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by Jeffrey D. Jorgeson, Richard Sands, Gary E. Freeman

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Final report

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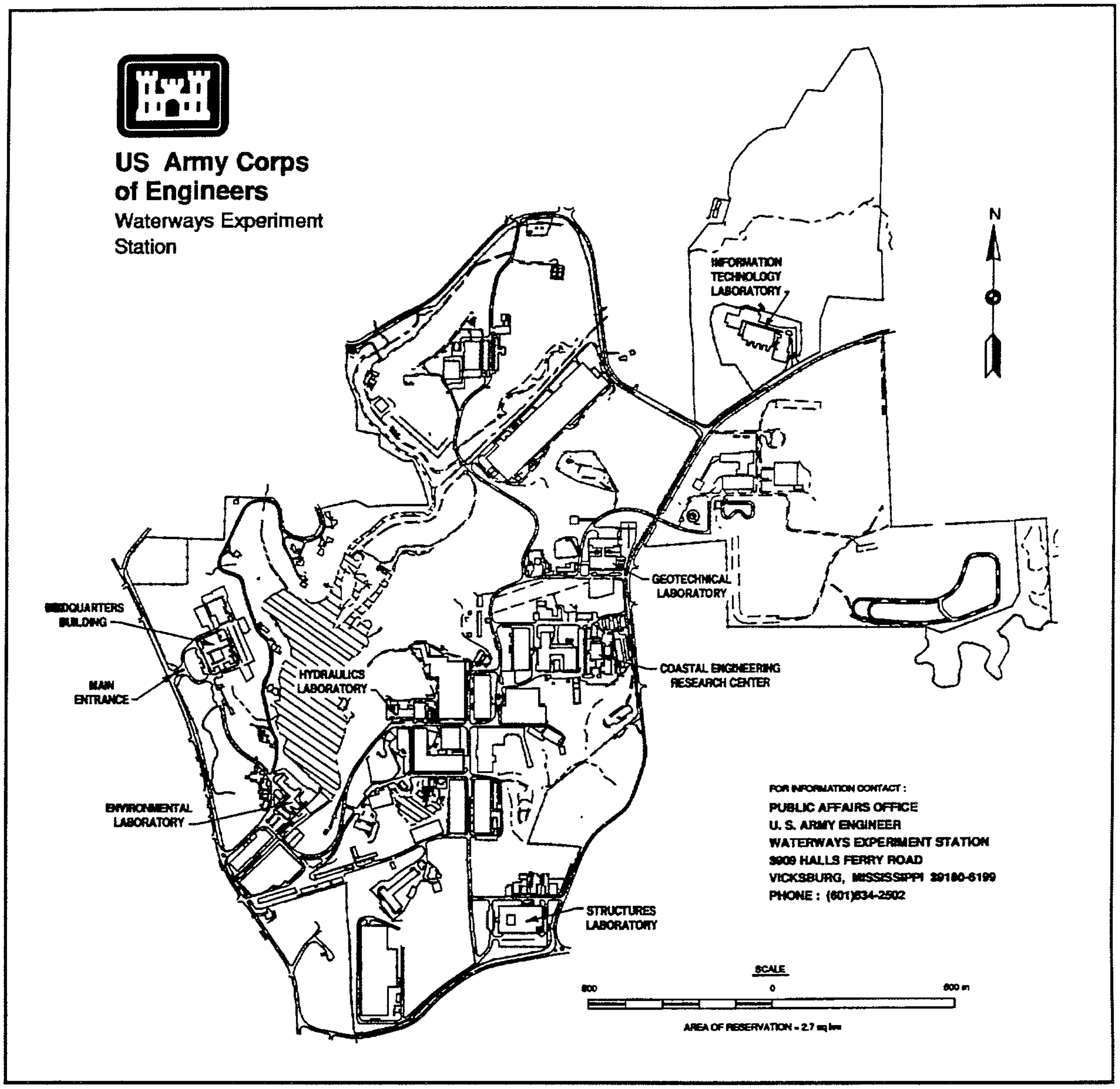

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Preface

This study was conducted by the Hydraulics Laboratory (HL) of the U.S. Army Engineer Waterways Experiment Station (WES) during February 1995 and was sponsored by the U.S. Army Engineer District, St. Paul (CENCS). The study was conducted and this report prepared by Mr. Jeffrey D. Jorgeson, Watershed Systems Group, Hydro-Science Division, HL; CPT Richard Sands, Hydro-Science Division, and Dr. Gary Freeman, Rivers and Streams Branch, Waterways and Estuaries Division, HL.

Special appreciation and acknowledgement are extended to Mr. Troy Nicolini of the U.S. Army Engineer Hydrologic Engineering Center, Davis, CA, and to Mr. Pete Cooper of the U.S. Department of Agriculture, Natural Resources Conservation Service, St. Paul, MN, for their cooperation and assistance in providing data for this study.

This report was prepared under the direct supervision of Mr. Michael J. Trawle, Chief, Rivers and Streams Branch; and Mr. William D. Martin, Chief, Hydro-Science Division; and under the general supervision of Mr. William H. McAnally, Jr., Chief, Waterways and Estuaries Division; Mr. Richard A. Sager, Assistant Director, HL; and Mr. Frank A. Herrmann, Jr., Director, HL.

At the time of publication of this report, Director of WES was Dr. Robert W. Whalin and Commander was COL Bruce K. Howard, EN.

Conversion Factors, Non-SI to SI Units of Measurement

Non-SI units of measurement used in this report can be converted to SI units as follows:

Multiply	By	To Obtain
acres	4,046.873	square meters
cubic feet	0.02831685	cubic meters
feet	0.3048	meters
miles (U.S. statute)	1.609347	kilometers
square miles	2.589988	square kilometers

1 Introduction

Background

In November 1993, the Scientific Assessment and Strategy Team (SAST) was created by direction from the White House to provide technical and scientific assistance related to recovery efforts from flooding in the Upper Mississippi River Basin that occurred in the spring and summer of 1993. Peak discharges during the flood of 1993 exceeded all previous peak discharges on record for many locations, and the costs, both human and economic, were high. In spite of those negative impacts, the flood resulted in some benefits as well, such as improved spawning areas and reconnection of the main channel with some backwater areas. This combination of negative and positive consequences raised longstanding issues related to flood control and habitat restoration. Thus, the SAST was formed to provide scientific advice to decision makers on recovery efforts and on future floodplain management issues (SAST 1994).

With the general goal of providing this scientific advice, the specific objectives of the SAST were:

a. To develop a database of readily available data to support map production, scientific analysis, and decision making.

b. To produce maps showing base information and vulnerability to flooding.

c. To prepare reports documenting the products of SAST and the methodology and analysis used to produce them, and identifying the ongoing monitoring, research, modeling, data management and distribution requirements needed to support integrated river basin management.

The overall SAST effort was multifaceted and included the generation of a multi-layer, multi-resolution database encompassing the Upper Mississippi River Basin. A host of other products from the database were also produced including maps, illustrations, analysis results and statistical information. Ultimately, the results of the SAST are being documented in a multi-volume report (SAST 1994).

Objective

One of the specific efforts undertaken by the SAST was to evaluate potential impacts of various nonstructural approaches to watershed management on flood control through peak flow reduction. These approaches included maximization of surface infiltration to reduce the amount of excess precipitation available for runoff, restoration of wetlands to reduce peak flows by temporarily storing runoff and attenuating the flood peak, and creation of small detention basins to temporarily store runoff and reduce the peak flow. The SAST determined that the best locations for applying these methods were in upland watersheds because upland watersheds generally cover larger land areas than do floodplains adjacent to main channels. To analyze these nonstructural approaches, four watersheds were selected for modeling, with each watershed being representative of a different terrain. Existing computer models were available for some of the watersheds, and new models were developed for the remainder. For each watershed, the models were verified to reasonably reflect the existing conditions in the watershed, and then the various nonstructural approaches were modeled to determine their potential effects on peak runoff. Those modeling efforts were originally completed for the SAST in early 1994, with the model results specifically directed at potential reductions in peak flow.

The purpose of this study was to revisit those original model studies and summarize the estimated reductions in total surface runoff volume for the various nonstructural alternatives on the study watersheds. The primary goal of the study was to compute the total volume of runoff, based upon the model results, that may occur under each nonstructural alternative of flood control in those watersheds, and to summarize the reductions in runoff as compared to a "base" or existing condition. Chapter 2 summarizes each of those original model studies, and provides some detail on the particular watersheds that were modeled.

Approach

To achieve the above stated objective, hydrographs from the original model studies were obtained, and the total volumes of flow represented by those hydrographs were computed. Each of the model studies included a "base" hydrograph representing the existing conditions in the watershed, and then a series of hydrographs for the various alternatives that were considered. Each study provided results for four precipitation events, including 100-, 25-, 5-, and 1-year return periods. With the flow volumes computed, the flow volumes resulting from the nonstructural watershed management approaches were compared to those for the base or existing conditions to determine if any potential reductions in flow might result if those approaches were implemented. Chapter 3 contains details on the actual computation of flow volumes as well as a summary of the results obtained during this study.

It must be noted that this study involved no actual hydrologic modeling, but rather used hydrographs produced from three earlier modeling studies to produce the results and conclusions contained herein. Detailed reports of those studies were generated (Jorgeson, Johnson, and Freeman, in preparation, U.S. Army Engineer Hydrologic Engineering Center (USAEHEC) 1994; U.S. Department of Agriculture 1994), and should be referred to for additional details. It must also be noted that four watersheds were originally evaluated for the SAST. Data for one of those watersheds, Whitebreast Creek, proved to be insufficient for calculating potential reductions in runoff volume. Consequently, Whitebreast Creek is not included as part of this study.

2 The Watershed Models

The Watersheds

The SAST selected four watersheds on which to evaluate the potential impacts of the various nonstructural flood reduction measures in upland areas. The study watersheds were selected to represent areas of different terrain as much as possible such that the results might be more widely applicable. With critical time constraints for completion of the SAST effort, a primary driving force behind the selection of watersheds was the existence of calibrated watershed models. The search for watersheds revealed that some data necessary for an HEC-1 model existed for the Boone River in Iowa, an HEC-1 model could be quickly set up using the GeoShed graphical interface for the West Fork Cedar River in Iowa, and that the Soil Conservation Service (SCS) had existing TR-20 models for Whitebreast Creek in Iowa and the Redwood River in Minnesota. In addition to the fact that models existed, or could be quickly established, for those watersheds, they also satisfied the criteria of representing widely varying terrain. The Boone River basin is a relatively flat watershed with low relief prairie pothole terrain, the West Fork Cedar River watershed is a relatively flat region with well defined drainage, the Whitebreast Creek watershed is relatively steep with well incised drainage, and the Redwood River basin is a high relief pothole region with some surface drainage for agriculture (SAST 1994).

The Nonstructural Alternatives

The original model studies performed on these watersheds were intended to show the potential effects of various alternatives for management, land use, and storage practices on the outflow from the watersheds. For the Boone River and West Fork Cedar River, the specific alternatives studied were as follows.

a. Maximizing wetland storage in upland and/or floodplain areas as applicable.

b. Converting highly erodible cropland to Conservation Reserve Program (CRP) as available (please refer to SAST 1994 for details on CRP).

c. Maximizing infiltration by using all applicable land treatments such as conservation tillage, terraces, and permanent cover.

d. Installing small flood prevention structures as applicable to temporarily store water for slow release.

e. Combining all nonstructural alternatives (*a*, *b*, and *c* above).

f. Combining all possible alternatives (*a-d* above) to simulate the maximum possible flow reduction without the use of medium to large reservoirs.

The Redwood River basin has terrain that is significantly different from the other study watersheds, and thus the objectives for that model study differed from the others. Specifically, the effects of wetlands could be better studied along the Redwood River. The objectives for the Redwood River model study were to determine if an increase in wetland areas may reduce flood peaks on this relatively high relief pothole basin. So, the alternatives selected for the Redwood River study were as follows:

a. Restore all depressional hydric soils with detention structures (19 percent of watershed).

b. Restore 50 percent of all depressional hydric soils (10 percent of watershed).

c. Restore 25 percent of all depressional hydric soils (5 percent of watershed).

d. Restore small wetlands with 50 percent assumed to be landlocked with no outlet to stream.

e. Restore large wetlands and lakes over 100 acres in size.

f. Restore large and small wetlands (combination of alternatives *a*, *b*, *c*, *d*, and *e* above) with no landlocked wetlands.

Since the primary focus of the Redwood River study was on the effects of wetlands, no land use alternatives were considered for that basin, i.e., no changes in the infiltration characteristics of the watershed. Also, for the other watersheds, not all of the six alternatives listed were readily applicable. For example, the West Fork Cedar River watershed includes no sites that were considered viable for consideration of wetland restoration or for small detention basins. Thus, those alternatives were not modeled for that basin

(SAST 1994). The following sections provide some detail for each of the original watershed model studies. Recall that the data from the Whitebreast Creek watershed was insufficient for computing potential runoff volume reductions and has not been included in this report.

Boone River

The watershed

The Boone River is located in Northern Iowa and has a 851-square-mile watershed. For modeling purposes, the watershed was subdivided into nine sub-basins for the study, including four local and five headwater sub-basins. The locations of sub-basin boundaries were chosen to desegregate the basin to the extent that wetlands could be located at various locations for modeling (USAEHEC 1994).

Alternatives modeled

The following five alternatives were considered in this study as briefly summarized. Additional details of the specific modeling techniques are contained in the original report by the USAEHEC (1994).

a. *Alternative 1, On-Stream Wetlands.* Three areas along the Boone River were identified for placement of on-stream wetlands. The Muskingum-Cunge routing method was used to represent the wetlands with an eight point channel cross section, roughness, slope and length to solve the diffusion wave equation for one-dimensional steady flow.

b. *Alternative 2, Potholes.* The Boone River basin has many depressional potholes capable of retaining runoff. The assumption was made that after being filled, the potholes ultimately contribute to direct runoff by surface connections to the stream. Each pothole had a surrounding contributing area within which rainfall resulted in overland flow into the pothole. Simultaneously, there were areas for which rainfall produced direct runoff to the stream network. Therefore, as long as the potholes were not full, flow at the watershed outlet was composed solely of runoff from areas not contributing to potholes. As the rainfall continued, the potholes filled up to their storage capacity and became contributing areas producing direct runoff to the stream network.

c. *Alternative 3, Conservation Reserve Program (CRP).* This alternative involved the inclusion of highly erodible land in CRP, which resulted in that land being removed from cultivation and returned to permanent cover. The SCS curve number used to reflect existing conditions was provided by the SAST. The SAST also provided reductions in curve numbers for CRP conditions for counties throughout the Boone River basin. This produced new curve numbers for each of the sub-basins and allowed production of simulated hydrographs.

d. *Alternative 4, Food and Security Act (FSA).* This alternative involved the inclusion of the Food and Security Act requirements (refer to SAST 1994 for details on FSA requirements). Again, the SCS curve number used to reflect existing conditions was provided by the SAST, and the SAST also provided reductions in curve numbers for FSA conditions for counties throughout the Boone River basin. This produced new curve numbers for each of the sub-basins and allowed production of simulated hydrographs.

e. *Alternative 5, Combining On-stream Wetlands, Potholes and Land Management Practices (All Combined).* In this alternative, simulations were performed to evaluate the combined impact of on-stream wetlands, potholes and land management practices on flood peaks. The resultant hydrographs showed the effects of this combination for maximum potential flow reduction.

West Fork Cedar River

The watershed

The West Fork Cedar River is located in Northern Iowa and has an 850-square-mile watershed above the gaging station at Finchford, Iowa. The fan-shaped basin is about 60 miles long and 30 miles wide at the widest point. The West Fork Cedar River originates at the confluence of Beaverdam Creek and the East Branch of Beaverdam Creek, and the river flows approximately 50 miles in a generally southeasterly direction to the gaging station at Finchford, Iowa.

The upper land segments of the watershed in the Beaverdam Creek area are characterized by hummocky topography and poorly defined drainage. Moving to the southeast, the land is characterized by gently rolling hills and well established drainage. The southern most portion of the watershed is a wide alluvial plain with low stream gradients and valleys that have gentle slopes. Relative to mean sea level, the elevation in the headwater area is approximately 1,250 ft and the outlet at Finchford, Iowa has an elevation of 875 ft (Jorgeson, Johnson, and Freeman, in preparation).

Alternatives modeled

Three nonstructural alternatives were presented in this study. The West Fork Cedar River included no areas that were considered appropriate for wetland restoration and no sites that were viable for small detention structures. Thus, the alternatives considered in this study included only those related to infiltration parameters and are summarized as follows. Additional details on the specific modeling techniques are available in the original model study report (Jorgeson, Johnson, and Freeman, in preparation).

a. *Alternative 1, Land Conservation Practices without CRP (FSA).* This alternative involved the implementation of FSA land conservation practices, such as conservation tillage and terracing, designed to reduce runoff and soil erosion, but with the acreage defined for CRP as described in Alternative 2 below excluded. The United States Department of Agriculture, SCS in Des Moines, Iowa provided data which included the reduction in runoff curve number as a result of these land conservation practices in each county in Iowa. Using that data, a weighted reduction in curve number over the entire watershed was computed.

b. *Alternative 2, Conservation Reserve Program (CRP).* This alternative involved the inclusion of highly erodible land (HEL) in CRP, which results in that land being removed from cultivation and returned to permanent cover such as grasslands. As with the land conservation practices, the SCS provided data on potential curve number reduction for each county in Iowa for the CRP acreage, and a weighted curve number reduction for the watershed was determined.

c. *Alternative 3, FSA Land Conservation Practices with CRP (All Combined).* This alternative was a combination of Alternatives 1 and 2 above, which essentially reflected true scope of FSA practices which by definition includes CRP acres. Again, SCS data for curve number reductions were provided for this alternative to estimate the curve number reduction over the watershed.

Redwood River

The watershed

The Redwood River is located in southwest Minnesota and has a 700-square-mile watershed. The watershed drains portions of Lincoln, Lyon, Redwood, Yellow Medicine and Murray Counties, and it outlets into the Minnesota River just downstream of Redwood Falls. The headwaters originate on a high level plain, and this plateau drops in a steep narrow escarpment to a lower flat and gently undulating region which occupies nearly two-thirds of the study area (USDA 1994).

Alternatives modeled

Six control method alternatives were presented in this study which correspond to alternatives *a* through *f* listed previously in the section entitled "The Nonstructural Alternatives." Again, the original report by the USDA Soil Conservation Service (USDA 1994b) should be referred to for additional details on this model study.

a. *Alternative 1, Restore 100 percent of depressional hydric soils (100 percent Restore).* For this alternative, it was assumed that all depressional hydric soils were restored as wetlands. These would have outlet structures that allowed all runoff entering the wetland to pass after peak discharges attenuate and included 19 percent of the watershed area.

b. *Alternative 2, Restore 50 percent of depressional hydric soils (50 percent Restore).* This was the same as Alternative 1, except that only 50 percent of a subwatershed's hydric soils and depressions were assumed to be restored to wetlands. This included 10 percent of the watershed area.

c. *Alternative 3, Restore 25 percent of depressional hydric soils (25 percent Restore).* This was the same as Alternative 1, with the exception that only 25 percent of a subwatershed's hydric soils and depressions were assumed restored to wetlands. This involved 5 percent of the watershed.

d. *Alternative 4, Small wetland restoration with 50 percent land locked (Small Wetland Restore),* This was the same as Alternative 1, except it was assumed that 50 percent of the restored wetland areas would not have outlets back to the stream channel. Thus, once flow entered those land locked areas, it would not return to the stream at a later point. This alternative effectively reduced the contributing drainage area of the watershed by approximately 68 square miles.

e. *Alternative 5, Large wetland restoration (Large Wetland Restore).* For this alternative it was assumed that all drained lake beds, swamps, and similar areas larger than 100 acres were restored as wetlands. Fifteen potential restorations were identified, and the surface area of these throughout the basin was approximately 5,710 acres. The contributing drainage area to these was approximately 46.1 square miles or 7 percent of the total watershed area.

f. *Alternative 6, Large and small wetland restoration (Large and Small Wetland Restore).* This alternative was essentially a combination of

Alternatives 5 and 1. This alternative assumed all areas still contribute runoff to the Redwood River and that there were no landlocked wetland areas.

Summary of Original Studies

As mentioned earlier, the specific goal of each of the original model studies detailed above was to estimate the effects of the various alternatives on the peak flow from the watershed. As expected, the models did indicate a potential for peak flow reduction for each of the alternatives to varying degrees. Also, the magnitude of the precipitation event effected the amount of peak flow reduction. For the Boone River, West Fork Cedar River and Redwood River studies, the potential reduction in peak flow decreased as the storm return period increased.

It must be noted that each of these model studies was performed during a very limited time, and some were done with very limited data. Thus, the results should not be construed to be applicable to more than the specific watersheds which were modeled. Additionally, the model studies were intended to show relative changes in peak flows due to potential changes in the watershed, and any specific flow values may not necessarily reflect specific flows that could be expected from the watersheds. Table 1 presents a summary of the estimated peak flow reductions for the various alternatives on the model watersheds given the 100-year, 25-year, 5-year, and 1-year return period storm events as taken from SAST 1994.

Table 1
Percent Reduction in Flood Peak for Model Watersheds

Return Period years	Watershed		
	Boone River	West Fork Cedar River	Redwood River
	Floodplain Wetlands		Alt. 5[1]
1	5		6
5	3		5
25	2		3
100	2		3
	Upland Wetlands or Potholes		Alt. 1[1]
1	9		23
5	8		15
25	7		11
100	5		10
	Conservation Reserve Program (CRP)		
1	3	7	
5	1	5	
25	1	4	
100	1	3	
	Maximum Infiltration (FSA)		
1	6	15[2]	
5	3	11[2]	
25	2	8[2]	
100	2	7[2]	
	Detention Structures		Alt. 6[1]
1			26
5			16
25			12
100			11
	Total of all Applicable Alternatives		Alt. 4[3]
1	18	15	27
5	14	11	21
25	12	8	17
100	9	7	16

[1] These alternatives for the Redwood River were most closely comparable with alternatives from the other watersheds.
[2] CRP acreage was inadvertently excluded for this alternative on the West Fork Cedar River in the SAST report.
[3] Alternative 4 showed the maximum peak reduction potential and was used for comparison with the maximums for the other watersheds.

3 Computation of Runoff Volumes

Computation Procedure

The preceding sections have been a summary of previous modeling efforts and the results of those efforts. Specifically, the potential impacts on peak flow for various nonstructural alternatives to watershed management. The primary goal of this project was to revisit the data from the model studies and analyze the potential reductions in total surface runoff volume for the various alternatives on the study watersheds. The procedure followed for the analysis was to reassemble the hydrograph data for each model study, plot the hydrographs, compute the volume under each hydrograph curve, and compare the reductions in runoff volume for each alternative to the runoff volume for the base or existing conditions. For reference purposes, Figures 1, 2, and 3 show hydrographs from a 100-year event for the base condition and maximum potential reduction alternative on the Boone River, West Fork Cedar River, and Redwood River, respectively.

The specific procedure used to calculate the volume under each hydrograph was to import the hydrograph data points into a computer software program entitled *Table Curve*. The individual data points for each hydrograph were entered into the program and it performed the calculus operations to determine the area under each hydrograph curve. *Table Curve* analyzes the input data and develops a mathematical equation to describe the specific hydrograph curves. The program then integrates this equation and determines the area found under the curve. The input data was entered with time (in seconds) on the abscissa and the rate of flow (in cubic feet per second) on the ordinate. Thus, the area calculated by the program provided the total volume of flow under each curve in cubic feet.

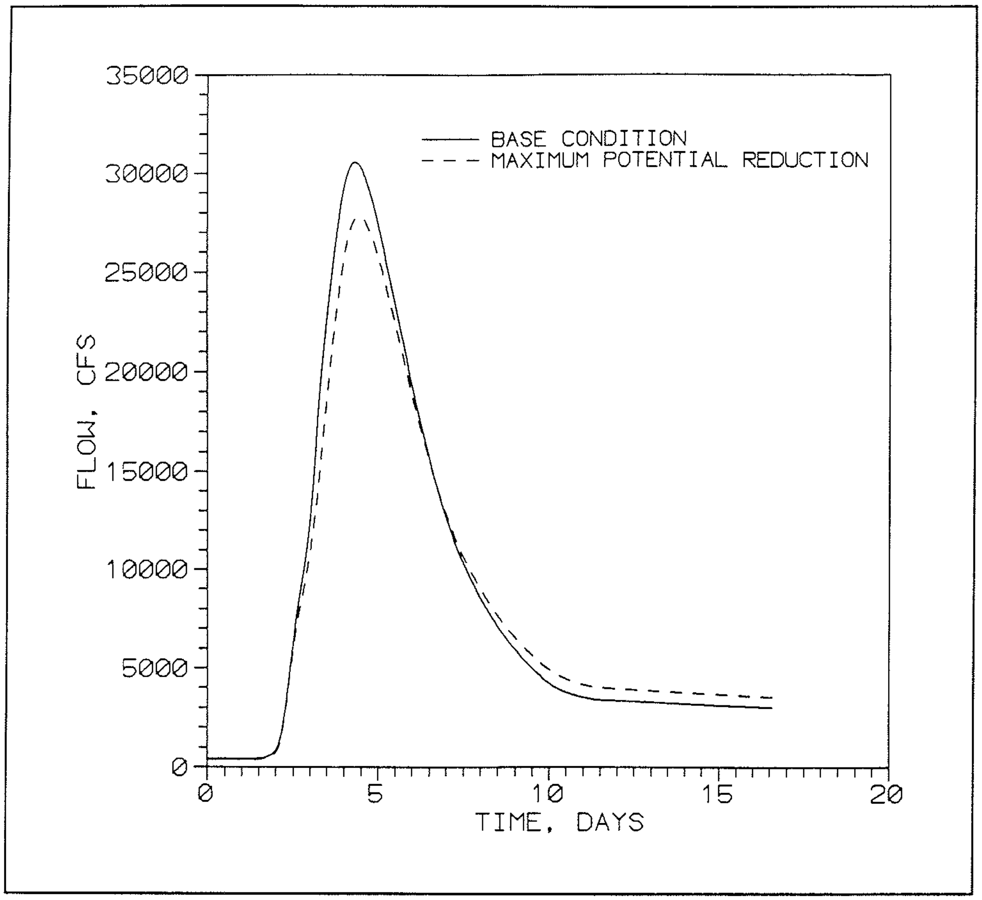

Figure 1. 100-year-event hydrographs for the Boone River

Results

The following sections summarize the results of the total runoff volume computations for the Boone River, West Fork Cedar River, and Redwood River. The results for each watershed are first presented individually, and a table similar to Table 1 is then presented to summarize the findings for all of the watersheds.

Boone River

A summary of the runoff volumes for the Boone River are included in Table 2. In this table, the base runoff volume represents conditions on the watershed with none of the listed alternatives in place, and the runoff volumes for each of the alternatives were compared to that base to determine the percent of potential reduction. As with the other data in this report, the relative changes in runoff volume are the numbers that are of interest, not necessarily the specific runoff values.

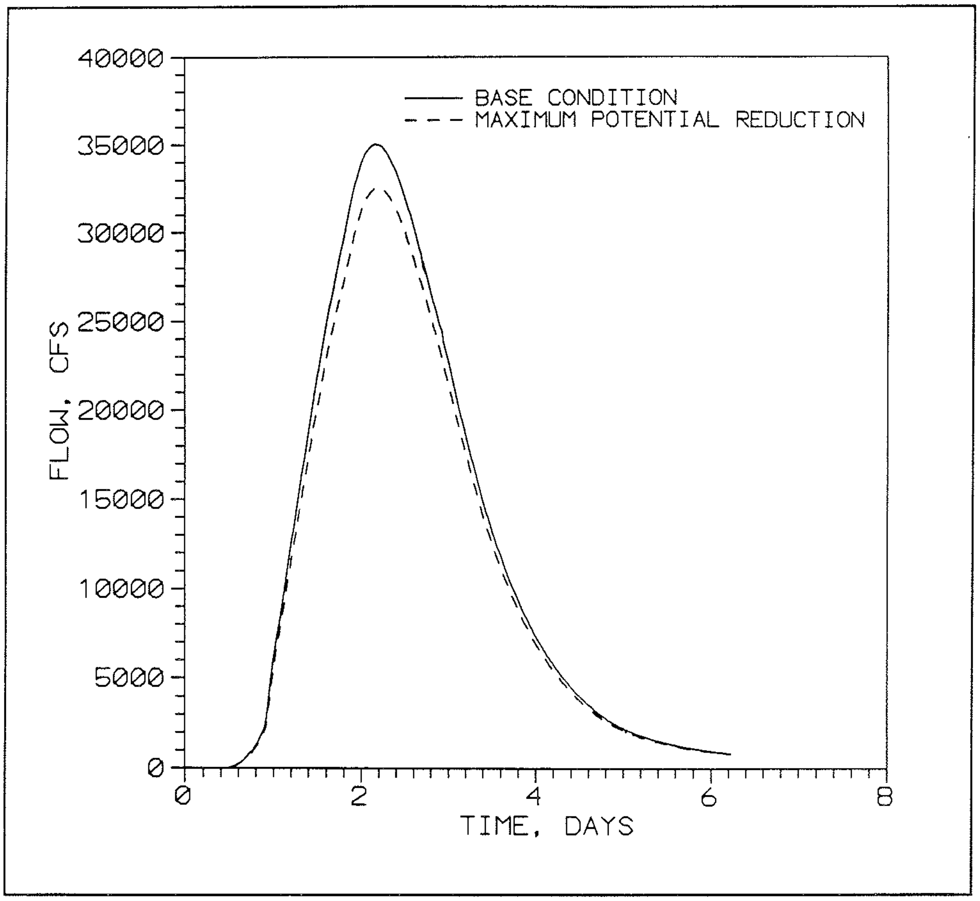

Figure 2. 100-year-event hydrographs for West Fork Cedar River

West Fork Cedar River

Table 3 presents a summary of the runoff volumes for the West Fork Cedar River, with the base flow volume representing conditions in the watershed with none of the alternatives in place, and the runoff volumes for each alternative are compared to that base to show the potential reductions. Note that the relative changes in runoff volume are of importance here and that the specific values for runoff volume should not be focussed on.

Redwood River

The results for the Redwood River are presented in Table 4, again with the base runoff volume representing conditions with no alternatives in place and the runoff volume for each alternative was compared to that base. The data contained in Table 4 indicate that almost all of the alternatives for this watershed showed little or no potential reduction in runoff volume. This is

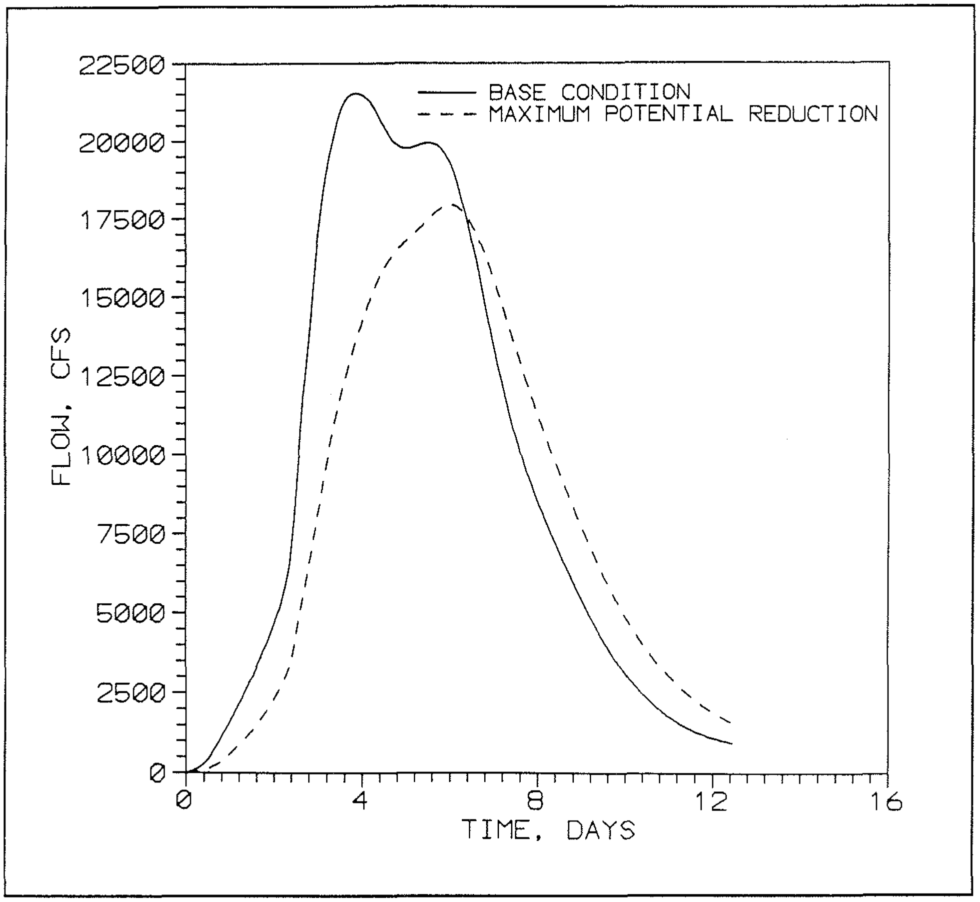

Figure 3. 100-year-event hydrographs for the Redwood River

due to the fact that the approach for the Redwood River model study was slightly different from those of the other watersheds. The Redwood River study emphasized wetland restoration, and did not include any alternatives which would alter the infiltration characteristics of the watershed. Thus, the only alternative on the Redwood River that resulted in any significant potential reduction in runoff volume was the alternative where some areas were assumed to be land locked, and the flow into those areas was not allowed to reenter the system. As with the other model studies, it is the relative changes in runoff volume and not the specific flow values from the that are important.

Summary of Peak and Volume Results

Table 1 presented the results from the original model studies for peak flow reduction over the study watersheds. That data is now combined in tabular format with the results for total runoff volume and is presented in Table 5.

Table 2
Summary of Runoff Volumes for the Boone River

Control Method	Total Runoff Volume	Storm Return Period, Years			
		100	25	5	1
Base	$ft^3 \times 10^6$	12,274	8,468	6,054	1,782
Wetlands	$ft^3 \times 10^6$	12,251	8,463	6,048	1,779
	% Reduced	0.2%	0.1%	0.1%	0.1%
Potholes	$ft^3 \times 10^6$	12,339	8,351	5,793	1,652
	% Reduced	-0.5%	1.4%	4.3%	7.3%
CRP	$ft^3 \times 10^6$	12,156	8,366	5,967	1,740
	% Reduced	1.0%	1.2%	1.4%	2.3%
FSA	$ft^3 \times 10^6$	12,044	8,270	5,886	1,702
	% Reduced	1.9%	2.3%	2.8%	4.5%
All Combined	$ft^3 \times 10^6$	12,052	8,112	5,592	1,569
	% Reduced	1.8%	4.2%	7.6%	12.0%

Table 3
Summary of Runoff Volumes for West Fork Cedar River

Control Method	Total Runoff Volume	Storm Return Period, Years			
		100	25	5	1
Base	$ft^3 \times 10^6$	6,282	4,436	2,669	1,187
CRP	$ft^3 \times 10^6$	6,098	4,281	2,550	1,113
	% Reduced	2.9%	3.5%	4.5%	6.2%
FSA (w/o CRP)	$ft^3 \times 10^6$	6,050	4,240	2,519	1,096
	% Reduced	3.7%	4.4%	5.6%	7.7%
All Combined	$ft^3 \times 10^6$	5,870	4,088	2,404	1,024
	% Reduced	6.6%	7.8%	9.9%	13.7%

Table 4
Summary of Runoff Volumes for the Redwood River

Control Method	Total Runoff Volume	Storm Return Period, Years			
		100	25	5	1
Base	$ft^3 \times 10^6$	10,065	6,345	2,632	616
100% Restore (Alt. 1)	$ft^3 \times 10^6$	9,861	6,116	2,556	602
	% Reduced	2.0%	3.6%	2.9%	2.2%
50% Restore (Alt. 2)	$ft^3 \times 10^6$	9,977	6,212	2,591	610
	% Reduced	0.95%	2.1%	1.6%	1.0%
25% Restore (Alt. 3)	$ft^3 \times 10^6$	10,054	6,297	2,618	614
	% Reduced	0.1%	0.8%	0.5%	0.3%
Small Wetland Restore (Alt. 4)	$ft^3 \times 10^6$	9,009	5,569	2,326	548
	% Reduced	10.5%	12.2%	11.6%	11.0%
Large Wetland Restore (Alt. 5)	$ft^3 \times 10^6$	10,028	6,287	2,599	608
	% Reduced	0.4%	0.9%	1.3%	1.3%
Lrg & Sm Wetland Restore (Alt. 6)	$ft^3 \times 10^6$	9,802	6,053	2,521	593
	% Reduced	2.6%	4.6%	4.2%	3.6%

Figure 4 and Figure 5 provide graphical representations of the percent reductions in peak flow and runoff volume versus storm return period for the watersheds. The data plotted in those figures is only for the alternative which provides for the maximum potential reduction in peak flow or surface runoff.

Table 5
Percent Reduction in Peak and Volume for Model Watersheds

Return Period Years	Boone River Peak	Boone River Vol	West Fork Cedar River Peak	West Fork Cedar River Vol	Redwood River Peak	Redwood River Vol
	Floodplain Wetlands				Alt. 5[1]	
1	5	0			6	1
5	3	0			5	1
25	2	0			3	1
100	2	0			3	0
	Upland Wetlands or Potholes				Alt. 1[1]	
1	9	7			23	2
5	8	4			15	3
25	7	1			11	4
100	5	0			10	2
	Conservation Reserve Program (CRP)					
1	3	2	7	6		
5	1	1	5	5		
25	1	1	3	4		
100	1	1	3	3		
	Maximum Infiltration (FSA)					
1	6	5	15[2]	14		
5	3	3	11[2]	10		
25	2	2	8[2]	8		
100	2	2	7[2]	7		
	Detention Structures				Alt. 6[1]	
1					26	4
5					16	4
25					12	5
100					11	3
	Total of All Applicable Alternatives				Alt. 4[3]	
1	18	12	15	14	27	11
5	14	8	11	10	21	12
25	12	4	8	8	17	12
100	9	2	7	7	16	11

1 Alternatives most comparable with alternatives from the other watersheds.
2 CRP acreage was inadvertently excluded for this alternative on the West Fork Cedar River in the SAST report.
3 Alternative 4 showed the maximum peak reduction potential and was used for comparison with the maximums for the other watersheds.

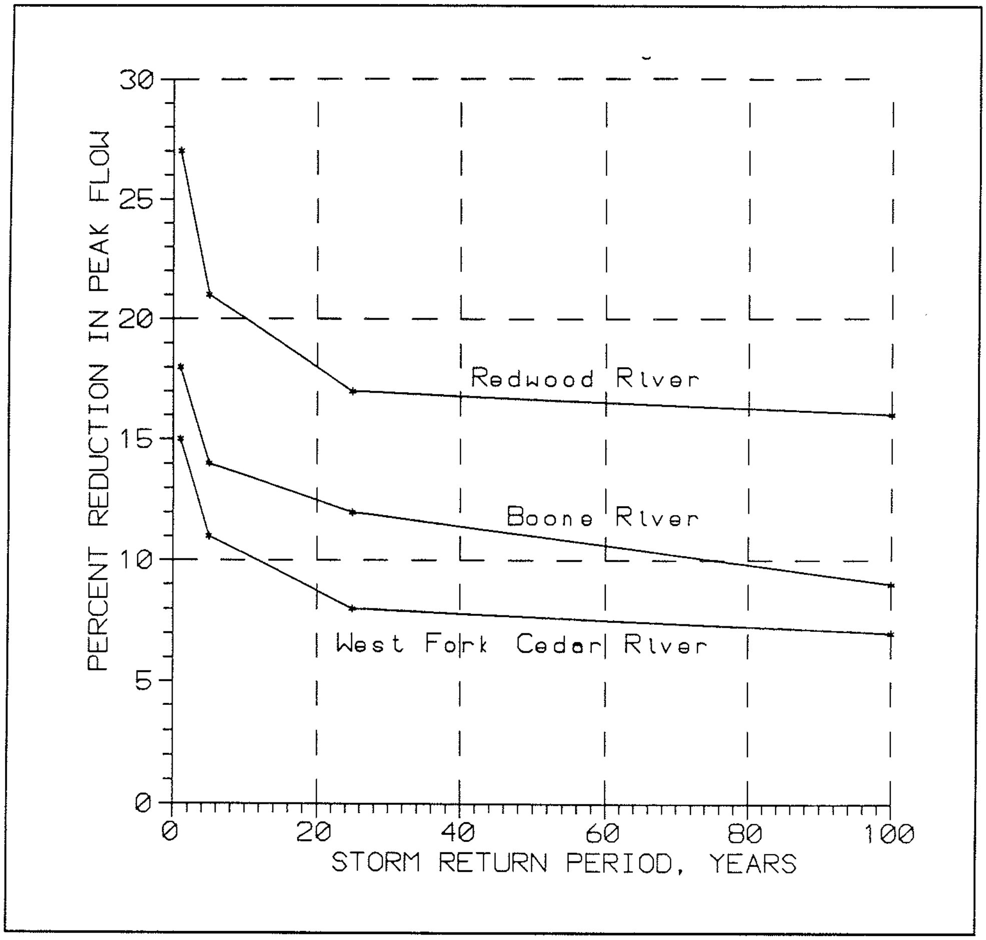

Figure 4. Percent peak flow reduction versus storm return period for maximum infiltration and storage alternatives

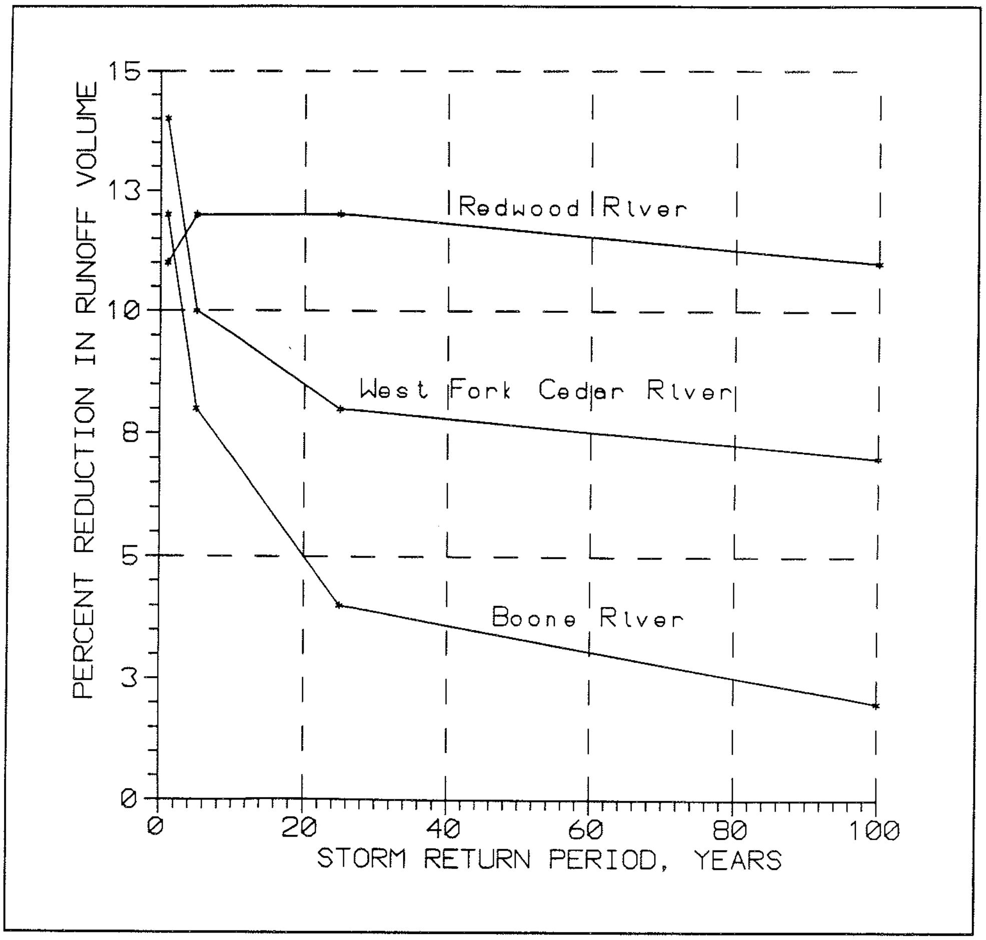

Figure 5. Percent runoff volume reduction versus storm return period for maximum infiltration and storage alternatives

4 Conclusions

The results of this study indicate that while the various nonstructural alternatives studied for these watersheds all show a potential for peak flow reduction, they do not all show a corresponding potential for reducing the total volume of runoff from a watershed. Those alternatives which serve to alter the infiltration characteristics of a watershed, thereby reducing the amount of excess precipitation available for runoff, do result in a potential runoff volume reduction during a given flood event. However, those alternatives which serve to retard or temporarily store some portion of the runoff do not show much potential for reducing the total volume of runoff. Alternatives involving only wetlands or detention structures do not actually prevent water from running off from a watershed, they merely slow down some portion of the runoff so as to reduce or attenuate the peak while the total runoff volume remains essentially constant. For example, although the peak flow may be reduced by temporary storage of flow in wetland areas, the total volume of runoff will remain the same. Only when some portion of the flow is not allowed to enter the stream channel will the total runoff volume be significantly changed. This was the case in these watershed studies when infiltration characteristics were changed such that more precipitation was able to infiltrate and less was available for runoff, and this was the case in the alternative on the Redwood River where some areas were assumed to be land locked (Small Wetland Restore). In those land locked areas, flow entering is not allowed to return to the main stream. Thus, that flow is "lost" as surface runoff, and the total runoff volume is reduced.

Although total runoff volume was the focus of this report, it is important to note that the potential reductions in peak flow from the original watershed studies are significant. A reduction in peak flow generally translates into a reduction in damages. Thus, even when the total volume of runoff is not reduced, a reduction in the peak flow can have extremely important benefits. One common method of estimating damages is through the use of a stage-damage curve for a particular watershed. Thus, the potential damages from a flood event are related to the peak stage. Higher stages typically relate to higher flows, and thus higher damages in the watershed.

It must be noted that this study was solely based on the hydrograph results of three of the four original studies conducted for the SAST. Each of those studies warned that the results are intended to provide estimates of relative changes in peak runoff, and that the prediction of specific flows was beyond the scope of the effort. Additional data and verification would be needed in order to make those types of predictions. The primary goal of this study was to determine the total volume of flow for the various watershed management alternatives for the given storm events, and to summarize the potential changes in total runoff volume relative to the base or existing condition. No analysis toward sensitivity or statistical differences associated with the potential relative changes was pursued in this study, but there is certainly room for additional work in that area. A full statistical and sensitivity analysis could be conducted to provide a more complete view of the potential effects of the various alternatives for these watersheds, and some correlation between topography or land use and the potential effectiveness of the various alternatives could be pursued.

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13. ABSTRACT *(Maximum 200 words)*

The Scientific Assessment and Strategy Team (SAST) was formed by direction of the White House to provide technical guidance on recovery efforts and future floodplain management issues in the upper Mississippi River basin as a result of the unprecedented flooding that occurred there during the spring and summer of 1993. The SAST conducted a series of watershed modeling studies to analyze the potential reduction in peak runoff for various nonstructural watershed management practices. The results of those studies are summarized. In addition to the potential peak flow reductions, the potential reductions in total runoff volume are compared for various nonstructural watershed management approaches. Those approaches include maximization of infiltration through land management changes, maximization of wetland storage, and installation of small flood prevention structures to temporarily store water. The watershed management practices, watershed modeling studies, and potential reductions in surface runoff are detailed.

14. SUBJECT TERMS

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Floods	Runoff	Watershed modeling
Hydrology	Storm runoff	
Land management	Surface runoff	

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