilities necessitated by the improve-

ments; and provided further that construction of the initial stage of the project as defined in the district engineer's report, at an estimated first cost to the United States of $2,676,500, may be undertaken whenever funds are available and the prescribed local cooperation has been provided, and whenever, in addition, local interests have agreed to remove, at their own expense concurrently with construction of the first-stage improvement, such buildings from the Battle Creek channel as in the opinion of the district engineer may jeopardize the effectiveness of that improvement.

3. After due consideration of these reports, I concur in the views and recommendations of the Board.

LEWIS A. PICK,
Lieutenant General, Chief of Engineers.

REPORT OF THE BOARD OF ENGINEERS FOR RIVERS AND HARBORS

DEPARTMENT OF THE ARMY,
BOARD OF ENGINEERS FOR RIVERS AND HARBORS,
Washington, D. C., June 6, 1951.

Subject: Kalamazoo River, Mich., at Kalamazoo, Battle Creek, and vicinities.

To: The Chief of Engineers, United States Army.

1. This report is submitted in response to the following resolution adopted June 24, 1947:

Resolved by the Committee on Public Works of the United States Senate, That the Board of Engineers for Rivers and Harbors, created under section 3 of the River and Harbor Act, approved June 13, 1902, be, and is hereby requested, to review the report on the Kalamazoo River, Michigan, contained in House Document Numbered 224, Seventy-second Congress, first session, with a view to determining whether flood-control improvements along that stream are advisable at this time with particular reference to Kalamazoo and Battle Creek, Michigan, and vicinities.

An interim report covering the local flood problem at Kalamazoo and vicinity was submitted by the Board to the Chief of Engineers on March 3, 1950. This report, dealing with the flood problem at Battle Creek, Mich., and vicinity, is the final report to be made in response to the resolution.

2. Kalamazoo River rises in the southern part of the Lower Peninsula of Michigan, flows northwesterly about 185 miles, and empties into Lake Michigan about 2 miles downstream from the village of Saugatuck. The basin is about 100 miles long and contains approximately 1,980 square miles. All of the principal tributaries except Portage Creek enter the main river from the north bank and only Battle Creek, which joins the river in downtown Battle Creek, and Portage Creek at Kalamazoo, have any appreciable effect on the flood problems of the basin. The drainage area at Battle Creek, mile 108, is about 840 square miles, of which 260 are in the Battle Creek Basin. Elevations range from about 700 to 1,200 feet above sea level. The river flows through a valley from one-fourth of a mile to about 3 miles wide, bounded by low hills or gently sloping uplands. Battle Creek and most of the smaller tributaries flow through extensive swamplands as they approach the main river channel. There are 3 small dams within the city of Battle Creek, 2 on Battle Creek and 1 on Kalamazoo River at North Monroe Street. The North Monroe Street Dam, owned by the Consumers Power Co. of Michigan, has an installed capacity of 150 kilowatts. Numerous small dams on the headwaters above Battle Creek are used for the development of both hydroelectric and direct mechanical power. The slope of Kalamazoo River through the city averages about 4.1 feet per mile above the junction with Battle Creek and 1.7 feet per mile below, while that of Battle Creek averages about 1.4 feet per mile. Channel capacities through the city are restricted by pile-supported buildings extending across the entire width of the channels. The headrace of the Monroe Street Dam joins Battle Creek about 2,300 feet upstream from the confluence of Battle Creek and the river. It has a controlling channel capacity of about 1,500 cubic feet per second, while the main river below the dam is restricted to a capacity of 500 cubic feet per second above the junction of Battle Creek and about 2,200 cubic feet per second below. Limiting channel capacity on Battle Creek is about 1,200 cubic feet per second. Channel widths vary from 90 to 125 feet and depths from 5 to 6 feet. Population of the basin was about 217,300 in 1940, including 43,453 in Battle Creek, 54,097 in Kalamazoo, and 86,300 fairly uniformly distributed in the rural areas. The basin supports a wide variety of industries concentrated mostly in and near the cities of Battle Creek and Kalamazoo, the former being noted as the breakfast cereal and health food center for the North Central States. The principal articles manufactured at Battle Creek also include automobile parts, cartons, machinery, kitchen ranges, railroad engines, and beverages. Agricultural areas are devoted chiefly to small dairy farms. There is no existing Federal flood-control project in the basin.

3. Average annual precipitation over the basin is about 33 inches including about 44 inches of snowfall. With rare exception, major floods at Battle Creek have occurred as a result of heavy spring rains on snow, covering ground already partly saturated, and at a time when stream stages were already rising. The maximum flood of record, having a peak flow estimated at 7,500 cubic feet per second, occurred in 1904; and only slightly lesser floods were experienced in 1887, 1908, 1918, 1947, and 1948. The floods of 1854, 1864, 1868, and 1869 are reported to have been greater than those of 1904 and 1908, but there are no records of actual stages for these earlier floods. Lesser floods have occurred at more frequent intervals, and minor floods almost annually. Major flooding at Battle Creek and vicinity is almost entirely within the city limits, except for low, vacant lands downstream from the city. When the combined discharge is in excess of 4,000 cubic feet per second, restrictions caused by buildings along both Battle Creek and Kalamazoo River cause backwater overflow of adjacent areas. The flood of April 1947, with a peak flow of 7,200 cubic feet per second, inundated an area of 1,558 acres in Battle Creek and vicinity, of which 268 were along Battle Creek. The flooded areas included residential, commercial, industrial, and public property within the city, and unimproved lowlands below the city. With flows greater than that of the 1947 flood, it is probable that one or more of the old buildings constructed on pile foundations and extending into or over the channels would collapse, creating a virtual dam which would back the water over a much larger area causing tremendous damages, suffering, and probable loss of life. Damages from the

1947 flood, adjusted to 1949 price levels, are estimated at $785,400. Damages from the 1948 flood, similarly adjusted, are estimated at about $50,000, but they would have been considerably greater had there not been ample warning of the flood's approach, permitting all possible precautions to be taken. The floods create serious health problems through flooding of basements and first floors and other hazards to life and health that cannot be measured in monetary terms. Average annual flood damages at and in the vicinity of Battle Creek are estimated by the district engineer at $320,900, of which $192,800 are for direct and $128,100 are for indirect damages.

4. Local interests desire a solution of the flood problem at Battle Creek and suggest several possible plans of improvement, including placing the channels in tunnels through the city, removing existing channel restrictions, clearing and straightening the channels through and below the city, and diverting the Kalamazoo River to a point downstream from its present junction witb Battle Creek. They are willing to cooperate in the desired improvements to the extent of their financial ability.

5. The district engineer finds that the stream channels at Battle Creek have been so encroached on through the years by construction of buildings into and over the natural river channels, and by use of the channels as community dumps, that flooding is due entirely to the inability of the greatly restricted channels to carry the flood flow at a lower stage. He has determined that the most practical plan of improvement would provide for a relocated Kalamazoo River channel below the Monroe Street dam, bypassing the existing restricted channel through the heart of the city and returning to the existing channel 700 feet downstream from the Washington Avenue Bridge; a wider, deeper, and more uniformly graded channel for Battle Creek extending from above the Union Street Bridge to its junction with the new Kalamazoo River cutoff; and a wider, deeper, and more uniformly graded channel for the Kalamazoo River from the new confluence downstream to a point 9,500 feet below the Fort Custer Waterworks Bridge. The plan also provides for riprapping the Kalamazoo River and Battle Creek channels where necessary to prevent erosion at critical locations; constructing 4 new railroad bridges and 5 new highway bridges and reinforcing existing railroad and highway bridges as required; removing buildings obstructing the channels; constructing levees and a submerged weir; and altering utilities and structures as necessitated by the improved channels. The improvements would be designed to afford protection against floods up to 8,000 cubic feet per second on Kalamazoo River above its junction with Battle Creek; 5,000 cubic feet per second on Battle Creek above the mouth of the Monroe Street Dam headrace and 6,000 cubic feet per second below, including 1,000 cubic feet per second diverted from Kalamzaoo River via the headrace; and a combined flow of 11,000 cubic feet per second in Kalamazoo River downstream from the confluence of the new cutoff and Battle Creek. They would thus afford protection against floods with peaks about 50 percent greater than those of record and would eliminate approximately 84 percent of all direct and indirect flood damages in the area. They would have no appreciable effect on flood stages downstream.

6. The district engineer estimates the cost of the proposed improvements at $5,563,000 of which $3,296,000 would be Federal costs for

construction and $2,267,000 would be non-Federal costs for lands, easements, new highway bridges across the cutoff channel, and miscellaneous utility and other alterations as required. Annual carrying charges are estimated at $261,700, of which $131,960 would be Federal and $129,740, non-Federal, the latter including $15,000 for maintenance and operation. Average annual benefits are estimated at $329,400, including $60,100 for enhancement of property values. The benefit-cost ratio is 1.26. The district engineer finds that it would be practicable to undertake the construction in two stages, the first to consist of the proposed new cutoff and improvement of the Kalamazoo River channel downstream therefrom, and the second to consist of improvements to the Battle Creek channel above the junction of the cutoff. The estimated first cost of the initial stage improvement is $3,843,200, of which $2,607,500 would be Federal, and $1,235,700, non-Federal cost. The district engineer points out that, although construction of the initial stage would produce about 90 percent of the total benefits at about 65 percent of the total cost, failure to complete the Battle Creek portion of the project might nullify these benefits; and he considers it undesirable to invest Federal funds in a partial protection project that would produce unreliable results. He states that while assurance of compliance with local cooperation should be required for the entire plan of improvement, it should be understood that actual compliance with the features of local cooperation for the second-stage construction could be deferred until completion of the first-stage improvement. The district engineer recommends that a Federal project be authorized for flood protection along the Kalamazoo River at and in the vicinity of Battle Creek, Mich., generally as outlined above, at a total estimated Federal first cost of $3,296,000, provided that no funds shall be expended by the United States until local interests have given assurances satisfactory to the Secretary of the Army that they will furnish without cost to the United States all necessary lands, easements, and rights-of-way; hold and save the United States free from all claims for damages incident to construction and operation of the project; maintain and operate the project after completion, including supervision of maintenance and operation of the existing Monroe Street Dam and headrace on the Kalamazoo River under an agreement with its owners, in accordance with regulations prescribed by the Secretary of the Army; prescibe and enforce regulations satisfactory to the Secretary of the Army designed to prevent encroachments on the proposed rights-of-way and improved channels; construct new highway bridges across the new Kalamazoo River cutoff; and make all changes and additions to streets, water mains, electric power lines, sewers, and other miscellaneous utilities necessitated by the channel improvement. He further recommends that the initial stage of the plan, consisting of the proposed cutoff and improvement of the existing Kalamazoo River channel downstream therefrom may be undertaken at an estimated Federal first cost of $2,607,500, after the prescribed conditions of local cooperation therefor have been complied with. The division engineer concurs.

7. Local interests were informed of the nature of the division engineer's report and afforded an opportunity to furnish additional information to the Board. At a hearing held before the Board at their request, representatives of the city of Battle Creek expressed

their general approval of the overall plan, but doubted that the city would be able financially to meet the conditions of local cooperation for the entire project at one time. They believe the city would be able to finance the local cost of the project if it were constructed in two stages, as recommended by the district engineer, with the second and final stage of construction deferred until some time after completion of the first.

VIEWS AND RECOMMENDATIONS OF THE BOARD OF ENGINEERS FOR RIVERS AND HARBORS

8. The Board of Engineers for Rivers and Harbors concurs generally in the views of the reporting officers. The project will eliminate average annual flood damages estimated at $269,300, and in addition will provide enhanced property values estimated at $60,100 annually. The Board believes that the project is economically justified and that the construction can feasibly be undertaken in stages substantially as desired by local interests. It concurs in the view that the initial stage of construction should consist of the proposed new cutoff and improvement of the Kalamazoo River downstream therefrom, but is of the opinion that certain buildings extending into and over the channel of Battle Creek, the collapse of which might impair the effectiveness of the initial-stage improvement after its completion, should be removed by local interests at their expense concurrently with construction of the first-stage improvement.

9. The Grand Trunk Western Railroad Co. furnished the Board additional information, which was concurred in by the district engineer, indicating that the estimated cost of their bridge should be $69,000 more than that shown in the report. By including this amount, the total project cost is raised from $5,563,000 to $5,632,000 and the Federal cost from $3,296,000 to $3,365,000. The benefit-cost ratio becomes 1.24.

10. The Board accordingly recommends improvement of Kalamazoo River and its tributary, Battle Creek, for flood control, at and in the vicinity of Battle Creek, Mich., by a Kalamazoo River cutoff and channel rectification on Battle Creek and Kalamazoo River, generally in accordance with the plan of the district engineer and with such modifications thereof as in the discretion of the Chief of Engineers may be advisable, at an estimated first cost to the United States of $3,365,000 for construction, provided that no money shall be expended on the construction by the United States until responsible local interests have given assurances satisfactory to the Secretary of the Army that they will (*a*) provide without cost to the United States all lands, easements, and rights-of-way necessary for the construction of the project; (*b*) hold and save the United States free from damages due to the construction works; (*c*) maintain and operate all the works after completion, including supervision of maintenance and operation of the existing Monroe Street Dam and headrace on the Kalamazoo River, in accordance with regulations prescribed by the Secretary of the Army; (*d*) prescribe and enforce regulations designed to prevent encroachments on the rights-of-way and improved channels; (*e*) construct new highway bridges across the new Kalamazoo River cutoff; and (*f*) make all changes and additions to streets, water mains, electric power lines, sewers, and other utilities necessitated by the improvements; and provided further, that construction of the initial stage of the project as defined in the district engineer's report, at an estimated first cost to the United States of $2,676,500, may be undertaken whenever funds are available and the prescribed local cooperation has been provided, and whenever, in addition, local interests have agreed to remove, at their own expense concurrently with construction of the first-stage improvement, such buildings from the Battle Creek channel as in the opinion of the district engineer may jeopardize the effectiveness of that improvement.

For the Board:

D. G. SHINGLER,
Brigadier General, Chairman.

REPORT OF THE DISTRICT ENGINEER

SYLLABUS

The district engineer finds that a flood problem exists along the Kalamazoo River, Mich., and its tributary Battle Creek, at the city of Battle Creek and vicinity, and that floods considerably larger than any that have occurred are probable. He finds that the most practical plan of flood protection would provide for a wider, deeper, and straighter Battle Creek channel from above the Union Street Bridge in the city of Battle Creek downstream to its confluence with the Kalamazoo River; diversion of the constricted existing Kalamazoo River channel below the Monroe Street Dam away from and south of the congested downtown area, thence back to the existing channel and Battle Creek downstream from the Washington Avenue Bridge; and widening, deepening, and straightening the Kalamazoo River channel downstream from this confluence to below the Fort Custer Waterworks Bridge. He also finds that the improvements designed to safely pass floods equivalent to 11,000 cubic feet per second downstream from the confluence of Battle Creek and the Kalamazoo River will eliminate 84 percent of the flood damages in the area and that the cost of the work will be less than the benefits to be derived therefrom. He, therefore, recommends that a flood control project at Battle Creek, Mich., and vicinity be constructed at an estimated Federal first cost of $3,296,000 subject to certain specified conditions of local cooperation.

CORPS OF ENGINEERS, UNITED STATES ARMY,
OFFICE OF THE DISTRICT ENGINEER,
MILWAUKEE DISTRICT,
Milwaukee, Wis., February 20, 1950.

Subject: Review of Report on Kalamazoo River, Mich, for Flood Control With Particular Reference to Battle Creek and Vicinity
To: Division Engineer, Great Lakes Division, Corps of Engineers, United States Army, Chicago, Ill.

AUTHORITY

1. This report is submitted in compliance with a resolution of the Committee on Public Works of the United States Senate, adopted June 24, 1947, as follows:

Resolved by the Committee on Public Works of the United States Senate, That the Board of Engineers for Rivers and Harbors, created under section 3 of the River and Harbor Act, approved June 13, 1902, be, and is hereby, requested to review the report on Kalamazoo River, Michigan, contained in House Document Numbered 224, Seventy-second Congress, first session, with a view to determining whether flood control improvements along that stream are advisable at this time, with particular reference in Kalamazoo and Battle Creek, Michigan, and vicinities.

42947—54——3

2. The review report has been prepared in two parts as follows:

(*a*) An interim report, dated July 22, 1949, covering the local flood problem at Kalamazoo and vicinity as authorized by the Office, Chief of Engineers on November 17, 1948.

(*b*) This final report covering the local flood problem at Battle Creek and vicinity.

SCOPE OF SURVEY

3. This report is of survey scope as authorized by the Chief of Engineers, September 8, 1947. The report contained in House Document 224, 72d Congress, 1st session, which is reviewed herein, was also of survey scope. In general this report is confined to flood control in the vicinity of the city of Battle Creek, Mich., but will include a discussion of the entire Kalamazoo River Basin as related to the flood-control problems in this specific area. The resolution authorizing this review report was instigated by local interests at Kalamazoo and Battle Creek, Mich., following the floods of April 1947. The survey reports are in general limited to these two localities which are the principal areas in the basin experiencing appreciable flood damage. Field investigations, including topographic and damage surveys, and hydraulic and hydrologic studies were made of all areas pertinent to the flood problems in the principal areas under consideration. Public hearings were held at Kalamazoo and Battle Creek. The flood problem and solutions recommended herein have been discussed with local and State governments and with interested Federal agencies.

PRIOR REPORTS

4. *Federal.*—The only prior report on the Kalamazoo River which includes flood control within its scope is the one under review published as House Document No. 224, 72d Congress, 1st session, made under the provisions of House Document No. 308, 69th Congress, 1st session. That report was submitted to Congress January 14, 1932, in accordance with provisions of section 1 of the River and Harbor Act approved January 21, 1927. The report covered all phases of water resources development along the Kalamazoo River. It was unfavorable, concluding that improvement of the stream by the Federal Government for navigation, power development, flood control, or irrigation, or any combination thereof, was not justified at that time. There are no known flood-control reports by other Federal agencies on the Kalamazoo River.

5. *Non-Federal.*—The city of Battle Creek retained a consulting engineering firm in 1927 to analyze and report on their flood problem. This report recommended the general cleaning out of the channels and the elimination of obstructive practices in the future as a minimum protection against floods equal to those that have been experienced. The detailed recommendations and conclusions of this report are given in appendix D.[1]

DESCRIPTION

6. *Geography.*—(*a*) The Kalamazoo River, lying wholly within the State of Michigan, rises in Hillsdale County in the south-central part of the State, and flows in a west-northwesterly direction across

[1] Not printed.

southwestern Michigan about 185 river miles to its outlet in Lake Michigan, about 2 miles downstream from the village of Saugatuck. The basin, covering portions of Hillsdale, Jackson, Calhoun, Eaton, Barry, Kalamazoo, Van Buren, Allegan, Kent, and Ottawa Counties, is about 100 miles in length with 30 miles maximum and 20 miles average width and is about 1,980 square miles in area. The basin narrows to only 9 miles in width between the cities of Kalamazoo and Battle Creek.

(*b*) Details of the principal tributaries of the Kalamazoo River are shown in table 1.

TABLE 1.—*Tributaries*

Name	Confluence with Kalamazoo River (miles above Lake Michigan)	Drainage area (square miles)	Approximate elevation, feet	
			Headwaters	Outlet
Rabbit River	12	265	800	585
Gun River	57	95	900	700
Portage Creek	74 (at Kalamazoo)	50	900	754
Battle Creek	108 (at Battle Creek)	260	950	812
Rice Creek	125 (at Marshall)	100	1,050	880
North Branch	138 (at Albion)	80	1,100	935
South Branch (usually referred to as the main river; joins the North Branch at Albion)		145	1,200	935

All of these tributaries, except Portage Creek, enter the main river from the north or right bank. The location of these tributaries is shown on sheet 1 of the drawings with this report.

(*c*) Of these tributaries only Battle Creek, entering the main river in downtown Battle Creek, and Portage Creek at Kalamazoo have any appreciable direct effect on the flood problems of the basin. Battle Creek rises in northeastern Calhoun County and flows generally southwest to its mouth. This basin is about 25 miles in length and 12 miles in width. Portage Creek, with its small tributary, Axtell Creek, is entirely within Kalamazoo County and flows generally north-northeast to its mouth.

(*d*) The area along the Kalamazoo River covered by detailed studies for this report commences about 2 miles downstream from the waterworks bridge upstream from the village of Augusta and about 6 miles downstream from Battle Creek. It extends upstream through Battle Creek to the old Upper Mill Pond on the Kalamazoo River and to Verona Dam on Battle Creek. The drainage area at Battle Creek includes about 580 square miles on the main river and 260 square miles on Battle Creek, a total of 840 square miles.

7. *Topography.*—The entire watershed is generally rolling with prairie, swamp, and hilly sections alternating at frequent intervals. Numerous small lakes and spring hollows are scattered throughout the watershed, holding ponded water part or all of the time. Many of these small lakes have no surface outlets and feed the main streams only through ground water flow and seepage. In 4 of the counties, with 1,545 square miles of the tributary area or 78 percent of the watershed, there are 183 tributary and 141 nontributary lakes over one-sixteenth mile in diameter. These nontributary lakes represent a reduction of 5 to 6 percent of the area directly tributary to the river. There are no large lakes in the basin, the largest being

Kalamazoo Lake near the river mouth at Saugatuck. The river flows through a rich agricultural region, in a valley from one-quarter of a mile to about 3 miles in width, bounded by low hills or sloping gently to the upland. The general elevation of the headwater terrain along the basin edges is about 150 to 200 feet above the river channel. It is about 1,200 feet above sea level at the eastern end of the watershed and drops to about 700 feet near Lake Michigan. Battle Creek and most of the smaller tributaries flow through extensive swamplands as they approach the main river channel.

8. *Geology.*—The major geologic features of the Kalamazoo River Basin were shaped during the last stages of the glacial period. The overburden consists generally of morainal ridges covering about 35 percent of the watershed, till plains covering about 30 percent, and glacial outwash deposits covering the remainder. These outwash deposits underlie many tributaries as well as much of the main stream course. The source of the river is in Hillsdale County where the underlying sandstone bedrock surface is at the highest elevation found in the southern Michigan Peninsula, or about 1,000 to 1,100 feet above sea level. Here the bedrock is thinly mantled, with numerous exposures. Many of the bridge and building foundations in the low river bottom lands at Battle Creek are placed on ledge rock. At Kalamazoo and westward rock exposures are unknown.

9. *Soils.*—The soils are diversified, gravel, clay, and sand, alternating in relatively small areas. The flood plain of the main river from Plainwell through Kalamazoo and Battle Creek to Marshall consists mainly of fairly level sand and gravel deposits free from large stones and normally covered with loam or clayey loam. These comparatively flat areas comprise the richest farmlands in the basin. Although numerous small lakes and marshy tracts are scattered through the basin, the soils of the basin are commonly porous which increases the infiltration, materially reducing runoff peaks and equalizing the ground water supply reaching the streams. The streams of the basin are not characterized by rapid erosion and their silt content is low. No local mention has been made of severe erosion either from the fields or river banks.

10. *Stream slopes.*—Table 2 shows stream slopes of the Kalamazoo River and the tributaries pertinent to this report:

TABLE 2.—*Stream slopes*

Location	Distance above mouth of river or tributary	Elevation (low water)	Average slope	Dams in section
Kalamazoo River:	*Miles*	*Feet*	*Feet-mile*	
Lake Michigan	0	578.5	0.9	1
Allegan	39	615.0	4.9	6
Plainwell	60	718.0	2.6	0
Kalamazoo	74	754.0	1.7	1
Battle Creek	108	812.0	4.1	2
Marshall	125	882.0	4.0	2
Albion	138	934.0	2.5	3
Mosherville	164	1,000.0		
Portage Creek:				
Confluence with Kalamazoo River	0	754.0	5.0	0
Kalamazoo (below Bryant Pond Dam)	2	764.0		
Battle Creek:				
Confluence with Kalamazoo River	0	812.0	1.4	2
Bellevue	21	841.0		

11. *Cross-sectional dimensions and channel capacities.*—Table 3 gives the approximate controlling channel dimensions and capacities of the Kalamazoo River and its tributaries at critical points pertinent to this report:

TABLE 3.—*Channel conditions*

Location	Approximate controlling channel dimensions		Approximate bank-full capacity (second-feet)
	Width (feet)	Depth (feet)	
Kalamazoo River:			
Morrow Dam to 20th St. at Battle Creek	100	6	1,600
20th St. to junction with Battle Creek	125	6	2,200
Junction with Battle Creek to Monroe St. Dam	90	6	[1] 500
Monroe St. Dam headrace			1,500
Monroe St. Dam to Ceresco	90	4	800
Battle Creek:			
Junction with Kalamazoo River to Verona Dam in Battle Creek	120	5	[1] 1,200
Verona Dam to Bellevue	60	5	1,000

[1] Channel capacity in these reaches is greatly restricted by pile-supported buildings across the entire width of the channel.

ECONOMIC DEVELOPMENT

12. *Population.*—The population of the Kalamazoo River watershed was about 217,300 in 1940 including a fairly uniformly distributed rural population of about 86,300. The populations of the portions of the counties and municipalities within the watershed are given in table 4:

TABLE 4.—*Population*

County	Percent of county in watershed	1940 urban population		1940 rural population	Total
		Municipality	Population		
(*a*) Watershed including the city of Battle Creek and above:					
Hillsdale	10			1,960	1,960
Jackson	23	Concord	618		
		Parma	575		
		Springport	502		
			1,695	9,250	10,945
Calhoun	59	Albion	8,345		
		Battle Creek	43,453		
		Marshall	5,253		
			57,051	20,480	77,531
Eaton	25	Bellevue	1,011		
		Olivet	604		
			1,615	4,570	6,185
Barry	3			460	460
Total for watershed at Battle Creek			60,361	36,720	97,081
(*b*) Entire Kalamazoo River watershed:					
Hillsdale, Jackson, Eaton, Calhoun		See (*a*)	60,361	39,040	99,401
Barry	34			5,210	5,210
Kalamazoo	49	Galesburg	1,040		
		Kalamazoo	54,097		
		Parchment	934		
		Augusta	785		
		Comstock	1,774		
			58,630	19,310	77,940
Allegan	70	Allegan	4,526		
		Otsego	3,428		
		Plainwell	2,424		
		Saugatuck	628		
		Wayland	1,005		
			12,011	20,880	32,891
Kent	2			1,380	1,380
Ottawa	1			300	300
Van Buren	1			210	210
Total for entire watershed			131,002	86,330	217,332

13. *Industries.*—The Kalamazoo River watershed supports a wide variety of industries located in the many municipalities in the basin. Most of the major industries are concentrated in the vicinities of Battle Creek and Kalamazoo, the major areas considered in this report. The principal articles manufactured at Battle Creek are health foods, automobile parts, cartons, machinery, kitchen ranges, railroad engines, and beverages. This city is the breakfast-cereal and health-food center for the North Central States. Paper and paper products, pharmaceuticals, stoves, taxicabs, machine tools and machinery, furnaces, chemicals, brushes, and auto transmissions are manufactured in and around Kalamazoo.

14. *Banking facilities.*—Banks are located in most of the rural communities in the basin. As of June 30, 1949, there were 3 banks at Battle Creek with total deposits of about $60 million and 4 banks at Kalamazoo with total deposits of about $90 million. Branch banks are located at Parchment, Galesburg, and Augusta.

15. *Agriculture.*—The land in this basin is devoted chiefly to small dairy farms averaging about 100 acres each. Fruits, grains, and vegetables are raised to a limited extent. The rich river bottom lands in the vicinity of Kalamazoo are famous as celery beds. Much of the land is good for agricultural purposes. However, large areas are swampy or poorly drained and in the lower reaches of the basin the soil is too sandy for successful farming.

16. *Transportation.*—The watershed is well served by good Federal, State, county, and township roads and several railroads. Both Battle Creek and Kalamazoo are on the main line of the New York Central Railroad and Federal Highway U. S. No. 12 between Chicago, Ill., and Detroit, Mich. The main line of the Grand Trunk Railroad from Chicago, Ill., to Canada and the Northeast passes through Battle Creek. Kalamazoo is also served by the Grand Trunk and Pennsylvania Railroads. The entire area is adequately served by interconnected buslines operating over the highway network. Battle Creek is served by a commercial airline.

17. *Navigation.*—The Federal project for improvement of the river (Saugatuck Harbor and Kalamazoo River, Mich.) for navigation provides for an entrance channel between parallel piers, 200 feet apart, having lengths of 2,778 and 2,514 feet, for the north and south piers, respectively, and for a channel 16 feet deep and 100 feet wide, extending from that depth in Lake Michigan to the mouth of the river, thence 14 feet deep and 90 feet wide in the Kalamazoo River up to Saugatuck, a distance of 9,000 feet. At Saugatuck there are several landing places for small vessels and one for commercial vessels. The latest modification of the navigation project was authorized by River and Harbor Act approved June 25, 1910, and provided for deepening the channel as recommended in House Document No. 635, 61st Congress, 2d session. The costs of work under the existing project to June 30, 1949, have been $364,527 for new work and $687,910 for maintenance, a total of $1,052,437. The average commerce of the harbor for the last 5 years has been 140 tons of fresh fish, excluding 1,100 tons of Government materials in 1948. There were about 2,100 trips of pleasure craft to or from the harbor in 1947 involving about 11,500 persons. The present established head of navigation for purposes of Federal jurisdiction is at Allegan, about 38 miles above the mouth. There is practically no navigation above Kalamazoo Lake at Saugatuck and no existing or anticipated navigation on the upper reaches of the river above Calkins Dam, 26.1 miles from the mouth, except for rowboats and outboard motorboats using the established pools.

18. *Power.*—Most of the sites on the Kalamazoo River and its tributaries suitable for waterpower plants have been developed. In the steepest portion of the main river from Allegan to above Plainwell, downstream from the principal areas considered in this report, there are 7 dams developing a total head of 98 feet and with total installed wheel capacity of about 10,000 horsepower. Four of these

dams are operated by the local municipalities and three by the Consumers Power Co. of Michigan. Table 5 lists the existing dams within the area pertinent to this report:

TABLE 5.—*Dams*

Dam	Location	Owner	Head	Use
			Feet	
North Monroe St.	Kalamazoo River in Battle Creek.	Consumers Power Co.	10	150-kilowatt hydroelectric installation.
Elm St.	Battle Creek in Battle Creek.	do	1	Maintain pond for cooling water for steam powerplant at site.
Verona	Battle Creek in Verona.	City of Battle Creek	7	Maintain ground water level for city water supply.

Numerous small dams are located on the headwaters above Battle Creek developing 7 to 20 feet head for both hydroelectric and direct mechanical power.

19. *Water supply.*—Water supply for domestic purposes at the cities of Battle Creek and Kalamazoo and the villages of Augusta, Galesburg, Comstock, and Parchment is from private or municipal wells. No domestic water supply in the area pertinent to this report is taken directly from the Kalamazoo River. Many of the industrial establishments along the river obtain part or all of their industrial water direct from the Kalamazoo River and its tributaries.

20. *Sewage disposal.*—The city of Battle Creek passes its sanitary sewage through an activated sludge plant discharging the effluent into the Kalamazoo River about 2 miles downstream from the city. All the residences of Augusta and Comstock and a major portion of those of Galesburg and Parchment have private septic tanks. Both Battle Creek and Kalamazoo have storm sewer systems discharging directly into the river and its tributaries. Industrial wastes in this area are dumped directly into the river. A major problem in the vicinity of Kalamazoo downstream is the deposition of paper-mill wastes including chemicals, clay, wood fiber, printing ink, and filler containing considerable solids, and also sewage directly into the river and its tributaries.

21. *Bridges.*—Many highway and railroad bridges and culverts span the Kalamazoo River and its tributaries. Table 6 lists pertinent data on the bridges involved in this report in the vicinity of Battle Creek. Downstream between Lake Michigan and the New York Central Railroad bridge at Augusta, there are 22 highway and 8 railroad bridges spanning the Kalamazoo River.

TABLE 6.—*Bridges over the Kalamazoo River in the vicinity of Battle Creek, Mich.*

Name or location	Miles above mouth of river	Kind	Type	Width of roadway (feet)	Number of tracks	Spans: Number	Spans: Clear width (feet)	Clear width normal to abutments (feet)	Clear waterway area (square feet)
KALAMAZOO RIVER									
Below city of Battle Creek:									
New York Central R. R., Augusta	93.1	Railroad	Steel girder		2	2	73	146	1,500
Michigan Ave., Augusta	93.2	Highway	Steel truss	18		2	88	176	2,070
Michigan Electric R. R. (abandoned)	94.4	Railroad	Piles only			3	40	120	1,630
Fort Custer (waterworks bridge)	100.8	Highway	Steel girder and reinforced concrete	10					
City of Battle Creek:									
Stringham Rd.	103.1	do	Steel truss	16		1	140	140	2,822
20th St.	106.1	do	do	16		1	216	216	1,515
Angell St.	106.9	do	Concrete arch	32		3	52	156	1,420
Kendall St.	107.2	do	Reinforced concrete	33		5	30	150	1,770
South Washington Ave.	107.6	do	do	42		5	30	150	1,435
New York Central R. R.	107.7	Railroad	Steel girder		2	4	33	132	1,180
Barney St.	107.8	Highway	Reinforced concrete	30		5	25	125	1,280
(Junction of Battle Creek and Kalamazoo River)									
Carlyle St.[1]	107.8	do	do	40		4	27	108	760
South McCamly St.[1]	108.0	do	do	40		3	27	81	670
Grand Trunk Ry. spur[1]	108.1	Railroad	Steel girder			1	57	57	370
Capital Ave. SW.[1]	108.2	Highway	Concrete arch	42	1	2	42	84	630
Madison St.[1]	108.2	do	Reinforced concrete	28		3	29	87	730
Michigan Electric R. R. (abandoned)[1]	108.3	Railroad	Piles only					60	
Grand Trunk Ry.[1]	108.4	do	Pile trestle		2	9	13.5	120	770
New York Central R. R.[1]	108.4	do	do		1	7	14	97	630
Fountain St.	108.5	Highway	Reinforced concrete	32		3	30.5	92	900
(Monroe St. Dam)	108.6								
BATTLE CREEK									
(Junction of Battle Creek and Kalamazoo River)									
West Michigan Ave.	.1	do	Concrete arch	46		2	56	112	850
North McCamly St.	.2	do	do	42		2	53.5	107	1,010
Capital Ave. NE.	.4	do	Reinforced concrete	46		3	27	81	840
Monroe St.	.5	do	do	23		3	27	81	900
Division St.	.6	do	do	43		3	22	66	860
New York Central R. R.	.6	Railroad	Steel girder		4	3	20	60	500
Elm St.	.9	Highway	Reinforced concrete	32		4	27	108	1,000
Union St.	1.2	do	do	32		4	27	108	1,120
East Ave. (foot bridge)	1.8	Foot	Pile trestle	5		7	22	154	770
Maple Grove St. (foot bridge)	2.3	do	do	8		4	20	80	830
Emmett St.	3.1	Highway	Concrete arch	32		2	55	110	1,060
(Verona City Dam)	3.2								

[1] Bridges over portion of channel to be abandoned.

CLIMATOLOGY

22. The climate of the Kalamazoo River watershed is moderated by Lake Michigan to the west and Lake Huron to the east. Winters are ordinarily fairly severe with considerable snow and ice, and summers are warm. Precipitation and temperature distribution over the basin is fairly uniform, except snowfall is normally heavier near Lake Michigan. The approximate temperature data for the basin above Kalamazoo is as follows:

	°F.
Average winter (December to February)	25
Average spring (March to May)	46
Average summer (June to August)	70
Average fall (September to November)	51
Average annual	49
Average daily maximum	56
Average daily minimum	37
Absolute maximum	109
Absolute minimum	−35

The prevailing winds in the winter and spring are from the west, and during the summer and fall from the southwest. The length of the growing season is generally about 155 days. The average annual precipitation is about 33 inches, including about 44 inches of snowfall. Thunderstorms occur frequently during the summer. Additional details on climatological data are given in appendix A.[1]

RUNOFF AND STREAM FLOW DATA

23. *Runoff records.*—Kalamazoo River discharge records for the area considered in this report, as obtained by the United States Geological Survey, are given in table 7:

TABLE 7.—*Discharge record*

Station	Drainage area (square miles)	Period of record	Discharge (cubic feet per second)				
			Mean	Average annual maximum	Average annual minimum	Absolute maximum	Absolute minimum
Kalamazoo River at Comstock.	1,010	April–August 1931; October 1932–September 1948.	843	1,351	518	6,860 Apr. 8, 1947	185 Aug. 7, 1934
Kalamazoo River near Battle Creek.	849	July 1937–September 1948.	690	1,158	399	7,210 Apr. 7, 1947	143 Aug. 21, 1941
Battle Creek at Battle Creek.	241	October 1930–July 1931; October 1932–September 1948.	215	427	98	3,660 Apr. 7, 1947	1 Jan. 22, 1931

These detailed runoff records do not cover a period long enough for establishing good frequency-discharge relations but are sufficient to determine the lower discharge portion of this relationship. Intermittent records since 1929 have been kept of Calkins Dam, near Allegan about 48 miles downstream from Kalamazoo, but the discharge there is partly regulated and is affected by some control at six additional dams located between this dam and Plainwell which

[1] Not printed.

reduce peak flows, making the records of little value for this report. New gages were installed in 1948 at Marshall on the Kalamazoo River and in Kalamazoo on Portage Creek. Further details on the records at the stations are included in appendix A.[1]

24. *Runoff factors.*—Table 8 shows monthly, seasonal, and annual average runoff, average precipitation and resultant runoff factors for the periods of record for the discharge stations noted above.

TABLE 8.—*Runoff factors*

Period	Kalamazoo River at Comstock			Kalamazoo River near Battle Creek			Battle Creek at Battle Creek		
	Average Runoff	Average precipitation	Runoff factor	Average runoff	Average precipitation	Runoff factor	Average runoff	Average precipitation	Runoff factor
	Inches	*Inches*	*Percent*	*Inches*	*Inches*	*Percent*	*Inches*	*Inches*	*Percent*
Winter:									
December	0.76	1.88	40.43	0.72	1.87	38.50	0.68	1.63	41.72
January	.86	1.94	44.33	.74	1.94	38.14	.74	1.74	42.53
February	.89	1.65	53.94	.89	1.65	53.94	.91	1.65	55.15
Season	2.51	5.47	45.89	2.35	5.46	43.04	2.33	5.02	46.41
Spring:									
March	1.40	2.31	60.61	1.49	2.31	64.50	1.76	2.18	80.73
April	1.37	2.56	53.52	1.42	2.58	55.04	1.62	2.24	72.32
May	1.20	4.05	29.63	1.29	4.10	31.46	1.27	3.94	32.23
Season	3.97	8.92	44.51	4.20	8.99	46.72	4.65	8.36	55.62
Summer:									
June	1.04	4.37	23.80	1.12	4.41	25.40	1.14	5.07	22.49
July	.72	2.57	28.02	.62	2.50	24.80	.52	2.41	21.58
August	.63	3.86	16.32	.56	3.77	14.85	.42	3.87	10.85
Season	2.39	10.80	22.13	2.30	10.68	21.54	2.08	11.35	18.33
Fall:									
September	.63	3.69	17.07	.54	3.72	14.52	.44	3.69	11.92
October	.66	3.03	21.78	.58	2.94	19.73	.50	3.11	16.08
November	.76	2.39	31.80	.68	2.39	28.45	.67	2.22	30.18
Season	2.05	9.11	22.50	1.80	9.05	19.89	1.61	9.02	17.85
Annual	10.92	34.30	31.84	10.65	34.18	31.16	10.67	33.75	31.61

FLOODS OF RECORD

25. *Flood history.*—The flood history of the Kalamazoo River at Battle Creek is similar to its history at Kalamazoo. The drainage area between the two cities is small and narrow in width so that the peak runoff from this area passes Kalamazoo prior to the arrival of the peak from the area above Battle Creek. Peak discharges at Kalamazoo may be slightly less than, equal to, or greater than those for the same flood period at Battle Creek depending on the operation of the taintor gates in the Bryce E. Morrow Dam above Comstock during the peak of the flood, and to a limited extent on the areal distribution of the rainfall. These elements have greater effect on smaller flood flows, increasing the Kalamazoo peak discharge appreciably above that at Battle Creek, in some instances. The maximum flood of record at Battle Creek was in March 1904 with floods of slightly less volume occurring in March 1908, April 1947, March 1918, 1887, and March 1948, in that decreasing order of peak discharge. A historian reports floods in 1854, 1864, 1868, and 1869 greater in magnitude than

[1] Not printed.

the 1904 and 1908 floods but actual stages are not available for these peaks. This historian reported that the flood of 1864 "probably contained the most water." Lesser floods have occurred at more frequent intervals with minor flooding in the lower areas occurring almost annually. With the exception of the flood in June 1864 all of the major floods noted above occurred in the spring as a result of heavy spring rains on snow cover over ground in a fairly saturated condition and at a time when stream stages were already rising. Additional data on flood history is given in appendix A.[1]

26. *Flood frequencies.*—Table 9 lists the estimated frequencies of flood peaks at Battle Creek. Additional details on flood frequencies are given in appendix B.[1]

TABLE 9.—*Estimated flood frequencies*

Percent chance of occurrence in any one year	Peak discharge in cubic feet per second	
	Kalamazoo River at Battle Creek (including Battle Creek)	Battle Creek at Battle Creek
90	2,600	1,000
75	3,200	1,200
50	3,400	1,300
25	4,000	1,500
15	5,200	2,000
10	6,400	2,500
5	8,300	3,100
2	10,400	4,000
1	12,000	4,600
0.5	14,000	5,400

These frequencies are based on fairly complete records of major floods since about 1883 for the river at Battle Creek and Kalamazoo, plus a historical report of peaks at Battle Creek between 1854 and 1883.

STANDARD PROJECT FLOOD

27. *General.*—Table 10 shows the relation between the standard project floods and the maximum floods of record for the Kalamazoo River for the cities of Kalamazoo and Battle Creek. Further details on development of these standard project floods are given in appendix A.[1]

TABLE 10.—*Flood estimates*

Location	Maximum flood of record		Standard project flood, cubic feet per second
	Cubic feet per second	Year	
Kalamazoo River at Kalamazoo	[1] 7,900	1904	41,000
Kalamazoo River at Battle Creek [2]	[1] 7,500	1904	38,000
Battle Creek at Battle Creek	[1] 4,000	1904	15,000

[1] Estimated.
[2] Including Battle Creek.

[1] Not printed.

28. *Standard project flood.*—The standard project flood is based on the transposition to the Kalamazoo River Basin of the maximum storms of record from surrounding areas, including Ohio, Indiana, Illinois, Iowa, Wisconsin, Minnesota, and Michigan that would result in the greatest peak discharges on the Kalamazoo River at Battle Creek and Kalamazoo. It has been generally concluded that the most severe Minnesota and Wisconsin storms may be transposed across Lake Michigan to the Kalamazoo River Basin without reducing intensities. Likewise the high intensity Ohio storms may be transposed to the basin at full intensity. In general, the high intensity storms of Ohio, if transposed to the Kalamazoo River Basin and placed so as to center the heaviest rainfall in the most critical area, would produce the controlling maximum rainfall for the area. The Ohio storms of August 6–7, 1935, and September 10–13, 1878, if so transposed, would be most critical and are used as the basis for these determinations. The resultant floods, as they affect the cities of Kalamazoo and Battle Creek, would be about 5.5 times greater in volume than the maximum floods of record and would cause water to flow 12 to 15 feet deeper over the extensive commercial, industrial, and residential areas of the cities than these ciites have experienced in the past. If the study had been limited to storms that have actually been experienced in Michigan, northwestern Ohio, northern Indiana, and northeastern Illinois, as transposed to the Kalamazoo River Basin, the resultant peak runoff would be only about 60 percent of the standard project floods. These estimates of standard project floods are based on high intensity summer rainfalls. The maximum runoff rates anticipated under spring rainfall and snow cover conditions are only about 70 percent of the standard project floods.

EXTENT AND CHARACTER OF FLOODED AREA

29. *Extent of flooded area.*—The major flooding at Battle Creek and vicinity is along the Kalamazoo River and Battle Creek and is almost entirely within the city limits, except for low vacant lands downstream from the city. Along the Kalamazoo River flooding commences below the Monroe Street Dam (Lower Mill Pond) covering a large area through the downtown business, industrial, and adjacent residential area, mainly along the southerly side of the river, in the vicinity of Hamblin Avenue and Liberty Street, and extending downstream to 20th Street. Flooding along Battle Creek commences below Verona Dam above Emmett Street and extends downstream along both banks in most places to its junction with the Kalamazoo River. Table 11 indicates the location, extent, and general character of areas flooded by the April 1947 flood. The damage valuation for this report is based on this flood which was slightly below the maximum flood stage of record (1904). The flood area was more extensively developed in 1947 and this is the only major flood for which complete damage data are available. Photographs of typical flooded areas for the April 1947 flood are included in appendix B.[1]

[1] Not printed.

TABLE 11.—*April 1947 flood areas*

Flood area and limits of inundated area	Area inundated, acres				
	Residential	Commercial	Industrial	Vacant	Total
KALAMAZOO RIVER					
(*a*) Hamblin Ave:					
Both banks, Monroe St. Dam to junction with Battle Creek (north of Grand Trunk RR main line)	6	25	24	8	63
Both banks, junction with Battle Creek to Kendall St. (north of Grand Trunk RR main line)	7	7		5	19
Both banks, Kendall St. to 20th St	46	4		61	111
(*b*) Liberty St.: Left bank, south of Grand Trunk Railroad main line	62	12	5		79
(*c*) Stringham Rd.:					
Both banks, 20th St. to Stringham Rd				314	314
Both banks, Stringham Rd. to end of project below waterworks Bridge				704	704
Subtotal, Kalamazoo River	121	48	29	1,092	1,290
BATTLE CREEK					
(*d*) Above Elm St.:					
Both banks, Verona Dam to East Ave. (extended)				130	130
Both banks, east Ave. (extended) to Union St.	13		6	53	72
Both banks, Union St. to Elm St	8	1	23	6	38
(*e*) Below Elm St.:					
Both banks, Elm St. to Division St	1	6	14	1	22
Both banks, Division St. to junction with Kalamazoo River		6			6
Subtotal, Battle Creek	22	13	43	190	268
Grand total, city of Battle Creek and vicinity (Kalamazoo River and Battle Creek)	143	61	72	1,282	1,558

30. *Character of flooded areas.*—The flood-damage area in the vicinity of Battle Creek as inundated by the April 1947 flood includes residential, commercial, industrial, and public property along with considerable areas of low vacant land. Homes in the flooded area range from low- to medium-value residences, some of which have deteriorated in value because of their location. Many of these homes have basements that are flooded almost annually and the basements of many of the homes adjacent to this inundated area are flooded through inability of the drains to function properly during high river stages. Because of the early spring occurrence of the 1947 flood, damage to garden lands and crops was negligible. However, if a flood of this intensity occurred during the summer months the crop loss in home gardens would be appreciable. Because of the proximity of the inundated areas to the downtown business district considerable flood damage is experienced through loss of stock stored in basements and loss of wages, business, and production. General descriptions of the inundated areas as listed in table 11 are as follows:

KALAMAZOO RIVER

(*a*) *Hamblin Avenue.*—The portion of this flooded area extending east of Barney Street is an extensively developed industrial and commercial zone adjacent to and including about one-half of the downtown business district of Battle Creek. Within this flood area are 46 retail and wholesale stores, a brewery, 3 large industries, and about 39 low-

to medium-priced residences. Water covered the first floor of many of these business establishments and residences to a depth of 2 or 3 feet. Fifteen commercial buildings with pile foundations extend either partially or entirely across the Kalamazoo River between Fountain Street Bridge and its junction with Battle Creek, creating considerable backwater buildup at each structure. North of the river along Michigan Avenue and Jackson Street in the thumb of land immediately above the confluence of and between the Kalamazoo River and Battle Creek, which area comprises the heart of the city, the terrain is slightly higher and was not inundated during the 1947 flood. However, the basements of about 51 business establishments in this area were flooded, causing considerable damage to stock or loss of wages or production. The main line of the Grand Trunk Railroad was covered to a depth of 1 foot in the vicinity of McCamly Street slowing all rail traffic and restricting it to 1 higher track for a period of 5 days. Five municipal buildings were also surrounded by floodwaters in this area. Downstream from Barney Street to 20th Street the left bank of the river was flooded to the embankment of the main line of the New York Central Railroad surrounding about 22 business firms, including garages, dairies, and wholesale warehouses and about 178 low- to medium-value residences. Many of these buildings had floodwaters over their first floors. About 50 residences adjacent to this flood area experienced basement flooding and damages. In the downstream portion of this area considerable low, vacant land was inundated.

(*b*) *Liberty Street.*—This area, known as the Flats, extending southerly from the Grand Trunk Railroad embankment to the natural slope in the vicinity of Upton Avenue, experienced the greatest suffering and personal property loss during the 1947 flood. Prior to the construction of the railroad embankment, floodwaters from the Kalamazoo River overflowed the area but drained rapidly into the river to the north. Inadequate outlets through the embankment caused the water to impound to a depth of 4 feet in this flat area surrounding about 284 low- to medium-valued residences, with water over the first floors of about half this number. Most of these homes have deteriorated in value and become undesirable as living quarters. Five churches, forty-one commercial and 4 industrial establishments were surrounded by water which was over the first floors in most cases. The Ralston Purina Co. plant was forced to shut down for 2 weeks because of inundation and floodwater damage to stocks and equipment. The American Red Cross rendered considerable assistance in evacuating people from this area. The period of inundation was longer here than in any other part of the city because of the poor outlet to the river. As sanitary sewers were available throughout only a small portion of this area a very unhealthy condition was created. However, this is being corrected at the present time through extension of the sewer system.

(*c*) *Stringham Road.*—Flooding downstream from 20th Street is limited generally to low swamp, brush, and wooded areas along both banks of the river.

BATTLE CREEK

(*d*) *Above Elm Street.*—Upstream from East Avenue (extended) to Verona Dam, the flood area is confined to the low vacant rather swampy river bottom lands along each side of Battle Creek with no

appreciable flood damage. Between East Avenue (extended) and Elm Street about 42 low- to medium-priced homes, 4 commercial establishments, and 2 industrial firms located along the southerly river bank in the flood zone were flooded and 7 outlying residences with 3 small businesses experienced basement damages. The Oliver Corp. located in this area received warehouse and farm-machinery damage. The Elm Street steam-electric plant of the Consumers Power Co. experienced flood damage and difficulty in continued operation during the flood. If the flood stage had been only slightly higher this plant would have been forced to cease operations. The 1904 flood stage was the basis for design of installations at this plant. The Grand Trunk Railroad yards were flooded 4 days to a maximum depth of 2 feet curtailing operations and damaging stored supplies and materials.

(*e*) *Below Elm Street.*—Between Elm Street and the junction of Battle Creek with the Kalamazoo River the wide overflow section noted upstream is reduced to only slight bank overflow in the vicinity of Capital Avenue and thence to Michigan Avenue is retained between the revetment on the south bank and the New York Central Railroad embankment and natural slope on the north. In this area 14 buildings on pile foundations extend entirely or partially across the channel creating a serious backwater buildup. These commercial and industrial buildings had considerable flood damage along with 17 stores in adjacent areas that had considerable damage to merchandise and equipment stored in basements. An additional equal number of stores saved their stocks only through extensive flood fighting. Three low- to medium-valued homes in the area received slight damage. Four manufacturing firms were forced to wholly or partly shut down for several days. The New York Central Railroad yards and main line tracks were inundated slowing through traffic and curtailing yard operations

31. The flooded area described above for the April 1947 flood is about equal in extent to the maximum flood of record (1904). Although the 1904 flood probably involved greater discharges than in 1947, additional channel restrictions since 1904 have produced higher flood stages for comparable flows. Flooding at Battle Creek and vicinity is dependent on two main factors, i. e., rainfall distribution and relation of resultant runoff between Battle Creek and the Kalamazoo River, and method of routing (using headrace or main river channel) below the Monroe Street Dam. The headrace, entering Battle Creek above Capital Avenue, has a greater capacity than the restricted main Kalamazoo River channel between the dam and its junction with Battle Creek. If the major portion of the Kalamazoo River flow is diverted down the headrace to Battle Creek, for floods of combined flow (Battle Creek plus Kalamazoo River) up to about 5,000 cubic feet per second, the restricted Kalamazoo River channel below the dam will not be overtaxed and the adjacent area will not have appreciable flooding. If, however, the main flow is passed down the restricted Kalamazoo River to the confluence, the area south of the river along Hamblin Avenue will be inundated. As flooding commences in the vicinity of Battle Creek the low bottom lands along Battle Creek upstream from Elm Street and along the Kalamazoo River downstream from Angell Street are the first to flood at about 1,200 cubic feet per second and 2,800 cubic feet per second respectively. With stages about 2 feet higher the low residential and commercial area south of the river and downstream from the confluence is flooded, usually including some areas along the Kalamazoo River between the confluence and Monroe Street Dam. When the combined discharge is in excess of about 4,000 cubic feet per second the building restrictions along both Battle Creek and Kalamazoo River create a substantial increase in the slope of the backwater curves above the restrictions causing appreciable overflow of low developed areas along the channels. With flows similar to the March 1948 flood (5,900 cubic feet per second combined flow) additional residential and commercial areas along Hamblin Avenue, downtown and up Battle Creek are inundated. With higher stages the combined capacity of the headrace and the Kalamazoo River is inadequate to carry the flow and the floodwaters back up below the Fountain Street Bridge diverting the waters westerly along Liberty Street over the Flats south of the Grand Trunk Railroad embankment. As this pool is built up the railroad serves as a submerged weir and the entire area north to the river is inundated, causing extensive damage to industry, residences, and stores in the area. Comparable discharges along Battle Creek create a pool behind the restricted downtown channel causing upstream flooding over built-up residential, commercial, and industrial areas. Under present conditions floods greater than those of record will produce flood stages in the Battle Creek area about as follows with respect to the April 1947 stage, assuming no further channel obstruction. It is more than probable, however, that if a larger flood occurred one or more of the existing old buildings constructed on pile foundations and extending into or over the channels would collapse creating a virtual dam which would back up the water over an unlimited area causing tremendous damages, suffering, and probable loss of life.

Flood discharge, cubic feet per second	Approximate flood stage at Battle Creek [1]	
	Elevation above mean sea level	Elevation above April 1947 flood stage
7,200 (April 1947)	816.0	0
11,000 (design flood)	818.0	2.0
15,000	820.0	4.0
25,000	824.0	8.0
38,000 standard project flood	828.0	12.0

[1] At Kendall St. Bridge below the junction of Battle Creek and the Kalamazoo River. Upstream along the obstructed Battle Creek and Kalamazoo River channels the increase in stage for the larger discharges would be greater.

FLOOD DAMAGES

32. *General.*—The numerous flood experiences in and around Battle Creek have been conducive to keeping flood damages comparatively low. About 10 floods with crests within 2 feet of the maximum of record have occurred during the past 100 years so that the local citizens have become accustomed to such flood stages. Valuables, merchandise, and machinery have been removed from basements in the flood areas where possible and most first floors are at or only slightly above this stage. However, because of the high value and crowded condition of this downtown area there is a tendency to use all available space.

Residents of this vicinity have apparently assumed that this rather common flood stage is the maximum probable flood. It is probable that some future floods will largely exceed those of record and a stage only a foot or two higher will cover many more first floors and cause flood damage several times that of the April 1947 flood.

33. *Damage surveys.*—A comprehensive field flood damage survey was made in 1947 following the April flood to ascertain the damages caused by that flood and to collect data for estimating damages for floods of lesser and greater intensities. Each industrial and commercial establishment in the area was checked and either spot or complete checks were made of the residential areas, depending on type, depth of water, and similarity of structures and conditions. Spot checks were also made of the rural areas to determine the extent of flood damage. Another field damage survey was made in 1948 following the March flood, spot-checking places that were covered in the 1947 damage survey to establish a damage relation between these two floods. All of the field data obtained was analyzed and supplemented with estimated data to establish damage-stage-assessed value relationships for the residential areas to be used in computing damage values for greater floods than those of record. For these larger floods each commercial and industrial firm was analyzed individually. An attempt was also made to collect all available flood-damage and stage data for previous floods through newspaper and historical records, city and library files, local people, and other sources but the data obtained was limited and of questionable accuracy.

34. *Damage estimates.*—Flood damages on which a monetary value can be placed are divided in general into direct and indirect damages as follows:

(*a*) Direct damages include the value of all property destroyed by a flood and not replaced and the cost of restoring damaged property to preflood conditions.

(*b*). Indirect damages are additional costs of operation necessitated by the flood if normal operations are not possible and include loss of wages, business, or production, costs of flood relief and flood fighting, and costs of evacuation and rehabilitation.

Table 12 summarizes the April 1947 flood damages for the Battle Creek area. These estimates are corrected for current price levels so that estimates of benefits derived will be on the same basis as the estimates of cost of a flood-control project. A detailed breakdown of these damages is given in appendix B.[1]

TABLE 12.—*April 1947 flood damages*

Flood area (see table 11)	Damage		
	Direct	Indirect	Total
Kalamazoo River:			
Hamblin Ave	$131,800	$185,000	$316,800
Liberty St	312,400	73,200	385,600
Stringham Rd	0	0	0
Battle Creek:			
Above Elm St	22,000	7,800	29,800
Below Elm St	20,800	32,400	53,200
Total	487,000	298,400	785,400

[1] Not printed.

For comparison, a newspaper article reported the 1904 flood damages at $250,000. Based on current values this damage would be about $1,400,000 which is probably not unreasonable if both tangible and intangible damages are included. A preliminary flood-damage estimate made by the mayor's committee after a survey immediately following the April 1947 flood was $519,200. This estimate is approximately equal to that given in table 12 if converted to 1949 price levels. However, the committee reported that this estimate was not complete as it did not include many of the lesser damages. The March 1948 total flood damages as summarized from the field survey was only about $50,000. However, as this flood followed the more disastrous April 1947 flood and the public was given ample warning by a newly organized flood-warning station that a flood of the 1947 magnitude was approaching, all possible flood precautions were taken, which reduced the resultant flood damage by a considerable amount.

35. Intangible damages include those hazards to life and health that cannot be measured in monetary terms. As far as is known no deaths have been directly attributed to floods in the Battle Creek area. The floods create serious health problems through flooding basements and first floors. Sanitary sewers do not function properly in the low areas during flood periods. Outside toilets in the Liberty Street area created a particularly unsanitary condition, some floating away in the floodwaters. Large gasoline tanks in this area nearly floated from their foundations, creating a serious fire hazard. During the 1947 flood about 200 families were evacuated from their homes in the Liberty Street-Hamblin Avenue area. In addition, a larger number of families were forced or desired to move to second floors. The Red Cross and other local organizations furnished valuable assistance in this evacuation and rehabilitation problem.

36. It is estimated that a flood of 15,000 cubic feet per second or about twice the maximum of record would add about 4 feet of water to the 1947 flood stage, more than doubling the inundated commercial, industrial, and residential area and causing an estimated tangible flood damage in excess of $7,400,000, based on the present state of development of the community. If one of the buildings spanning the channels collapsed during this flood, as is probable, and dammed the channel, the resultant flood damage would increase considerably. The intangible damage for this size flood would probably be many times higher because of the large increase in depth, area, and duration of inundation and with building failure would probably involve loss of life. A flood of the standard project flood magnitude would add at least 12 feet to the April 1947 stage exclusive of building failure, inundating practically all of the downtown and adjacent portions of the city. All through railroad and highway traffic would be stopped at the city and the damages probably would exceed $22 million. As these estimates are based on a nearly straight line extrapolation of the curves showing the damage-discharge relationship, they are conservative. It is probable that at these stages the damages would be considerably more than indicated above. Although the 1949 price level is comparatively high, it is not anticipated that this level will decline appreciably over the next 50 years, the assumed life of the project; and considering the normal growth of the community over this period, the anticipated future damages are estimated to be as much as 20 percent above the 1949 basic estimates.

37. *Average annual damages.*—Stage-discharge, stage-damage and discharge-frequency curves (see appendix B)[1] were plotted for the Battle Creek area based on actual April 1947 flood damages and computed flood damages for lesser and greater floods. Table 13 summarizes the average annual direct, indirect, and total flood damages for this area determined from stage, damage, and frequency relations thus established, plus an allowance for the anticipated normal growth of the community during the life of the project.

TABLE 13.—*Estimated average annual flood damages*

Flood area (see table 11)	Average annual damage		
	Direct	Indirect	Total
Kalamazoo River:			
Hamblin Ave	$52,000	$79,300	$131,300
Liberty St	124,000	31,400	155,400
Stringham Rd	0	0	0
Battle Creek:			
Above Elm St	8,600	3,400	12,000
Below Elm St	8,200	14,000	22,200
Total	192,800	128,100	320,900

EXISTING FEDERAL FLOOD-CONTROL PROJECTS

38. There are no existing Corps of Engineers flood-control projects completed or previously proposed in the Kalamazoo River Basin. The existing navigation project at the mouth of the river (see par. 17) has no effect on the flood problem. There are no known flood-control improvements by other Federal agencies in the Kalamazoo River Basin. An interim report on the city of Kalamazoo and vicinity (see par. 2a) recommended a channel enlargement type of flood-control project for that area.

IMPROVEMENTS BY LOCAL AGENCIES

39. The city of Battle Creek has done very little to protect itself against floods. It has attempted at several times to prohibit future construction or encroachment in or across the river channels, but has been unable to substantiate its claims in court. Following the April 1947 flood the city established a flood-warning station with a permanent chief observer. This station proved very beneficial during the March 1948 flood, considerably reducing the resultant flood damages. In recent years the city has attempted to coordinate its planning and development along a course that would also aid flood control, but no definite plan has been adopted. To date the city has undertaken practically none of the corrective measures recommended in the consulting engineer's report noted in paragraph 5 above.

IMPROVEMENTS DESIRED

40. *Public hearing.*—Public hearings were held at Battle Creek and Kalamazoo, Mich., by the district engineer on November 5, 1947, and January 21, 1948, respectively, the former being confined

[1] Not printed.

in general to the flood problem at and in the vicinity of Battle Creek. It was attended by about 80 persons including officials and representatives of Federal, State, county, township, and city of Battle Creek organizations, representatives of local industrial and commercial establishments, civic leaders, and private citizens. A copy of the notice,[1] minutes of the hearing,[1] and related exhibits [1] accompanies this report.

41. *Improvements requested.*—Several plans of improvement were suggested at the hearing as possible solutions to the flood problem including placing the channels in tunnels through the city; restricting future building encroachment on the channel; removing existing channel restrictions; diverting the Kalamazoo River down Liberty Street through the Flats and then north to the river; placing retaining walls along the river banks through the city; clearing out and straightening the channels through and below the city; enlarging the present channels; and establish a flood-warning system. Considerable interest was expressed in many of these possible solutions, but it was generally concluded that the final solution was one to be determined through the pending Corps of Engineers survey. There was no apparent opposition expressed to any of the proposed types of flood control.

42. *Local cooperation.*—The city of Battle Creek or other local or State organizations offered no specific items of local cooperation at the hearing. The mayor expressed his opinion that local interests would do everything in their power to comply with the prescribed conditions of local cooperation. The development of a flood-control project in this area would involve the city of Battle Creek, towns of Battle Creek and Bedford, Calhoun County, and possibly a small portion of Ross Township in Kalamazoo County. The features of local cooperation can best be carried out by coordinating the requirements of all subdivisions under one local or State agency for compliance. The Michigan State Legislature, by Act 117, P. A. 1949 (effective May 18, 1949), created a water resources commission to act as the State agency to cooperate and negotiate with other agencies, including the United States Government, in the preparation and coordination of flood-control plans and projects. This commission has reviewed and concurred in the plan of improvement for flood control at the city of Battle Creek and vicinity. To assist in actual construction of the approved project and distribution of local costs the Michigan laws relating to the construction of drains were amended by Act No. 122, P. A. 1949, authorizing two or more public corporations affected by an intercounty drain to petition the State department of agriculture to form a local drainage board. This board would have authority to assess, not only those public corporations benefiting by the project, but also those upstream areas contributing floodwaters to the affected zones, in distributing the cost of local cooperation. It is believed that each of the local governments in the proposed project area are willing and able to cooperate with the State water resources commission, a drainage board, and the United States in the development and construction of a flood-control project to the extent that such governing body is involved.

[1] Not printed.

SURVEYS

43. *Field survey.*—A topographic survey was made in 1947 and 1948 of the river valley from the B. E. Morrow Dam above Kalamazoo upstream through Battle Creek to Ceresco on the Kalamazoo River and to Bellevue on Battle Creek. Cross sections of the valley extending in general to above flood stages were taken at approximately 500-foot intervals and at all bridges. This data, supplemented by aerial photographs taken in 1948 by this office and controlled mosaics prepared therefrom by the Army Map Service, Corps of Engineers, for this office, were used to prepare detailed topographic maps to a scale of 200 feet to 1 inch with 1-foot-contour intervals for the metropolitan areas, and to a scale of 500 feet to 1 inch with 5-foot contours for the rural areas. Maps entitled "Flood Control, Kalamazoo River, Mich., Battle Creek and Vicinity," file No. 52–G–3 in four sheets, showing the principal features of the area surveyed, the present river channel, the design channel considered, with cross sections and profiles,[1] are included in this report.

44. *Underground explorations.*—Logs of subsurface borings taken by this office, the Michigan State Highway Department, the city, and local industry have been used to determine the character of materials to be encountered in channel excavation. Representative borings at pertinent locations are shown on the above-mentioned maps.

45. *Ground-water surveys.*—Information on ground-water levels was obtained from United States Geological Survey studies of the Battle Creek area.

46. *Flood-damage survey.*—Details of the flood-damage survey made by this office are given in paragraph 33.

47. *Miscellaneous.*—Other miscellaneous data pertinent to the flood problem have been collected as follows:

1. Precipitation data.
2. Streamflow data.
3. Assessed land values in flooded areas and for right-of-way.
4. Bridge and utility plans and data.

Summaries of these data are included in the appendixes to this report.

FLOOD PROBLEMS AND SOLUTIONS CONSIDERED

48. *Flood problem.*—The city of Battle Creek was founded in the Kalamazoo River Valley at its confluence with Battle Creek to obtain the benefits of waterpower from these streams. As the areal extent of the valley land between the adjacent slopes at this location was rather limited, the area was developed to the maximum over a period of many years. Industry desired to remain in these bottom lands to obtain the waterpower and railroad service located there. The narrow strip of land located between the two streams and above their confluence was the natural location for the center of this community. Because of the congestion in this downtown area, industry and business began to extend their buildings into and over the natural river channels with little or no consideration for their flood capacity. Bridge openings were adequate in most cases, but the buildings were founded on piling, at as little as 6 feet center to center in places,

[1] Not printed.

restricting the channel capacity to less than half that of the bridges. Low members on many of these buildings were considerably below those of the bridges. In addition the channels were used as community dumps at many locations further restricting their capacity. Efforts of the community to stop these obstructive practices were fruitless and the practice has been continued even into recent years. Hence, the flooding in the vicinity of Battle Creek is due entirely to the inability of the greatly restricted channels to carry the flood flow at a lower stage.

49. Major and minor floods are caused by excessive summer rainfalls, or spring rainfalls on snow cover and saturated or frozen ground, over the contributing upstream watershed. These floods can be caused by either Battle Creek or the Kalamazoo River; however, because of the rather small upstream tributary area, any precipitation of adequate intensity to produce appreciable flood runoff will normally have enough areal coverage to produce flood conditions on both streams. Normally Battle Creek peaks in the city several hours before the Kalamazoo River. However, this can be reversed under certain runoff conditions. Battle Creek and Kalamazoo River floodwaters combine in the city of Battle Creek producing the following sequence of events:

(*a*) Normally the Battle Creek peak reaches the downtown area first building up the river stage in that channel and the Kalamazoo River downstream. The restricted channel between Elm Street and the junction creates a steep backwater slope so that in the vicinity of the junction of the headrace, from the Lower Mill Pond on the Kalamazoo River, and Battle Creek, near flood stage is reached before the Kalamazoo River peak flow reaches Battle Creek. As the peak on the Kalamazoo River is reached, the headrace is used to its maximum available capacity, it having a greater water-carrying capacity than the main river channel below the Monroe Street Dam. When these waters discharge from the headrace into Battle Creek, between Capital Avenue and Monroe Street, which is above the major portion of the restricted part of the Battle Creek channel, considerable additional buildup is forced on the Battle Creek channel, both upstream and downstream, with resultant extensive flooding of commercial, industrial, and residential areas and sewer backup into basements of many industrial and business firms.

(*b*) As the headrace to Battle Creek is inadequate to carry all of the Kalamazoo River flood discharge, a major part of it is passed over the Monroe Street Dam into the seriously constricted Kalamazoo River channel extending through the heart of the business district of the city. The flood-carrying capacity of this channel is small below the Grand Trunk Railroad bridge causing a serious buildup above this bridge and the adjacent Michigan Carton Co. buildings over the river. This water flows westerly out of the channel along Liberty Street and back of the Grand Trunk Railroad embankment flooding the large adjacent area, the Flats, southerly to about Upton Avenue. As the pool is built up behind the railroad embankment it overflows the railroad and augmented by additional waters from the river to the east inundates practically the entire downtown area south of the Kalamazoo River. These latter two areas experience the greatest flood damage of the entire city. Even without the railroad embankment or with adequate drainage through it the flooded area would be

about the same but possibly it would be flooded to a little less depth and for a shorter time behind the embankment.

(*c*) As these floodwaters proceed north to the main river channel already at flood stage because of the Battle Creek flow, the stage at the junction of the two streams is raised to above the river banks. These floodwaters do not drain away from the city fast enough because of the crooked channel and flat gradient of the Kalamazoo River channel between 20th Street and below the Waterworks Bridge downstream from the west city limits of Battle Creek which causes a high backwater surface upstream to the confluence with Battle Creek. Hence, these floodwaters inundate considerable residential, industrial, and commercial property in the vicinity of Hamblin Avenue, south of the river, as they leave the city.

(*d*) Downstream from 20th Street large areas of potentially valuable low vacant river bottom land is inundated along both river banks.

50. Minor local flood problems have been encountered throughout the city in low pockets where there is inadequate drainage, following high intensity rainfalls. However, these are local problems which are being corrected by the local government and are not included in this report.

51. *Solutions considered*—(*a*) *Reservoirs.*—The entire watershed above Battle Creek contains no large reservoir site or combination of sites with sufficient capacity to materially lower flood heights at Battle Creek. The several small, low head sites above Battle Creek could not be economically developed for flood control or multiple-purpose use primarily because of their small storage capacity. The large spillway capacity required to pass maximum floods and the necessity for prompt emptying of the reservoirs to prepare for a possible following flood would leave no storage available for any purpose other than flood control, so multiple-purpose reservoirs are out of the question. The sites would be expensive to develop as the storage pools would occupy some of the best farms in the valley and relocation of several miles of principal highways and railroads would be necessary. Operation of such a system of small reservoirs would present many difficulties with consequent loss of efficiency. Consequently, the benefits derived from such flood-control reservoirs would be only a fraction of their costs and they are not further considered in this survey report.

(*b*) *Levees, walls, and tunnels.*—The flooded areas in the vicinity of Battle Creek cannot be adequately protected against a flood of the standard project flood magnitude by any practical system of dikes or walls. The cost of these structures including the reconstruction of many bridges and approaches and removal of buildings would exceed any derived benefits, and if constructed the controlled water level for the standard project flood would be several feet above the adjacent terrain. Partial protection by this method, especially in a metropolitan area, is not considered desirable since it creates a false sense of security among the people and any overtopping would probably cause damages comparable to or greater than might have occurred without this partial protection. Placing the Kalamazoo River in a tunnel or conduit from Fountain Street to its junction with Battle Creek, as suggested at the hearing, is physically possible but is not considered economically sound in view of the other possible solutions to the problem discussed herein.

(*c*) *Channel enlargement and relocation.*—The floodwaters in this area can be controlled best by channel widening, deepening, straightening, or relocation to provide a channel having an increased discharge capacity. Three possible plans of improvement were analyzed from an engineering and economic standpoint, as follows:

(1) Enlarge the existing Kalamazoo River channel from below Monroe Street Dam to its junction with Battle Creek so as to carry the Kalamazoo River flood flow. This would involve the procurement of a right-of-way along the channel through the heart of the city, removal of many commercial and industrial buildings adjacent to and extending into and over the channel, reconstruction of several important bridges, and excavation. The real estate alone for this channel enlargement would probably exceed $1,250,000 as considerable land and many buildings in the highest valued part of the city are involved.

Clean out and enlarge the Battle Creek channel from Union Street to its junction with Kalamazoo River. Several buildings extending into and over the channel must be removed to provide a clear right-of-way and unobstructed flow. Existing bridges in this channel provide adequate area for passing floodwaters but some will require substructure reinforcements.

Enlarge the Kalamazoo River channel downstream from its confluence with Battle Creek to 20th Street; thence enlarge and straighten the channel to below the Waterworks Bridge so as to eliminate cutbacks and increase the gradient. Some of the bridges in this reach require substructure reinforcements.

(2) Abandon the existing Kalamazoo River channel from the Monroe Street Dam to its junction with Battle Creek and enlarge the existing headrace to carry this discharge into Battle Creek. Thence, enlarge Battle Creek to the old confluence and the Kalamazoo River from there to below the Waterworks Bridge. Real estate, bridge, and other costs for this plan of improvement are more than for the first plan noted above, even though the downtown area benefits by the elimination of the old channel. In view of the cost no further consideration has been given to this plan.

(3) Abandon the Kalamazoo River channel from below Fountain Street Bridge to its confluence with Battle Creek diverting this flow in a new channel to be constructed northwesterly from Fountain Street along Liberty Street across Washington Avenue thence north to the Kalamazoo River in the vicinity of Cass Street. Place an intercepting storm sewer in and fill in the abandoned channel to develop a valuable piece of downtown real estate. During floods the flow will be directed down this cutoff practically eliminating flow to Battle Creek through the headrace. This will reduce the required flood capacity of Battle Creek below its junction with the headrace.

Enlarge Battle Creek from Union Street to its confluence with the Kalamazoo River cutoff, removing building constrictions as required.

Enlarge and straighten the Kalamazoo River channel downstream from the mouth of the cutoff to below the Waterworks Bridge to provide adequate downstream capacity for the floodwaters. This latter plan of improvement has been determined to

be the most feasible from an economic and engineering standpoint, and provides the best plan for future expansion and metropolitan development.

(*d*) *Evacuation.*—Because of the extensive development of these metropolitan flooded areas the elimination of the flood problem by complete evacuation is neither desirable nor justified.

FLOOD CONTROL PLANS

52. The three alternate plans of improvement for channel enlargement as noted in paragraph 51 (*c*) above were analyzed in detail. Because of the many complications and high costs involved in the plans for enlarging the existing Kalamazoo River channel between the Monroe Street Dam and its junction with Battle Creek, and for abandoning that portion of the river and diverting this flow down an enlarged headrace to Battle Creek, thence down an enlarged Battle Creek to the Kalamazoo River, these plans were eliminated in favor of the third plan of improvement which was found to be the most practical within the limits of economic justification. This plan involves Battle Creek and Kalamazoo River channel enlargements and Kalamazoo River diversion to bypass the existing Kalamazoo River channel between the Fountain Street Bridge and its junction with Battle Creek. It would provide protection to the area against floods up to a maximum of about 8,000 cubic feet per second on the Kalamazoo River above its junction with Battle Creek, 5,000 cubic per second on Battle Creek above its junction with the Kalamazoo River headrace, thence 6,000 cubic feet per second downstream to the cutoff including 1,000 cubic feet per second diverted from the Kalamazoo River via the headrace, and a combined flow of 11,000 cubic feet per second downstream from the confluence. The design discharge downstream from the confluence of the two tributaries is less than the combination of the design discharges of each tributary because of the probability of rainfall distribution over the basins and the timing of the runoff peaks. These design channels will protect the area against floods about 50 percent in excess of the maximum flood volumes that have been recorded to date. At the stage resulting from the design floods the channel would have a design freeboard of about 2 feet. The principal features of this plan of improvement are as follows:

(*a*) The existing Kalamazoo River channel would be widened, deepened, straightened, diverted, or abandoned from below the Monroe Street Dam in the city of Battle Creek to about 1 mile downstream from the Waterworks Bridge, a total distance of about 6 miles approximately as follows:

(1) Provide a channel with 80-foot bottom width, 1 on 2 side slopes paved with 18 inches of dumped riprap, 11-foot design depth, and 4.7-foot-per-mile gradient from the existing channel immediately below the Monroe Street Dam to approximately 200 feet upstream from the Foundation Street Bridge, a distance of about 700 feet. The existing channel and banks in this reach are adequate to provide for enlargement without any appreciable changes in the adjacent land.

(2) Abandon the existing Kalamazoo River channel from below the Fountain Street Bridge to its junction with Battle Creek, a distance of about 3,600 feet.

(3) Provide a new cutoff channel paved with reinforced concrete 8 inches thick, with 17-foot bottom width, 1 on 2 side slopes, 11-foot design depth, and 12.4-foot-per-mile gradient from the Fountain Street Bridge northwesterly across Capital Avenue along Liberty Street to Washington Avenue; thence northerly across Hamblin Avenue to the Kalamazoo River about 700 feet downstream from the Washington Avenue Bridge, a total distance of about 3,400 feet. Real estate developments and new bridge requirements in this reach make it more economical to use a narrow channel lined with concrete to reduce bank scour from higher velocities than to provide a wider all earth or riprapped channel. For a distance of approximately 200 feet above the Fountain Street Bridge this channel will be flared as a transition from the wider section upstream. Another transition section, including a stilling basin will be constructed downstream between Hamblin Avenue and the Battle Creek confluence.

(4) Provide a channel with 150-foot bottom width, 1 on 2 side slopes paved with 18 inches of dumped riprap, 11-foot design depth, and 4-foot-per-mile gradient from the confluence of the existing Kalamazoo River and the cutoff downstream to Angell Street Bridge, a distance of about 3,000 feet. Real estate development and existing bridge conditions in this reach make it more economical to use riprap on steeper side slopes to reduce bank scour from higher velocities than to provide a wider all-earth channel.

(5) Provide an unpaved earth channel with 220-foot bottom width, 11-foot design depth, 1 on 4 side slopes, and 1.6-foot-per-mile gradient extending from Angell Street Bridge downstream to the Stringham Road Bridge, a distance of about 12,300 feet.

(6) Provide an unpaved earth channel with 220-foot bottom width, design depth gradually reducing from 11 feet at the upper end to about 9 feet at the downstream end, 1 on 4 side slopes, 0.8-foot-per-mile bottom gradient and 1.6-foot-per-mile water surface gradient extending from the Stringham Road Bridge to about 9,500 feet downstream from the Waterworks Bridge, a total distance of about 19,000 feet.

(*b*) The existing Battle Creek channel would be widened, deepened, and straightened from above the Union Street Bridge downstream through the city of Battle Creek to its confluence with the new cutoff channel approximately 700 feet downstream from the Washington Avenue Bridge, a total distance of about 1.6 miles, approximately as follows:

(1) Provide an unlined earth channel with 70-foot bottom width, 1 on 4 side slopes, 11-foot design depth, and 2.2-foot-per-mile gradient from the existing Battle Creek channel about 500 feet upstream from the Union Street Bridge downstream to about 200 feet upstream from the New York Central Railroad bridge, a total distance of about 3,500 feet. About 500 linear feet of the upper end of this channel is to have the bottom sloped upward and be widened to meet the full existing channel.

(2) Provide a channel with 54-foot bottom width, 1 on 2 side slopes paved with 18 inches of dumped riprap, 11-foot design depth, and 4.7-foot-per-mile gradient from about 200 feet above the New York Central Railroad bridge to the confluence of the

headrace and Battle Creek located between the Monroe Street and Capital Avenue Bridges, a total distance of about 1,200 feet. Real estate values and existing bridge and building conditions in this reach make it more economical to use riprap and steeper side slopes in this section to reduce bank scour from higher velocities than to provide a wider all-earth channel. The upper end of this reach will be tapered to meet the adjacent unpaved channel dimensions with a minimum loss of head.

(3) Provide a channel with 69-foot bottom width, 1 on 2 side slopes paved with 18 inches of dumped riprap, 11-foot design depth, 4.5-foot-per-mile gradient from the junction of the headrace and Battle Creek downstream to the McCamly Street Bridge, a total distance of about 900 feet. Real estate values and existing bridge and building conditions in this reach make it more economical to use riprap and steeper side slopes in this section to reduce bank scour from higher velocities than to provide a wider all-earth channel.

(4) Provide a channel with bottom width varying from 69 feet at the upstream end to 95 feet at the downstream end, design depth gradually reducing from 11 feet at the upper end to 9 feet at the downstream end, 1 on 2 side slopes paved with 18 inches of dumped riprap, 4.5-foot-per-mile water-surface gradient and flat bottom extending from the McCamly Street Bridge downstream to the New York Central Railroad bridge, a total distance of about 2,000 feet. Real estate values and existing bridge and building conditions in this reach make it more economical to use riprap and steeper side slopes in this section to reduce bank scour from higher velocities than to provide a wider all earth channel. The bottom of this channel is retained at a level gradient so as to remain on top of a major portion of existing ledge rock in the area, and also to widen the channel so as to take advantage of the existing wider channel downstream from the confluence of Battle Creek and existing Kalamazoo River channel.

(5) Provide a channel with 95-foot bottom width, 1 on 2 side slopes paved with 18 inches of dumped riprap, 9-foot design depth, and 5.3-foot-per-mile gradient from New York Central Railroad bridge downstream to the mouth of the new cutoff about 700 feet downstream from the Washington Avenue Bridge, a total distance of about 1,100 feet.

These channel enlargements and alterations, involving approximately 1,585,000 cubic yards of materials other than ledge rock and 53,200 cubic yards of ledge rock are based on the following design criteria:

Manning roughness coefficient:

Earth and riprapped channel=0.03
Concrete lined channel=0.016

Maximum velocities the various channel sections are to be subjected to—

Earth channel=4.0 feet per second
Riprapped channel=6.0 feet per second
Concrete lined channel=16.0 feet per second
Through riprapped bridge=6.6 feet per second
Through concrete paved bridge=8.0 feet per second

The depth, width, and gradient of the channels are designed to require the least changes in existing bridge foundations and alterations or removal of existing buildings adjacent to the channel, and also to place the bottom elevation above the existing ledge rock in the area so far as is possible. The ledge rock to be excavated in the area is a weathered soft sandstone.

(*c*) Construct a concrete submerged weir in the Battle Creek channel immediately upstream from its confluence with the new Kalamazoo River cutoff to provide a 3-foot bottom and 1-foot design water surface drop in the design channel, thus eliminating the removal of a large quantity of ledge rock upstream from this point.

(*d*) Construct 5 new highway and 4 new railroad bridges over the Kalamazoo River channel, including some highway relocations. Because of the proximity of these roads and railroads to the metropolitan area and the heavy load they carry, it is not feasible to abandon any of these crossings.

(*e*) Reinforce pier and abutment foundations on 3 highway and 1 railroad bridge along the enlarged Kalamazoo River and Battle Creek channels.

(*f*) Riprap the channel at critical points and around bridge piers and abutments to reduce scour.

(*g*) Remove 30 commercial and industrial buildings from the existing Battle Creek channel and 48 industrial, commercial, and residential buildings from the new Kalamazoo River cutoff and enlarged channels to provide adequate right-of-way for construction and maintenance of the project.

(*h*) Clear right-of-way and disposal areas of trees and brush.

(*i*) Seed side slopes, except where protected by riprap, and right-of-way along the entire enlarged channel.

(*j*) Construct low earth levees along both banks of the new cutoff channel between Capital Avenue and Washington Avenue to provide the necessary channel depth and prevent overflow of the surrounding areas.

(*k*) Construct an earth levee approximately 2,500 feet long along the south side of the Battle Creek channel upstream from Union Street to protect the adjacent residential and commercial areas from minor overflow.

(*l*) Provide new storm sewer outfalls into improved channels.

(*m*) Lower 4 inverted siphon sanitary sewers, construct 6 new inverted siphons in existing sanitary sewers, and relocate 1 sanitary sewer force main.

(*n*) Provide intercepting storm and sanitary sewers in the existing and proposed to be abandoned Kalamazoo River channel between the Fountain Street Bridge and its junction with Battle Creek.

(*o*) Make necessary alterations to gas and water mains and electric powerlines, necessitated by the improved channels.

(*p*) Make necessary alterations to the industrial water intake for the Michigan Carton Co. located about 500 feet upstream from the Angell Street Bridge on the Kalamazoo River so as to permit continued use of river water at the lowered low water stage in the design channel.

(*q*) Relocate the existing 36-inch water intake along the south side of the enlarged Battle Creek channel between the headrace and the Consumers Power Co.'s Elm Street plant.

(*r*) Procure all necessary lands and buildings to provide adequate right-of-way for channel enlargement, straightening, and relocation and remove all buildings located thereon, including those over or obstructing the existing channel to be improved.

These channel improvements would have no appreciable effect on the water stages downstream from the project. The peaks of major floods would reach the downstream areas a little earlier than under existing conditions but there are no major tributaries downstream the runoff from which might combine with the earlier peaks to produce a higher flood stage due to the changed runoff timing. The flood peak immediately downstream from the project might be slightly higher than under existing conditions because of the elimination of storage in flooded areas; however, a major portion of this overflow storage will be compensated for by the enlarged channel, and any slight increase in the downstream peak during major floods will be reduced by the overflow storage in the unimproved existing channel between the end of the project and the B. E. Morrow Pond above Comstock, and also by the regulation of that pond.

MULTIPLE PURPOSE FEATURES

53. These improvements for flood control will not be a benefit or detriment to navigation, irrigation, waterpower, or other water resources developments in the area or downstream. The headrace between the Kalamazoo River Lower Mill Pond and Battle Creek will be retained to serve its present purpose of limited hydroelectric power production and cooling water supply for steam-electric plant.

GROUND WATER

54. Ground water in the vicinity of Battle Creek is used extensively for industry, municipal water supply, and air-conditioning systems. The area is underlaid with a rather uniform sandstone deposit about 150 feet in thickness. Most wells in the area have been drilled to near the bottom of this strata producing high and steady water yield. At present it is generally conceded that the ground-water supply is ample for all present and anticipated future demands. The proposed Kalamazoo River cutoff will be of benefit to the area through drainage of the low Liberty Street area to the south. The city had contemplated expending about $20,000 to drain this area; however, this would probably not be necessary if the cutoff were constructed. The proposed plan involves channel excavation that will lower the stage of low-water flow by as much as 6 feet in portions of the stream course. It will also expose the sandstone bedrock in some reaches where it is now thinly covered by alluvium and necessitate the removal of some bedrock. Under these conditions, the rate of ground-water discharge into the stream channel will be somewhat increased. An evaluation of the effects on the local ground-water supply has been prepared by the United States Geological Survey and is included in this report in appendix E. While this evaluation must at this time be general rather than specific, the condition has been presented to and found acceptable by the local interests.

RECREATIONAL DEVELOPMENT

55. There is no Federal recreational development connected with this project. The city of Battle Creek will probably extend its park system to include most of the right-of-way and other scattered areas along the river channels.

ESTIMATES OF FIRST COST

56. *First cost of project.*—The estimates of first costs of the Federal and non-Federal improvements, including engineering, overhead, and contingencies as outlined above and shown on the map accompanying this report are summarized in table 14 with additional details given in appendix C.[1]

TABLE 14.—*Estimated first costs—Proposed flood protection in vicinity of Battle Creek*

Item and description	Quantity	Unit	Unit cost	Total cost
A. FEDERAL FIRST COST				
1. Excavation and disposal of earth from Battle Creek and Kalamazoo River channels (including overhaul).	1,585,000	Cubic yard	$0.60	$951,000
2. Excavation and disposal of ledge rock from Battle Creek and Kalamazoo River channels.	53,200	do	5.25—	279,000
3. Placing dumped riprap on channel banks and at bridge piers and abutments.	37,400	do	7.60+	285,000
4. Reinforced concrete paving, 8 inches thick, along Kalamazoo River cutoff (including tile drainage and 12-inch subgrade).	29,800	Square yards	16.30+	486,000
5. Constructing submerged weir at mouth of Battle Creek.	----------	Lump sum	----------	27,000
6. Constructing 4 new railroad bridges and 1 highway bridge.[1]	5	Each	Varies	784,000
7. Reinforcing substructure on highway and railroad bridges.	4	do	Varies	277,000
8. Removing buildings from existing channels and new Kalamazoo River cutoff.	78	do	Varies	92,000
9. Clearing right-of-way and disposal areas of trees and brush.	500	Acre	130.00	65,000
10. Seeding side slopes and right-of-way along Battle Creek and Kalamazoo River channels.	100	do	200.00	20,000
11. Constructing earth levees along Battle Creek and Kalamazoo River cutoff.	----------	Lump sum	----------	30,000
Subtotal				3,296,000
B. NONFEDERAL FIRST COST				
12. Constructing new highway bridges	4	Each	Varies	497,000
13. Adapting storm sewer outfalls to Battle Creek and Kalamazoo River channels.	----------	Lump sum	----------	20,000
14. Lowering existing sanitary sewer siphon crossings and constructing new siphon crossings.	----------	do	----------	225,000
15. Constructing intercepting storm sewer in old Kalamazoo River channel.	----------	do	----------	79,000
16. Constructing intercepting sanitary sewer in old Kalamazoo River channel.	----------	do	----------	52,000
17. Relocating gas and water mains along new Kalamazoo River channel.	----------	do	----------	9,000
18. Altering electric powerline crossings over Battle Creek and Kalamazoo River channels.	----------	do	----------	6,000
19. Altering existing water intake structures in Battle Creek and Kalamazoo River channels.	2	Each	Varies	55,000
20. Rerouting Liberty St. crossing of new Kalamazoo River channel.	400	Linear foot	$65.00	26,000
21. Lands including buildings to be furnished for right-of-way (including legal and engineering costs).	195	Acre	Varies	1,260,000
22. Easements for disposal areas (including legal and engineering costs).	420	do	Varies	38,000
Subtotal				2,267,000
Total project cost				5,563,000

[1] Replacement of existing federally owned and maintained 1-way access road bridge, lying entirely within the Fort Custer Military Reservation, which connects the station waterworks on the right bank of the river with Fort Custer proper on the left bank.

[1] Not printed.

ESTIMATES OF ANNUAL CHARGES

57. The estimated annual charges for the project based on the first costs as allocated in paragraph 56 are as follows:

(*a*) Federal annual charges:	
Investment:	
1. Total Federal first cost	$3, 296, 000
2. Interest during construction at 3 percent (estimated construction period 2 years)	98, 880
3. Total Federal investment	3, 394, 880
Annual carrying charges:	
1. Interest at 3 percent	101, 850
2. Amortization at 0.887 percent (based on 50-year life of project)	30, 110
3. Maintenance and operation to be by local interests, no Federal cost	0
4. Total Federal annual carrying charge	131, 960
(*b*) Non-Federal annual charges:	
Investment:	
1. Total non-Federal first cost	2, 267, 000
2. Interest during construction at 3½ percent (estimated construction period 2 years)	79, 350
3. Gross non-Federal investment	2, 346, 350
4. Less accrued amortization charges on structures that will be replaced by new improvements	0
5. Total non-Federal investments	2, 346, 350
Annual carrying charges:	
1. Interest at 3½ percent	82, 120
2. Amortization at 0.763 percent (based on 50-year life of project)	17, 900
3. Maintenance and operation of project	15, 000
4. Loss of taxes on land acquired for right-of-way $507,500 x $29 per $1,000 (average tax rate)	14, 720
5. Total non-Federal annual carrying charge	129, 740
(*c*) Total Federal and non-Federal annual carrying charges	261, 700

ESTIMATES OF BENEFITS

58. The estimated average annual benefits that will be realized in the vicinity of Battle Creek as a result of this flood-control plan will include the elimination of a major portion of direct and indirect flood damages, the enhancement of property values, plus many intangible benefits for which a monetary value cannot be determined.

59. *Direct benefits.*—A major benefit to be derived is the prevention of a large portion of the direct flood damages in the area. These average annual direct damages have been estimated at $192,800 (see par. 37) based on past frequency and damage records expanded to include probable damages from floods greater than those of record. The proposed plan of improvement would provide complete flood protection for all floods up to the 11,000-cubic-feet-per-second design flood for the combined Battle Creek-Kalamazoo River channel. It is quite possible that a flood in excess of the channel capacity, such as a standard project flood—38,000 cubic feet per second, or larger—might occur, in which case these channel improvements will reduce, but not entirely eliminate, the resultant flood damages. Average annual direct damages from floods greater than the design flood not prevented by the proposed plan of improvement are estimated at $30,600. The average annual direct benefits to be derived by this plan are the direct damages reduced by this amount or $162,200.

60. *Indirect benefits.*—The indirect benefits to be realized through the proposed plan of improvement are equal to the total average annual indirect damages of $128,100 (see par. 37) less $21,000 of damages from floods in excess of the design flood that will not be eliminated or a total of $107,100.

61. *Increased utilization of property.*—Appreciable benefits will be realized in this area through the increased utilization of property. These benefits, representing the increased value of the land only if the flood hazard is removed by filling the lowlands and by confining the floodwaters to the design channel, are not a duplication of the benefits discussed above resulting from the elimination of direct and indirect damages which in most cases are damages to buildings and other improvements on the land. Due to the nature of the flooded areas, there were practically no direct or indirect damages chargeable directly to the land. Approximately 215 acres of swamp, vacant, and partially developed lowlands along the stream channels, that are inundated during flood stages, will be used for disposal of excavated materials and be filled to a grade of about 2 feet above the design floodwater surface in the proposed channels. About 60 acres are in industrial zones within the Battle Creek city limits, are accessible by highway and railroad, and are desirable for industrial expansion. The remaining acreage is along the river downstream from the city limits but has highway and railroad connections and is a logical area for industrial and residential expansion of the city. Partially filled-in vacant lands farther downstream from the above-noted sections are less valuable and having a lesser degree of flood protection will be developed for agricultural and possibly park purposes. The present value of these disposal areas is about $95,000 for land only and it is estimated that its enhanced value when filled in will be about $633,000. These increased values cannot be realized until the land is sold or put to a more profitable use. It is estimated that the most desirable areas will be developed over a period of about 10 years with other areas farther from the metropolitan area and of a less desirable nature requiring 25 and 50 years for complete improvement. The average annual benefit from these increased land values, based on a 50-year assumed economic life of the project, would be $14,500 to the landowners. This estimated enhancement of land values is due entirely to the filling of the lowlands and does not include additional streets, utilities, and other public services. It is considered that when these latter facilities are added there will be a sufficient additional increase in property values to provide for the annual cost of such improvements. No credit has been taken for enhancement of lands only partially filled and not receiving full design flood protection.

62. Real estate that is now periodically flooded, outside of the spoil-disposal areas which are to be filled to above design flood stage, involving about 730 residential lots and 600 residences and about 95 commercial and industrial establishments, especially in the Liberty Street and Hamblin Avenue areas, will increase in value because of

this flood-protection plan. In addition, about 410 residential lots and 385 residences and about 280 industrial and commercial establishments adjacent to this flooded area, the majority experiencing basement flooding, will also realize a land enhancement from the project. This increase is contingent upon sale or more profitable use of the property and will apply generally to the land only. The existing buildings will not increase appreciably in value until an expenditure is made to improve them which will offset the building value enhancement. The present estimated value of these flooded and adjacent areas is about $11 million for land only and it is estimated that the enhancement in value of these lands by eliminating the flood threat would be about $1,700,000. Assuming that this enhancement will be realized as a uniform increase over a period of about 50 years, the estimated average annual benefit over a 50-year period, the assumed economic life of the flood-control project, would be about $36,500 to the landowners. By filling in the old Kalamazoo River Channel between Fountain Street Bridge and its junction with Battle Creek, about 3.6 acres of open channel will be reclaimed at an estimated annual benefit of $4,100 to the community. In addition, slight building value enhancement estimated at about $5,000 annually will be realized immediately through the ability of many residents to again use the basements of their homes with safety.

63. *Intangible benefits.*—These benefits to be derived from the flood-control project include elimination of adverse health conditions arising from living in damp quarters and the possible spreading of disease by the general spreading of filth, the possible loss of life from floods of the design flood or greater magnitude, and enhancement of the general welfare and security of the people. Elimination of the flood problem in the Liberty Street and lower Hamblin Avenue areas, which are located only a few blocks from downtown Battle Creek and from the upper Hamblin Avenue area which is in the center of the city, will be a major asset to the city. Rerouting of the Kalamazoo River out of the downtown area will be of major importance in the future expansion and development of the municipality. Along with this, hundreds of families adjacent to these flood areas will feel a definite sense of security against floods which should result in further development and betterment of the entire area. By removing the buildings from over the river channels and adequate zoning to prevent future encroachments the ever present threat of greater flood disasters from building failure and resultant river damming will be eliminated.

64. *Other benefits.*—The proposed flood-control plan will have no effect on fish and wildlife, or navigation. The proposed cutoff channel will act as a natural drain to the low Liberty Street area eliminating the current need for drainage in the area. It is possible that excavation of ledge rock sandstone from the river channel will increase the base flow of the river. This would be a decided benefit to the downstream area during low-flow summer months by making more water available to industry. Cleaning out the channels and creating a more constant flow gradient will eliminate stagnant pools during the low-flow periods to the benefit of the general health of the area.

65. *Average annual benefits.*—The average annual benefits which may be credited to the plan of improvement for flood control as considered herein are summarized in table 15.

TABLE 15.—*Average annual benefits*

Benefit:	Average annual amount
Prevention of direct flood losses	$162, 200
Prevention of indirect flood losses	107, 100
Enhancement of property values:	
1. In disposal areas	18, 600
2. In flooded nondisposal areas	41, 500
Total average annual benefits	329, 400

COMPARISON OF BENEFITS AND COSTS

66. The ratio of costs to benefits for the recommended plan of flood-control improvement in the vicinity of Kalamazoo is as follows:

Estimated average annual cost	$261, 700
Estimated average annual benefit	$329, 400
Ratio: Costs to benefits	1. 00 to 1. 26

PROPOSED LOCAL COOPERATION

67. In compliance with the general policy on flood control as expressed by Congress in section 1 of the Flood Control Act of 1936 and section 3 of the Flood Control Act of 1944, and since the benefits to be derived from the project will be predominately benefits to local interests, the following items of local cooperation are considered justified and reasonable.

(*a*) Furnish without cost to the United States all necessary lands, easements, and right-of-way.

(*b*) Hold and save the United States free from all claims for damages incident to the construction and operation of the project.

(*c*) Maintain and operate the project after completion, including supervision of maintenance and operation of the existing Monroe Street Dam and headrace on the Kalamazoo River, under an agreement with its owners, in accordance with regulations prescribed by the Secretary of the Army.

(*d*) Prescribe and enforce regulations satisfactory to the Secretary of the Army designed to prevent encroachments on the proposed right-of-way and improved channels.

(*e*) Construct new highway bridges across the new Kalamazoo River cutoff.

(*f*) Make all changes and additions to streets, water mains, electric powerlines, sewers, and other miscellaneous utilities necessitated by the channel improvements.

68. The estimated total non-Federal first cost of the above items of local cooperation is $2,267,000 as indicated in paragraph 56. The additional estimated present value of cost to local interests for annual maintenance is $352,000. These costs to local interests are about 44 percent of the total cost of the proposed project. The estimated annual benefits which are anticipated to result from the proposed improvements include about $60,000 due to enhancement of land values. These benefits are of a local nature and comprise about 18 percent of the total annual benefits to be realized from the project. As the extent of local cooperation stated above is substantially in excess of the amount indicated by the extent of land-enhancement benefits, it is not considered necessary that local interests make an additional cash contribution toward the cost of the project.

ALLOCATION OF COSTS

69. The allocation of first costs of the proposed project is subdivided between Federal and non-Federal interests as follows:

1. Total Federal first cost:	
(a) Corps of Engineers	$3, 296, 000
(b) Other Federal agencies	0
Total	3, 296, 000
2. Total non-Federal first cost: (see par. 67 "Proposed local cooperation")	2, 267, 000
3. Total project first cost	5, 563, 000

4. All costs of operation and maintenance of the project, estimated to be $15,000 annually, are to be at local expense.

COORDINATION WITH OTHER AGENCIES

70. The proposed plan of improvement has been reviewed by representatives of interested Federal and State of Michigan agencies. A summary of the comments of these agencies follows:

(a) *United States Fish and Wildlife Service.*—Only minor harmful effects on fish and wildlife are foreseen within the limits of the project. Suggest elimination of stream pollution as part of the project.

(b) *United States Federal Power Commission.*—No specific interest in the project as it will not affect hydroelectric power.

(c) *United States Forest Service.*—No immediate interest in the project as it is for local flood protection only.

(d) *United States Soil Conservation Service.*—Of no particular interest as it will have no significant effect on the drainage of the watershed.

(e) *United States Weather Bureau.*—Plans continuation of present cooperation with and possible improvement of the flood forecasting service on the Kalamazoo River.

(f) *United States Public Health Service.*—Expresses approval of the project, subject to the following conditions:

"1. That any bends or reaches of the abandoned stream bed along the course of the improvement be drained or filled so as to prevent the accumulations of stagnant water that would otherwise create a nuisance.

"2. That present industrial and municipal sewer outlets or connections be extended to or joined with the changed course of the stream as finally improved."

(g) *Michigan State Water Resources Commission.*—This State commission acting for all State agencies approves the Battle Creek project, subject to the following conditions:

"1. That the city of Battle Creek or the local sponsor of the flood-control project can satisfy the Board of Engineers (or your office) of its willingness and ability to meet the financial and/or other obligations which will devolve upon the local sponsor of this project.

"2. That changes in existing bridges or their supports under the jurisdiction of the State highway department shall be made with the knowledge of and under the supervision of that department, from plans prepared by that department, the expense of such changes to be included in the financing for the flood-control project.

"3. That bends or reaches of the abandoned stream bed along the course of the improvement shall be drained or filled so as to prevent the accumulations of stagnant water that would otherwise create a nuisance; that present industrial or municipal outlets or connections shall be extended to or joined with the changed course of the stream as finally improved."

71. The proposed plan of improvement has been discussed with and generally concurred in by the affected railroads operating in the area. Battle Creek city officials have endorsed the plan in its entirety. It is believed that although the cost of local cooperation is relatively high, the city is willing and probably able to comply with all conditions. At the present time the mayor of Battle Creek is analyzing the costs of local cooperation to ascertain a proper means for their allocation within the city's financial structure. Letters from interested agencies relative to this plan are included in appendix E.[1]

DISCUSSION

72. The city of Battle Creek suffers periodic flooding of areas along the Kalamazoo River and its tributary, Battle Creek, causing estimated average annual direct and indirect damages of about $320,900. Lesser floods inundate several hundred acres of scattered low vacant lands along the stream channels and many low to medium value residences south of the main river along Battle Creek. As the magnitude of the floods increase more residential areas are flooded along with extensive industrial and commercial zones adjacent to the heart of the city. Approximately 90 percent of the total direct and indirect damages in the vicinity of Battle Creek are in the Hamblin Avenue-Liberty Street areas which are inundated both by the high downstream stage of the Kalmazoo River during floods and the overtopping of the river banks below the Monroe Street Dam caused by the seriously constricted channel from there to the confluence of the Kalamazoo River and Battle Creek. Flood discharges from Battle Creek in passing through the obstructed city portion of its channel are forced to back up, flooding considerable adjacent commercial, industrial, and residential property. The disastrous flood of April 1947 (peak stage about 0.75 feet below the March 1904 maximum flood of record) caused an estimated total direct and indirect damage of about $785,400, at 1949 price levels, according to a flood-damage survey made by the Corps of Engineers. In addition, the areas experienced many intangible damages, including inconvenience and suffering, estimated to about equal the direct and indirect damages in amount. No loss of life due directly to the floods has been reported. Records for approximately 100 years indicate that floods of approximately this magnitude or greater have about an 8 percent chance of occurence in any 1 year. Although the majority of the floods of record occurred during spring runoff periods, practically eliminating agricultural losses, the maximum anticipated floods more probably will be caused by high intensity summer storms with resultant home garden and other agricultural loss.

73. There are no sites available above Kalamazoo at which reservoirs with sufficient capacity to materially reduce the flood-peak stages at Battle Creek could be constructed at economically justified costs. As any reservoirs that might be developed necessarily would be emptied as soon as possible after a flood to retain their storage capacity to reduce subsequent floods, there could be no material benefits to wildlife preservation, navigation, water power, recreational improvement, sanitation, soil preservation, or other multiple-purpose uses which would economically justify the construction of reservoirs. Protection of the flooded areas entirely by levees or dikes is not desirable and cannot be economically justified.

74. Local flood protection in the vicinity of Battle Creek by enlarging the stream channels to provide for a more uniform and lower

[1] Not printed.

streamflow gradient during floods and including diversion of the Kalamazoo River to bypass the existing constricted channel through the center of the city is desirable. The plan of improvement found most practical involves clearing and enlargement of the Battle Creek channel to such an extent that it will safely pass a flood of about 6,000 cubic feet per second including 1,000 cubic feet per second bypassed from the Kalamazoo River via the headrace, rerouting the downtown portion of the Kalamazoo River channel to safely pass a flood of about 7,000 cubic feet per second, and enlarging and straightening the Kalamazoo River channel downstream from the confluence of the cutoff and Battle Creek to safely pass a flood of about 11,000 cubic feet per second. This improvement would eliminate approximately 84 percent of all direct and indirect damages in the area that are directly attributable to the Kalamazoo River and Battle Creek flooding. Protection against this design flood represents only about a 30 percent degree of protection against the standard project flood which is the peak flood discharge considered probable under weather and ground conditions most conducive to maximum rate of runoff from the river basin. However, it will protect the area against floods with peaks approximately 50 percent greater than those of record which is considered to be reasonable protection, considering the local flood history, the characteristics of the flooded areas, and the nature of the channel improvements. The proposed plan of improvement designed to safely pass a flood of 5,000 cubic feet per second in Battle Creek, 8,000 cubic feet per second in the Kalamazoo River above its junction with Battle Creek and 11,000 cubic feet per second below this junction will provide a wider, deeper, and more uniformly graded channel for Battle Creek extending from above Union Street Bridge to its junction with the new Kalamazoo River cutoff; a relocated concrete-lined Kalamazoo River channel from below the Monroe Street Dam to bypass the existing restricted channel through the heart of the city and returning to the existing channel and Battle Creek downstream from the Washington Avenue Bridge; and a wider, deeper, and more uniformly graded channel for the Kalamazoo River from the above confluence downstream to below the Fort Custer Waterworks Bridge. The plan also provides for riprapping of the Kalamazoo River and Battle Creek channels where necessary to prevent erosion at critical locations; construction of new and reinforcement of existing railroad and highway bridges as required; removal of existing buildings obstructing the channels, construction of a submerged weir, and alterations to existing utilities and structures as necessitated by the improved channels.

75. This plan of improvement will have no noticeable effect on the flood stages downstream. Materials excavated from the proposed channel would be disposed over the low submarginal areas along the stream banks, raising these lands to about 2 feet above the design flood stage in the proposed channel. A major portion of these disposal areas have good railroad and highway connections making them desirable for industrial development. Other sections located further from the metropolitan area will become better adapted for parks, residential and agricultural purposes. The enhancement of land values in these disposal areas is estimated to be equivalent to an average annual benefit of $18,600 to the local people. In addition the elimination of floods in the developed flooded areas will enhance

those property values an amount equivalent to an estimated average annual benefit of $41,500. The completion of the proposed plan of improvement would result in an average annual benefit of $329,400 to the community through the elimination of direct and indirect flood damages and enhancement of property values.

76. The total estimated first cost of this plan of improvement is $5,563,000 and the estimated costs-benefits ratio for the plan is 1 to 1.26. In view of the large benefits that will accrue to the community as a result of the proposed improvements it is considered proper that local interests furnish all easements and rights-of-way, protect the Federal Government against all claims for damages incident to construction and operation of the project, operate and maintain the completed project, construct new highway bridges across the cutoff channel, and make miscellaneous utility and other alterations as required at an estimated total first cost of $2,267,000. Based on these assumptions the allocation of first cost of the project is approximately 59 percent to the Federal Government and 41 percent to local interests.

77. This plan of improvement for flood control is substantially as suggested by local authorities. It is considered that local interests are financially able and willing to meet all conditions of local cooperation. The State of Michigan has recently created a water resources commission to cooperate and negotiate with local and other agencies, including the Federal Government, in the construction of flood-control projects, and this commission has approved the proposed plan of improvement.

78. In view of the interrelations of the improvements to that portion of the Kalamazoo River channel downstream from the city and the proposed new cutoff, it is considered desirable that these two sections be constructed simultaneously at an estimated Federal first cost of $2,607,500 and a non-Federal first cost of $1,235,700, a total of $3,843,200. Construction of this portion of the project would realize approximately 90 percent of the total benefits at approximately 65 percent of the total cost and would return to the community the major portion of land enhancement and general betterment to the industrial, commercial, and residential areas. It is feasible to defer construction of the Battle Creek portion of the project until the phases noted above have been completed. Although the estimate of tangible flood damages prevented are less than the annual charges for the improvement of Battle Creek, the collapse of one of the numerous buildings in poor condition extending over the Battle Creek channel would dam up floodwaters and cause overflowing of the entire downtown area, with consequent nullification of the benefits from construction of the cutoff and downstream improvements. It is not considered desirable to invest Federal funds in a partial protection project that would produce unreliable results. While assurance of compliance with local cooperation should be given for the entire flood-protection plan for the city of Battle Creek, it should be understood that actual compliance with the features of local cooperation may be undertaken for the new cutoff and Kalamazoo River downstream thereof prior to that required for the Battle Creek improvement. The city of Battle Creek has expressed a desire to construct the cutoff as the first phase of the project. Although the construction of the cutoff alone would theoretically return to the city

about 50 percent of the total benefits at only about 40 percent of the total project cost, this plan is not recommended. Full benefit would not be derived from the cutoff, if constructed alone, due to backwater from the downstream channel. Flooding of the areas adjacent to the downstream channel and in the vicinity of the confluence of the cutoff with the existing Kalamazoo River channel would continue causing some damage with probable unfavorable local reaction. Overtopping of the banks of the existing downstream channel occurs at a discharge of about 3,000 cubic feet per second. At a discharge of about 4,500 cubic feet per second, which has about a 20-percent chance of occurrence in any 1 year, resultant damages would approximate $20,000. At a discharge of about 6,400 cubic feet per second, which has about a 10-percent chance of occurrence in any 1 year, damages along the downstream channel and in the vicinity of the downstream end of the cutoff would be about $83,000. For a flood of 7,200 cubic feet per second, comparable to the 1947 flood, resultant damages would be approximately $200,000. In addition, construction of the cutoff alone would probably result in a false sense of security with subsequent building in the only partially protected flood plain which would result in even greater damages than those noted above.

79. Local interests should adopt suitable regulations that will prohibit future encroachment on the proposed right-of-way and the improved channel. Local interests should also consider the possibility of floods greater than the design flood in magnitude in issuing permits for constructing new bridges and buildings or reconstructing existing bridges, buildings, and other improvements along the river.

CONCLUSIONS

80. The plan of improvement for flood control in the vicinity of Battle Creek as summarized in paragraph 74 above would eliminate about 84 percent of the direct and indirect flood damages in the area by providing complete protection against damage from floods 50 percent larger than the largest flood of record. The average annual benefits to be realized from this project are $329,400 including the prevention of direct and indirect damages and the enhancement of property values. The estimated average annual cost of the project is $261,700, including the estimated cost of operation and maintenance. In view of the above tangible benefits to be effected by the proposed plan of improvement even though the degree of protection is relatively small, plus the benefits from the elimination of many intangible flood losses not included in the estimates, and the enhancement of the general health and welfare of this metropolitan area, the proposed plan of improvement is considered justified and adequate. A project to protect the area against a possible greater but very rare flood cannot be economically justified and is not considered necessary at this time. The plan of channel enlargement and improvement proposed will substantially reduce damages in the event of the occurrence of a flood exceeding its designed capacity.

RECOMMENDATIONS

81. It is recommended that a Federal project be authorized for flood protection along the Kalamazoo River at, and in the vicinity of, Battle Creek, Mich., to consist generally of excavation and clearing of the Battle Creek channel to provide for an enlarged channel within the city of Battle Creek extending from above the Union Street Bridge downstream to its junction with the Kalamazoo River; rerouting the Kalamazoo River channel in the vicinity of Liberty Street and Washington Avenue to bypass the constricted existing channel through the heart of the city; excavation and straightening the Kalamazoo River channel downstream from the confluence of Battle Creek and the new rerouted Kalamazoo River channel to below the Fort Custer Waterworks Bridge; riprapped or paved channels at critical locations in the new and enlarged channels where the velocity of flood flow might be high enough to cause damage; constructing new and reinforcing existing highway and railroad bridges as required and constructing a submerged weir and levees; all with a view to safely passing such peak flood discharges in the channels as would cause, when combined, a discharge of approximately 11,000 cubic feet per second below the confluence of Battle Creek and the Kalamazoo River; at a total estimated Federal first cost of $3,296,000, provided that no funds shall be expended by the United States until local interests have given assurances satisfactory to the Secretary of the Army that they will—

(*a*) Furnish without cost to the United States all necessary lands, easements, and right-of-way;

(*b*) Hold and save the United States free from all claims for damages incident to construction and operation of the project;

(*c*) Maintain and operate the project after completion, including supervision of maintenance and operation of the existing Monroe Street Dam and headrace on the Kalamazoo River, under an agreement with its owners, in accordance with regulations prescribed by the Secretary of the Army;

(*d*) Prescribe and enforce regulations satisfactory to the Secretary of the Army designed to prevent encroachments on the proposed right-of-way and improved channels;

(*e*) Construct new highway bridges across the new Kalamazoo River cutoff;

(*f*) Make all changes and additions to streets, water mains, electric powerlines, sewers, and other miscellaneous utilities necessitated by the channel improvement.

82. It is further recommended that the initial step as defined below of the flood-protection project at and in the vicinity of the city of Battle Creek may be undertaken after the prescribed conditions of local cooperation therefor have been complied with. The initial step of the improvement would comprise the portion of the project consisting of the proposed cutoff and the existing channel downstream therefrom, at an estimated total Federal first cost of $2,607,500.

D. A. MORRIS,
Colonel, Corps of Engineers,
Acting District Engineer.

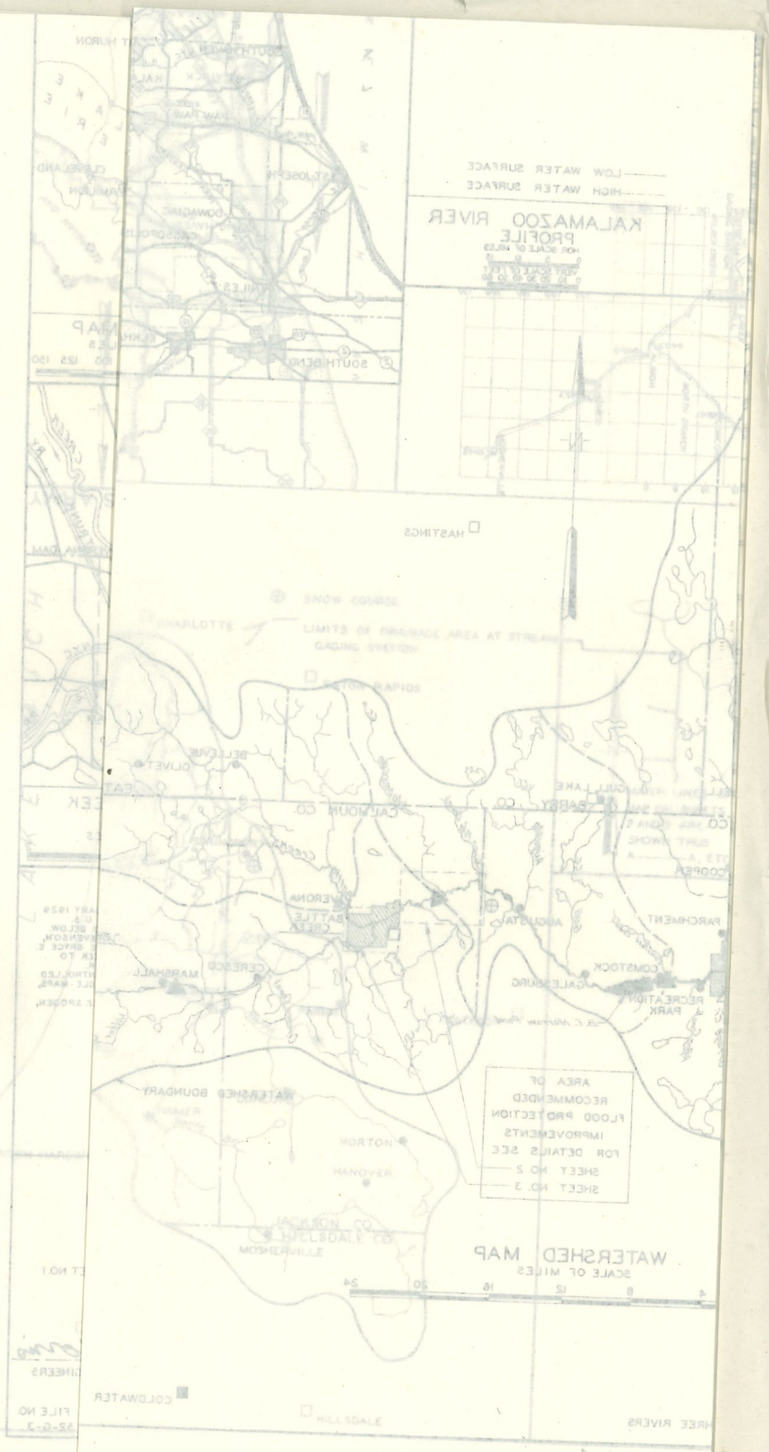
[First endorsement]

OFFICE, DIVISION ENGINEER,
GREAT LAKES DIVISION,
CORPS OF ENGINEERS,
Chicago, Ill., April 14, 1950.

To: Chief of Engineers, Department of the Army, Washington, D. C.
Subject: Review of report on Kalamazoo River, Mich., for flood control with particular reference to Battle Creek and vicinity.

I concur in the conclusions and recommendation of the district engineer.

JOHN R. HARDIN,
Colonel, Corps of Engineers,
Division Engineer.



CORPS OF ENGINEERS

U.S. ARMY

KALAMAZOO RIVER PROFILE

HOR SCALE OF MILES 0 5 10 15

VERT SCALE OF FEET 0 10 20 30 40 50 60

ELEVATION ABOVE SEA LEVEL IN FEET

LAKE MICHIGAN

SAUGATUCK KALAMAZOO LAKE

NEW RICHMOND RABBIT RIVER

EMMY CREEK STREAM GAGING STATION

CALHOUN BRIDGE DAM

ALLEGAN

KALAMAZOO RIVER

OTSEGO

GUN RIVER PLAINWELL

PORTION OF RIVER COVERED BY THIS REPORT

PARCHMENT

COOPER

KALAMAZOO LAKE

STREAM GAGING STATION

ALLEGAN DAM

COMSTOCK

BRYCE E. MORROW DAM

GALESBURG

GULL CREEK

BATTLE CREEK

AUGUSTA

AUGUSTA CREEK

SEVEN MILE CREEK

WILLOW CREEK

MORROW LAKE

VERONA DAM

STREAM GAGING STATION

BATTLE CREEK

MONROE ST. DAM

CERESCO

CROOKED CREEK

STONY RAPIDS

MARSHALL

GAGING STATION

WILDER CREEK

NORTH BRANCH

CONCORD

ALBION

HORTON

HOMER

MOSHERVILLE

MILES ABOVE RIVER MOUTH

——LOW WATER SURFACE

- - - -HIGH WATER SURFACE

LOCALITY MAP

SCALE OF MILES 10 0 10 20 30 40

LAKE MICHIGAN

BAY CITY

SAGINAW

MUSKEGON

GRAND HAVEN

GRAND RAPIDS

ALMA

IONIA

FLINT

DWOSSO

HOLLAND

LANSING

SAUGATUCK

HASTINGS

CHARLOTTE

ALLEGAN

OTSEGO

PLAINWELL

BELLEVUE

SOUTH HAVEN

KALAMAZOO

BATTLE CREEK

MARSHALL

ALBION

JACKSON

ANN ARBOR

PAW PAW

ST. JOSEPH

DOWAGIAC

CASSOPOLIS

THREE RIVERS

COLDWATER

HILLSDALE

ADRIAN

NILES

ELKHART

INDIANA

SOUTH BEND

LEGEND

U.S. HIGHWAY

STATE HIGHWAY

VICINITY MAP

SCALE OF MILES 25 0 25 50 75 100 125 150

LAKE SUPERIOR

MICHIGAN

LAKE HURON

GEORGIAN BAY

WISCONSIN

ALPENA

FRANKFORT

GREEN BAY

MANISTEE

MANITOWOC

LUDINGTON

BAY CITY

SAGINAW

MUSKEGON

GRANDHAVEN

PORT HURON

MILWAUKEE

LANSING

SAUGATUCK

KALAMAZOO RIVER WATERSHED

BATTLE CREEK

DETROIT

KALAMAZOO

ST. JOSEPH

CHICAGO

MICHIGAN CITY

TOLEDO

CLEVELAND

SANDUSKY

VERMILION

LAKE ERIE

OHIO

ILLINOIS

INDIANA

LAKE MICHIGAN

HOLLAND

OTTOWA CO. KENT CO.

SAUGATUCK

KALAMAZOO LAKE

NEW RICHMOND

Rabbit River

WAYLAND

Kalamazoo River

ALLEGAN

Swan Creek

Gun River

OTSEGO

PLAINWELL

VAN BUREN CO.

ALLEGAN CO.

KALAMAZOO CO.

BARRY CO.

GULL LAKE

Augusta Creek

Gull Creek

Willow Creek

CALHOUN CO.

BELLEVUE

OLIVET

EATON CO.

SPRINGPORT

SOUTH HAVEN

BLOOMINGDALE

COOPER

PARCHMENT

Portage Creek

AUGUSTA

Battle Creek

VERONA

BATTLE CREEK

KALAMAZOO

COMSTOCK

GALESBURG

RECREATION PARK

E. C. Morrow Pond

Portage Creek

North Br.

CERESCO

MARSHALL

Rice Creek

Willow Creek

Crooked Creek

ALBION

North Br.

PARMA

JACKSON

COLOMA

PAW PAW

WATERSHED BOUNDARY

CONCORD

HORTON

HOMER

South Br.

HANOVER

JACKSON CO.

HILLSDALE CO.

MOSHERVILLE

BENTON HARBOR

DOWAGIAC

EAU CLAIRE

AREA OF RECOMMENDED FLOOD PROTECTION IMPROVEMENTS FOR DETAILS SEE SHEET NO. 2 SHEET NO. 3

WATERSHED MAP

SCALE OF MILES 0 1 2 3 4 8 12 16 20 24

LANSING

HASTINGS

CHARLOTTE

EATON RAPIDS

LEGEND

- RECORDING STREAM GAGING STATION
- NON-RECORDING STREAM GAGING STATION
- RECORDING PRECIPITATION STATION
- NON-RECORDING PRECIPITATION STATION
- SNOW COURSE
- LIMITS OF DRAINAGE AREA AT STREAM GAGING STATION

MATCH LINES OF MAP ON SHEETS 2 AND 3 ARE SHOWN THUS A——A, ETC.

LIMITS OF AREA ON SHEET NO. 2

LIMITS OF AREA ON SHEET NO. 3

KALAMAZOO CO.

CALHOUN CO.

FORT CUSTER

BATTLE CREEK

CITY LIMITS

VERONA DAM

MONROE STREET DAM

KALAMAZOO

GOGUAC LAKE

N.Y.C. RY.

GRAND TRUNK R.R.

BATTLE CREEK AND VICINITY

SCALE OF MILES 0 1 2

NOTES

SURVEYED AS FOLLOWS:
GENERAL BASIN: CORPS OF ENGINEERS TOPOGRAPHIC SURVEY OF JANUARY 1929 TO DECEMBER 1930 SUPPLEMENTED WITH TOPOGRAPHIC DATA FROM U.S. GEOLOGICAL SURVEY QUADRANGLE MAPS AND FROM SURVEYS NOTED BELOW.
BATTLE CREEK AND VICINITY: RIVER CROSS-SECTION SURVEY BY K.A. STEVENSON, ENGINEER(CIVIL), MAY 1948 TO AUGUST 1948, FROM THE VICINITY OF THE BRYCE E. MORROW POND ABOVE COMSTOCK UPSTREAM THROUGH BATTLE CREEK TO CERESCO ON THE MAIN RIVER AND TO BELLEVUE ON BATTLE CREEK.
THIS SURVEY WAS SUPPLEMENTED BY THE CORPS OF ENGINEER CONTROLLED PHOTO MAPS TAKEN IN 1948, BY U.S. GEOLOGICAL SURVEY QUADRANGLE MAPS, AND CITY OF BATTLE CREEK MAPS.
FIELD SURVEY AND PREPARATION OF MAPS UNDER SUPERVISION OF J.F. SPODEN, ENGINEER(CIVIL).
ALL ELEVATIONS IN FEET ARE REFERRED TO MEAN SEA LEVEL.

FLOOD CONTROL
KALAMAZOO RIVER, MICHIGAN
BATTLE CREEK & VICINITY
GENERAL MAP

IN 4 SHEETS — SHEET NO. 1

SCALES AS NOTED

MILWAUKEE DISTRICT, MILWAUKEE, WISCONSIN

SUBMITTED: A.K. Stevenson
CHIEF, ENGINEERING DIVISION

APPROVED: E.C. Morris
COLONEL, CORPS OF ENGINEERS

CORPS OF ENGINEERS

U. S. ARMY

BUILD NEW BRIDGE

FORT CUSTER WATER WORKS

EXTEND EXISTING EFFLUENT PIPE TO NEW CHANNEL

MUNICIPAL SEWAGE DISPOSAL PLANT

BUILD NEW INVERTED SIPHON FOR 54" INTERCEPTING SEWER AND REMOVE EXISTING SIPHON IF NOT INCORPORATED IN NEW STRUCTURE.

U.S.G.S. STREAM GAGING STATION (RECORDING)

RIPRAP PIERS AND ABUTMENTS AT ALL BRIDGES

WIDEN, DEEPEN AND STRAIGHTEN EARTH CHANNEL

LOWER AND LENGTHEN EXISTING INVERTED SIPHON

SHEATH ABUTMENTS

APPROXIMATE DOWNSTREAM LIMIT OF AREA PROTECTED AGAINST DESIGN FLOOD.

ELECTRIC POWER LINE TO SPAN NEW CHANNEL

BATTLE CREEK CITY LIMITS

ELECTRIC TRANSMISSION LINE

54" INTERCEPTING SEWER

MERGE IMPROVED CHANNEL WITH EXISTING CHANNEL

WELL

TAYLOR AVE.

KELLOGG ST.

SPAULDING AVE.

MICHIGAN AVE.

WILLARD AVE.

W. MICHIGAN AVE.

NEW YORK CENTRAL R.R.

LAFAYETTE ST.

20TH ST.

KALAMAZOO RIVER

WABASCON CREEK

SEVEN MILE CREEK

STRINGHAM ROAD

MASON AVE.

SIEGLE AVE.

BEDFORD ROAD

KALAMAZOO CO.

CALHOUN CO.

CLARK EQUIPMENT CO.

DETROIT-MICHIGAN STOVE CO.

BATTLE CREEK FOOD CO.

EATON MFG. CO.

BORING

806.0	TOPSOIL
804.4	GRAY CLAY
803.2	MUCK
802.5	SAND & SILT
799.8	SAND & FINE GRAVEL
793.0	

NOTE:

DOWNSTREAM FROM DESIGNATED DISPOSAL AREAS EXCAVATED MATERIAL IS TO BE DEPOSITED ALONG THE CHANNEL BANKS, BUT ONLY PARTIAL DESIGN FLOOD PROTECTION WILL BE AVAILABLE TO THESE AREAS.

800.8	TOPSOIL
798.8	COARSE SAND & GRAVEL
778.8	COARSE GRAVEL
758	SOFT SANDSTONE WITH LAYERS OF GRAVEL
	MARSHALL SANDSTONE
721.8	SHALE

LEGEND

EARTH CHANNEL (RECOMMENDED) — SIDESLOPES, BOTTOM

DISPOSAL AREA (RECOMMENDED)

1947 FLOOD LIMIT

STANDARD PROJECT FLOOD LIMIT

MILES ABOVE MOUTH OF RIVER (ALONG ORIGINAL CHANNEL) (103)

RECOMMENDED IMPROVEMENTS

LAND USE

PARK OR MUNICIPAL	P
RESIDENTIAL	R
COMMERCIAL	C
INDUSTRIAL	I
AGRICULTURAL	A
WASTE	W
25% DEVELOPMENT	⌐
50% DEVELOPMENT	└
75% DEVELOPMENT	⊏
100% DEVELOPMENT	□

FLOOD CONTROL
KALAMAZOO RIVER, MICHIGAN
BATTLE CREEK & VICINITY
RECOMMENDED IMPROVEMENTS

IN 4 SHEETS

SCALE OF FEET 500 0 500 1000 1500 2000

SHEET NO. 2

MILWAUKEE DISTRICT, MILWAUKEE, WISCONSIN

SUBMITTED:

APPROVED:

CORPS OF ENGINEERS

U.S. ARMY

BATTLE CREEK

WIDEN, DEEPEN, & STRAIGHTEN EARTH CHANNEL

LOWER ANGELL ST. SIPHON

EXISTING INTERCEPTING SEWER

LOWER WATER INTAKE

LOWER CASS ST. SIPHON

CONSTRUCT NEW KALAMAZOO RIVER CHANNEL WITH CONCRETE LINED BOTTOM & BANKS. CONSTRUCT LOW EARTH LEVEES BETWEEN WASHINGTON AVE. AND CAPITAL AVE.

CONSTRUCT NEW RAILWAY BRIDGES

CONSTRUCT NEW HIGHWAY BRIDGES

RELOCATE STREET

SHEATH PIERS & ABUTMENTS

WIDEN & DEEPEN CHANNEL & RIPRAP BANKS

MONROE STREET DAM

LOWER MILL POND

CONSTRUCT SUBMERGED WEIR

LOWER TOMPKINS ST. SIPHON

WIDEN & DEEPEN CHANNEL & RIPRAP BANKS

REMOVE BUILDINGS

EXTEND PIERS & ABUTMENTS

REINFORCE PIERS AND PAVE THRU BRIDGE

RELOCATE WATER INTAKE

RIPRAP PIERS & ABUTMENTS AT ALL BRIDGES

WIDEN, DEEPEN, & STRAIGHTEN EARTH CHANNEL

LOWER UNDERGROUND ELECTRIC POWER LINE

CONSTRUCT INTERCEPTING STORM & SANITARY SEWERS & FILL OLD CHANNEL FROM NEW CUTOFF TO BATTLE CREEK

TAPER INTO EXISTING CHANNEL

CONSTRUCT LEVEE

WIDEN, DEEPEN, & STRAIGHTEN EARTH CHANNEL

CONSUMERS POWER CO. E.B. ELM ST. PLANT

INCREASE SPAN OF ELECTRIC POWER LINES

VERONA DAM

U.S.G.S. STREAM GAGING STATION (STAFF)

FOOT BRIDGE

FOOT BRIDGE

ELECTRIC TRANSMISSION LINES

BATTLE CREEK

BATTLE CREEK CITY LIMITS

BATTLE CREEK CITY LIMITS

PERCY JONES GENERAL HOSPITAL

MICHIGAN CARTON CO.

GOSS PRINTING PRESS CO.

UNITED STEEL & WIRE CO.

RALSTON PURINA CO.

LIBERTY

U.S. REGISTER CO.

UNITED STEEL & WIRE CO.

MT. OLIVET CEMETERY

OAKHILL CEMETERY

OLIVER CORP.

POST CEREALS

RIVERSIDE COUNTRY CLUB

OLD UPPER MILL POND DAM SITE

KALAMAZOO RIVER

PARK

MANCHESTER

CHAMPION

VAN BUREN

MICHIGAN

KALAMAZOO

CASS

HAMBLIN

LAFAYETTE

GRAND TRUNK R.R.

DICKMAN ROAD

UPTON AVE.

GRAND

COURT ST.

GROVE

SPRING ST.

FOUNTAIN

GOGUAC

BURNHAM ST.

TERRITORIAL ROAD

CAPITAL AVE.

MEACHEM

RIVERSIDE DRIVE

CENTRAL

JACKSON

WASHINGTON AVE.

MCCAMLY

CARLISLE

STATE ST.

CHERRY ST.

ELM ST. DAM

FLINT

CAPITAL

CHESTNUT

FREMONT

NORTH

CALHOUN ST.

EMMETT ST.

SHERMAN ROAD

EAST AVE. N.E.

MAIN

GRAND TRUNK R.R.

MICHIGAN CENTRAL R.R.

YORK

SHEPARD ST.

THIRD ST.

FIRST ST.

CLIFF ST.

LATHROP AVE.

POST AVE.

KINGMAN AVE.

E. COLUMBIA AVE.

U.S. 12

BATTLE CREEK CITY LIMITS

LEGEND

1947 FLOOD LIMIT

STANDARD PROJECT FLOOD LIMIT

EARTH CHANNEL (RECOMMENDED) — SIDESLOPES / BOTTOM

RIPRAPPED CHANNEL (RECOMMENDED)

PAVED CHANNEL (RECOMMENDED)

DISPOSAL AREA (RECOMMENDED)

BORING ◉2

MILES ABOVE MOUTH OF RIVER (ALONG ORIGINAL CHANNEL) (107)

LAND USE

PARK OR MUNICIPAL	P
RESIDENTIAL	R
COMMERCIAL	C
INDUSTRIAL	I
AGRICULTURAL	A
WASTE	W
25 % DEVELOPMENT	—
50 % DEVELOPMENT	L
75 % DEVELOPMENT	⊏
100 % DEVELOPMENT	□

LOGS OF TYPICAL BORINGS

◉1
- 811.7 SAND & SILT
- 808.6 MUCK
- 807.3 SAND & SILT
- 805.0 SANDY CLAY
- 803.7 SAND
- 802.4 SANDSTONE

◉2
- 817.8 CINDER & RUBBISH FILL
- 808.4 SAND
- 807.2 CLAYEY FINE SAND
- 804.7 CLAY
- 798.5 SANDSTONE

◉3
- 822.5 GRAVEL FILL
- 809.8 COARSE SAND
- 805.7 FINE SAND
- 789.5

◉4
- 826.0 BLUE CLAY

◉5
- 818.5 WATER
- 805.0 COARSE GRAVEL
- 791.5 WEATHERED SANDSTONE

◉6
- 827.8 SAND
- 814.2 SAND & GRAVEL
- 807.3 SAND
- 796.8

N

FLOOD CONTROL
KALAMAZOO RIVER, MICHIGAN
BATTLE CREEK & VICINITY
RECOMMENDED IMPROVEMENTS

IN 4 SHEETS — SCALE OF FEET 500 0 500 1000 1500 2000 — SHEET NO. 3

MILWAUKEE DISTRICT, MILWAUKEE, WISCONSIN

SUBMITTED: A.R. Peterson

APPROVED: C.M. Morris