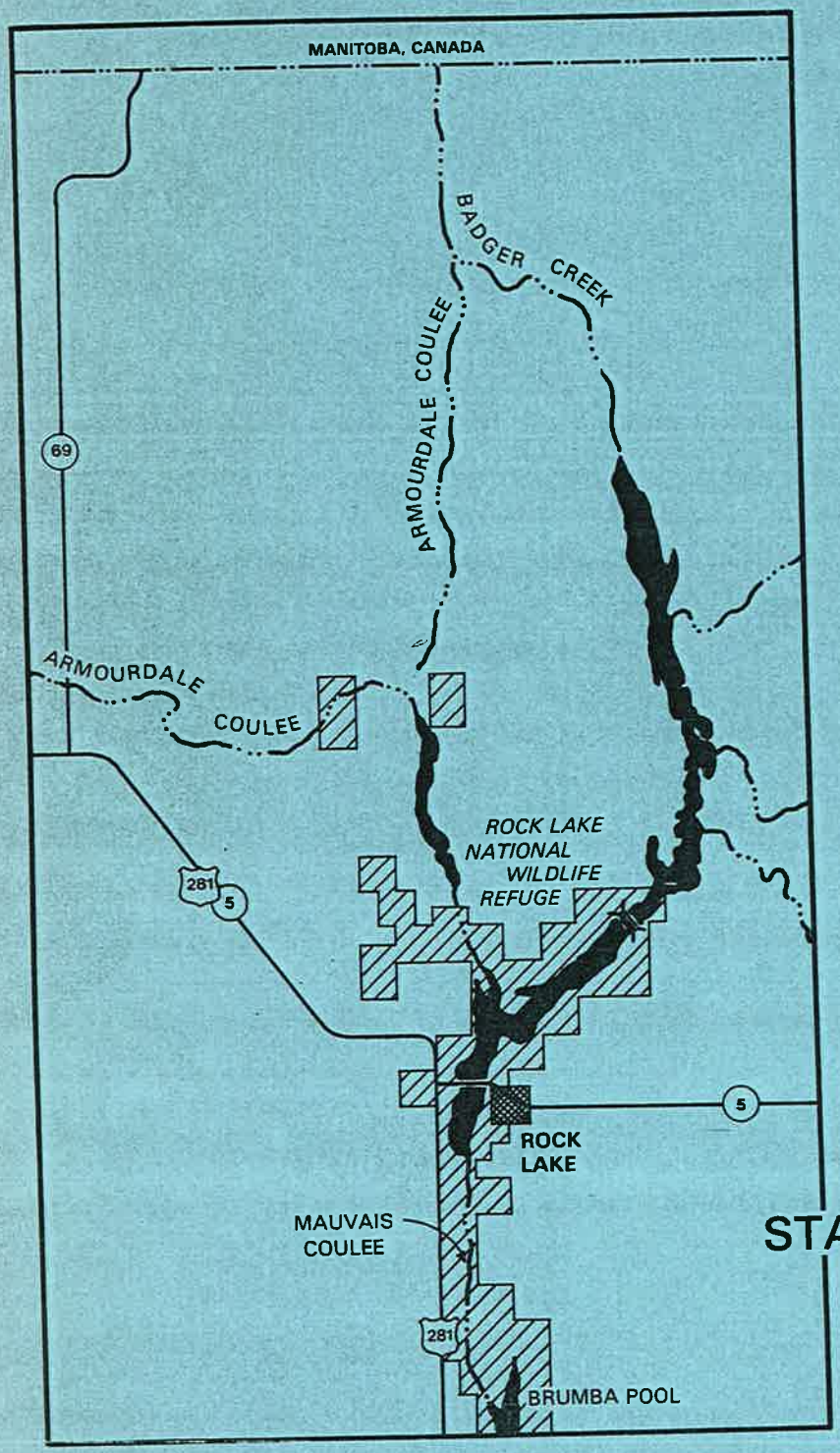
PRELIMINARY ENGINEERING REPORT

ROCK LAKE FLOOD CONTROL

BADGER CREEK - ARMOURDALE COULEE

TOWNER COUNTY, NORTH DAKOTA

SWC PROJECT NO. 1767 also check # 1362



NORTH DAKOTA
STATE WATER COMMISSION

JULY, 1985

PRELIMINARY ENGINEERING REPORT

Rock Lake Flood Control Project
Armourdale Coulee - Badger Creek
SWC Project #1767

July 1985

North Dakota State Water Commission
900 East Boulevard
Bismarck, North Dakota 58505-0187

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I. INTRODUCTION

In October of 1982, the North Dakota State Water Commission entered into an agreement (Appendix A), with the Towner County Water Resource District to investigate the current flooding problems in the Rock Lake area and to review possible alternatives to reduce these problems. Figure 1 shows the location of the Rock Lake Watershed within the state.

Rock Lake and Badger Creek have a drainage area of approximately 276 square miles located in Towner County, with small portions in both Rolette and Cavalier Counties. It is located within the Hudson Bay Drainage Basin just north of the divide to the Devils Lake Drainage Basin. Badger Creek, the outlet to Rock Lake, flows north for about seven miles to where it enters Canada, then an additional twenty miles until it flows into the Pembina River, which drains into the Red River, which flows into Lake Winnipeg.

Prior to the 1930s, the waters entering the western portion of Rock Lake, near the City of Rock Lake, flowed primarily into the Hudson Bay Basin. On larger runoff events, however, water was able to overflow to the south into the Devils Lake Basin through Mauvais Coulee. A review of historical information shows that this southern overflow was at or near elevation 1530 msl, and the northern outlet somewhat lower at elevation $\pm$ 1528.0 msl, near the midpoint of the lake and $\pm$ 1526.0 msl at the outlet into Badger Creek.

Originally Armourdale Coulee, having a watershed of about 44 square miles, entered Badger Creek approximately two and one-half miles south of the Canadian Border. The upper 33 square miles flowed into a wide low flat where prior to the 1930s the flows could split during heavy runoff periods. The primary outlet for these flows was into Badger Creek. The remaining high flows spilled to the south into the Western Rock Lake Reservoir and possibly into Mauvais Coulee. Figure 2 shows the location of Badger Creek, Armourdale Coulee, Western Rock Lake Reservoir, and Mauvais Coulee, with respect to Rock Lake.

ROCK LAKE DRAINAGE BASIN
ARMOURDALE COULEE - BADGER CREEK
SWC NO. 1767

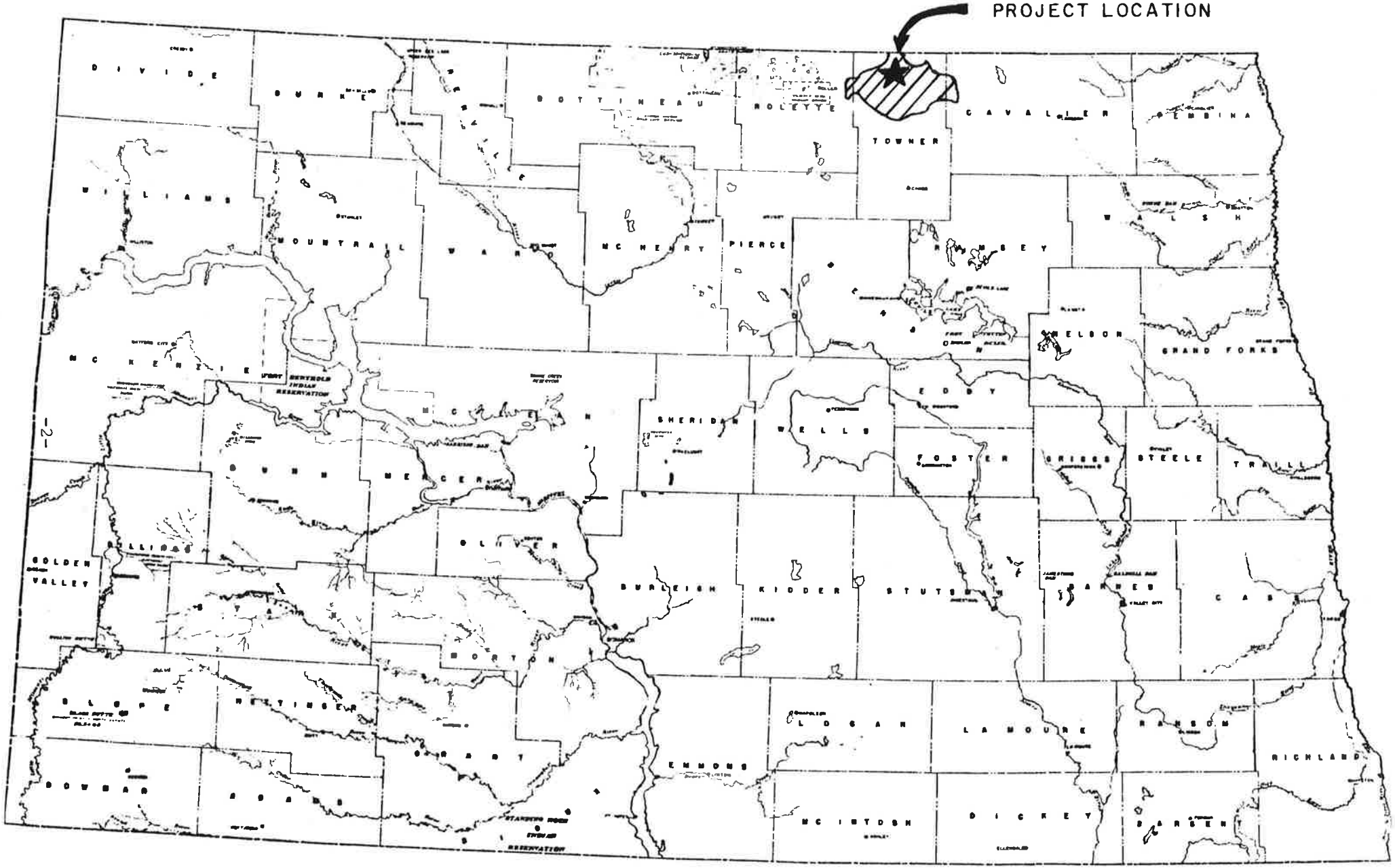


FIGURE 1

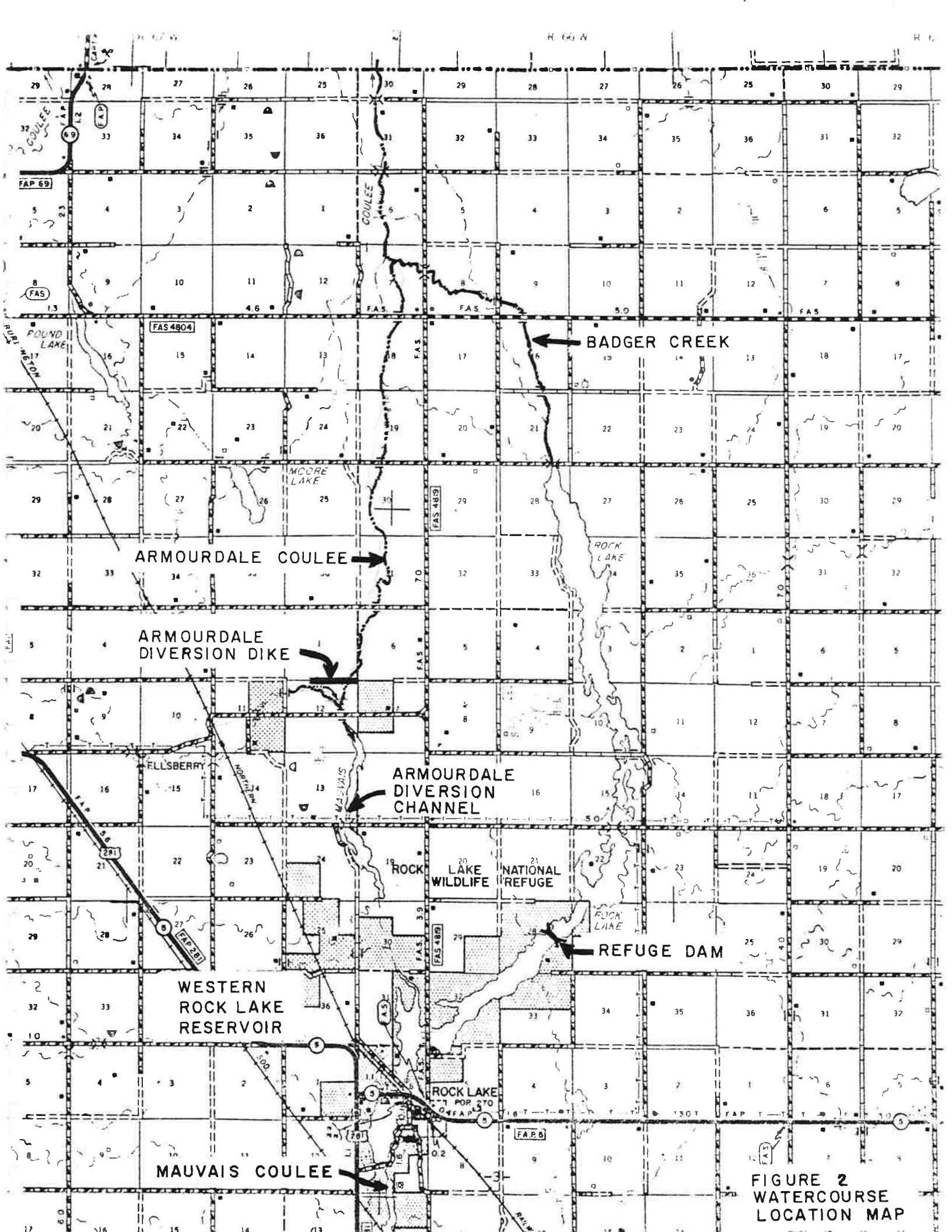


FIGURE 2
WATERCOURSE
LOCATION MAP

In 1932, the Rock Lake National Wildlife Refuge was established. The construction of the refuge included the complete diversion of Armourdale Coulee, just north of where the natural split occurred. The construction of a low level dam across a portion of Rock Lake, and the raising of the southern outlet into Mauvais Coulee, along with the diversion were used to maintain the water levels in the refuge. The original plan called for the diversion of some of the waters stored in the refuge into Mauvais Coulee to supply Devils Lake; which was experiencing record low water levels. As time passed and climatic conditions changed, the need for this diversion diminished and it was never constructed. Currently, all waters entering the refuge flow north through Rock Lake and down Badger Creek into Canada. The location of the refuge dam is also shown on Figure 2.

Flooding has occurred on Rock Lake in 1949; April of '69, '71 and '74; May '74; April of '79; and June of 1982. During these events, flooding has occurred on some 6,000 to 7,000 acres of lowlands near the lake (See Figure 3). The flooding of these lands occurs primarily when the water surface elevations exceed elevation 1529 msl. There are several areas of flooding, each having its own problem created by these floodwaters.

The major flooding of land occurs to the west of Rock Lake. Two other problem areas lie along Badger Creek as it flows into Canada and along that portion of channel into which Armourdale Coulee was diverted. A fourth problem area is the township roadway leading to the north of the City of Rock Lake; it has been washed out on at least five separate occasions. The refuge dam has also been washed out several times.

The Rock Lake Flood Control Association was formed in April of 1971 as a result of concerns over flooding that occurred on Rock Lake in April of 1969. This group established a number of goals to help prevent the type flooding that had occurred. The first was to improve Badger Creek to increase its efficiency in removing floodwaters from Rock Lake. The second was to re-divert Armourdale Coulee back into its original channel to reduce inflows into the Western Rock Lake Reservoir. The

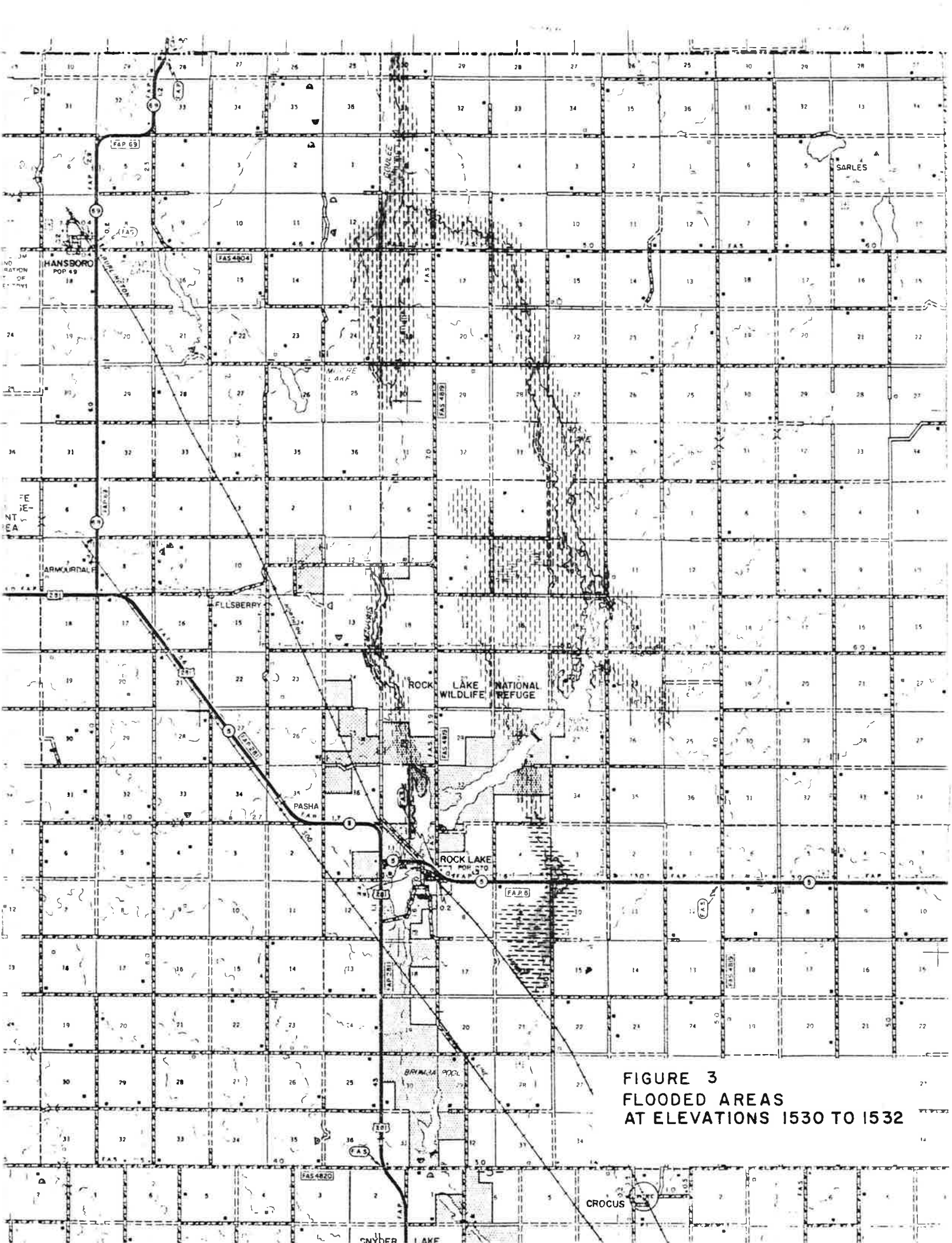


FIGURE 3
FLOODED AREAS
AT ELEVATIONS 1530 TO 1532

Flood Control Association claimed that from 25 to 28 percent of the floodwaters flowing into the western portion of Rock Lake were the direct result of the diversion. The third was to review all existing drains within the watershed and to plug those that were illegal.

Letters written to the Towner County Water Resource Board and the Association during 1974 note the problems that existed in proceeding with the proposed projects. The moratorium passed by the North Dakota State Water Commission in April 1971, Resolution #71-4-294, "...does hereby prohibit and order the cessation of construction of drainage structures within the Pembina River Basin west of Highway No. 32 in North Dakota" (See Appendix B). Responses to the proposed projects from the Manitoba Water Resources Branch indicated their concern over increased flooding along Badger Creek, which had a history of flooding. These increases could also cause problems along the Pembina River which had been experiencing serious flooding that prompted the moratorium. Because of the Canadian position, the Water Commission determined that it could not at that time justify the necessary project surveys without some agreement with Canadian officials.

The Association has held numerous meetings with federal, state and local representatives to discuss the flooding problems. Initial meetings brought little results because of Canadian concerns and the moratorium. This moratorium does not, however, appear to preclude the improvements to Badger Creek. It states in part: "BE IT FURTHER RESOLVED that this order shall not apply to any legal drainage project designed by engineers employed by any federal, state or local governmental entity which is approved by the State Water Commission." At this point, the moratorium is still in effect and any project that is to be constructed appears to require approval from the State Water Commission and the appropriate Canadian authorities.

In 1982, the Association petitioned the Towner County Water Resource District to assist them in pursuing their goal to improve flooding conditions within this watershed. In February 1984, the Towner County

Water Resource Board met with representatives from the Devils Lake office of the U.S. Fish and Wildlife Service to discuss the cleanout of Badger Creek through areas currently under easement. The Fish & Wildlife Service requested surveys of the creek to evaluate the impacts of the proposed improvements on the easement areas. In the fall of 1984, the Board completed a cleanout of approximately 2½ miles of Badger Creek, from the border south, located outside the easement areas.

On March 18, 1985, the Towner County Board held a hearing on the establishment of an assessment district for Badger Creek. This assessment district would allow the Board to obtain the funding necessary for the improvements along the creek, and provide future funding for maintenance. This district was officially established in May 1985, and does not include any funding for the proposed Armourdale Coulee Diversion.

II. PURPOSE

This preliminary engineering investigation is intended to gather information to determine what can be done to improve conditions along Badger Creek and whether the lower reach of Armourdale Coulee can carry the flows which used to flow in its channel, but are now diverted into Rock Lake. The investigation is to include all the surveys necessary to develop a hydrologic model of the Rock Lake Watershed, and hydraulic models of Badger Creek and Armourdale Coulee to establish their capacity to carry flows. The investigation will also include an evaluation of the impacts of the proposed projects, on flows and durations in flood prone areas.

III. SCOPE

This investigation is comprised of a hydrologic study model of the Rock Lake Watershed and a hydraulic study model of Badger Creek and Armourdale Coulee. The hydrologic model will be used to analyze the existing conditions of the watershed and determine the peak flows that occur at various points within the watershed. This will include an evaluation of the changes that may occur to peak flows and durations due to the construction of the potential projects. The hydraulic study of Badger Creek and Armourdale Coulee will be used to estimate capacity to carry flows and to review possible improvements.

After all the information obtained from these models has been reviewed, recommendations on alternatives will be made to the Towner County Water Resource Board. These will include recommendations on which projects should be pursued. Also, an explanation will be made of changes that may occur in flood prone areas and in Canada. All information obtained will be available to the Board for use in developing a water management plan for the Rock Lake Watershed.

IV. HYDROLOGY

A hydrologic analysis of the Rock Lake Watershed was performed using the HEC-1 computer model developed by the U.S. Army Corps of Engineers. This model is used to determine peak discharges and flow volumes for various frequency storms and watershed conditions. It formulates a numeric hydrologic model of the watershed basin based on the following data: the amount of rainfall or snowmelt runoff, the temporal distribution of this runoff, soil type, land use, and the hydraulic characteristics of basin channels and drainage areas. The HEC-1 model is designed to calculate the surface runoff of the watershed by representing the basin as an interconnected system of hydrologic and hydraulic components. A single component may represent a hydrograph from subbasin runoff, combined subbasins, channel routing or a reservoir routing.

The first step in the analysis was to delineate the watershed boundary on a topographic map. In this case, the USGS 7.5' topographic maps of the area were used. Once the watershed was delineated, the watershed basin was divided into a number of subbasins. These subbasins are areas of similar hydrologic features. Their limits are most often determined by changes in hydraulic conditions or by defining areas of specific interest or function. Figure 4 shows the outline of the Rock Lake Drainage Basin.

The North Dakota Hydrology Manual, developed by the Soil Conservation Service, was then used to determine the data required for input into the HEC-1 computer model. After the subbasins were determined, the time of concentration for each was calculated. The time of concentration is the time it takes for a raindrop falling at the most distant point in the subbasin drainage area to reach the outlet point of the subbasin. Profiles of the stream channels were then drawn to determine their gradients. From this, average flow velocities for specific reaches were calculated and used to determine the travel time for each basin. Next

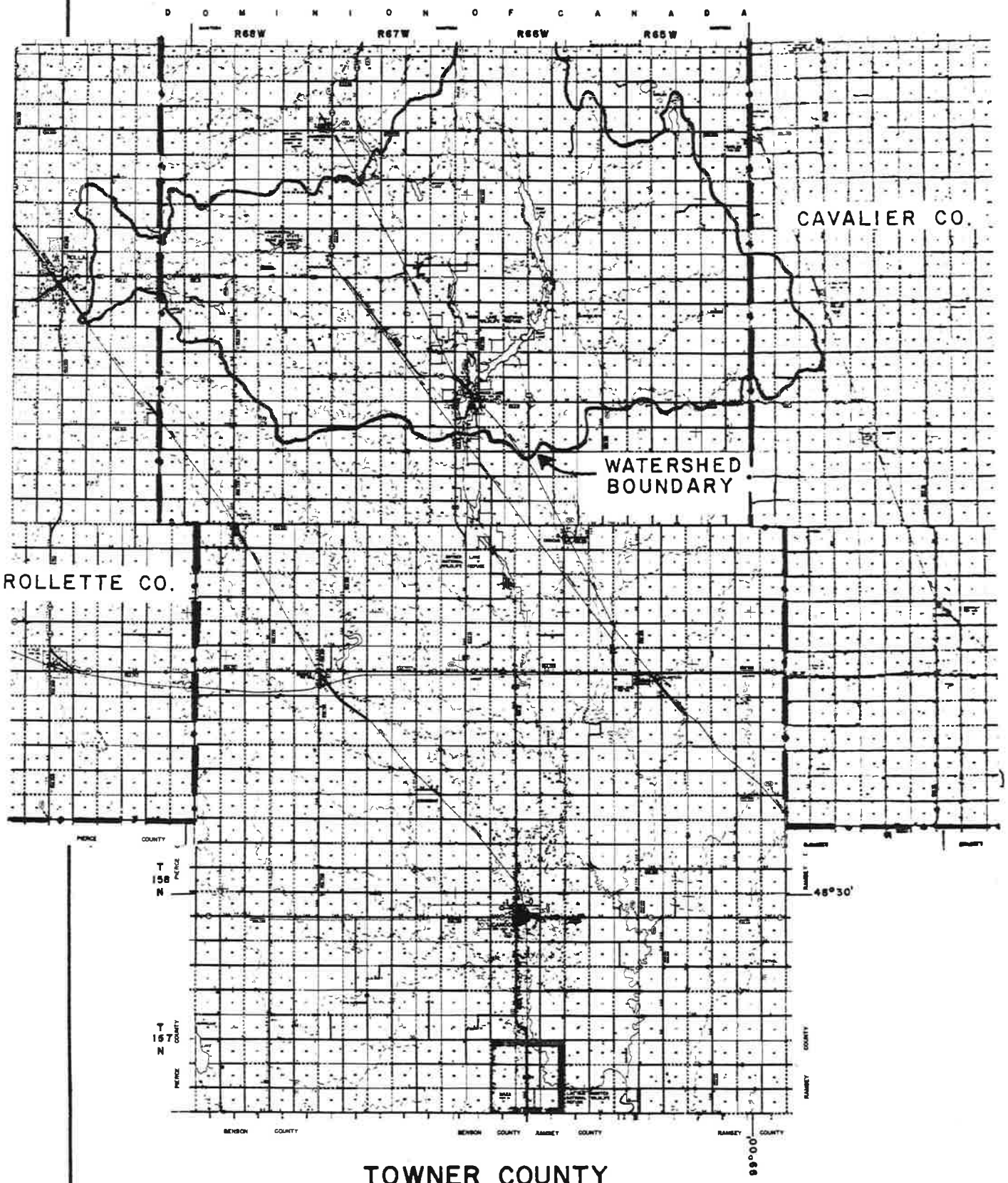


FIGURE 4
ROCKLAKE
DRAINAGE BASIN

the land use and soil type of each basin was evaluated. This information was then used to determine a curve number which represents the infiltration characteristics of each subbasin. The precipitation for a given event was then selected based on the watershed's location and adjusted to consider the ponding of water within the subbasin. All of this data is then entered into the HEC-1 model to determine the flows for various hydrologic events.

The hydrologic data for each situation investigated in this report is used in a comparison with existing conditions. For this reason, the information obtained from the models will not be described here, but will be discussed in the various sections of this report to which they apply. Appendix C includes tables of the data obtained from the HEC-1 hydrologic model.

V. BADGER CREEK IMPROVEMENTS

A. Existing Conditions - Phase I

One of the first goals of the Rock Lake Flood Control Association was to improve the outlet conditions along Badger Creek. In 1984, the Towner County Water Resource Board decided to proceed with a cleanout of Badger Creek rather than attempt major channel modifications. This would allow the Board to implement the project sooner and without the requirement for a state permit. This proposed cleanout from the north end of Rock Lake into Canada will be considered as Phase I.

Initially, the investigation agreement for this report was developed with the intent to review existing hydrologic and hydraulic conditions, and to consider possible channel improvements. Considering the actions taken by the Towner County Board regarding Badger Creek, the intent has been changed to reflect the proposed cleanout. The investigation will now review the existing conditions, prior to 1984, and evaluate the impacts of the proposed channel cleaning to provide the Board with the necessary information to continue the planning of the project.

Currently, Badger Creek is silted in and clogged with vegetation, reducing its effectiveness in removing floodwaters from Rock Lake. The proposed cleanout consists of the re-establishment of an adequate channel gradient comparable to conditions prior to sedimentation and vegetation. This will be completed by the removal of sediment and obstructions to flow along the natural channel from Rock Lake into Canada. It is estimated that this will require cuts ranging from 1 to 2 feet. The current design calls for a slope of 0.0002 ft/ft, and 2:1 side slopes. The proposed bottom width from Rock Lake to the confluence of Badger Creek and Armourdale Coulee is 30 feet. The remaining portion of Badger Creek to the border has a proposed bottom width of 36 feet.

Considering the improvements implemented in 1984, there are two remaining areas along Badger Creek that require cleaning for the completion of the proposed Phase I project. The first of these areas lies

along Badger Creek from the north end of Rock Lake to its confluence with Armourdale Coulee. The majority of this is covered by Fish and Wildlife easements. Currently, the information relating to the proposed cleanout has been given to the U.S. Fish and Wildlife Service for their review. Because of the easements, it may be necessary to reduce the bottom width of the proposed cleanout in some areas to prevent any violation of the easements.

The second area is along Badger Creek in Canada which requires a cleanout in order to provide for an adequate channel gradient. Meetings were held with Canadian officials in 1984, and again in January of 1985, to discuss these areas. Presently, they appear to be receptive if improvements are made into Canada for a distance of about 17,000 feet. This distance was requested by the Canadian farmers to reduce some of the flooding problems they have suffered.

As outlined in the introduction there are several specific areas that should be addressed when considering flooding in the Rock Lake area. Each will be addressed separately beginning at the most upstream area.

B. Armourdale Diversion

This area is located along the channel into which Armourdale Coulee was diverted with the establishment of the Rock Lake National Wildlife Refuge. This channel flows into the western portion of Rock Lake. Since the channel is very flat, the effects of flooding are primarily the result of the water elevations in the refuge. The reservoir that affects this area is located west of the City of Rock Lake and on the west side of the roadway leading north from the city. This reservoir will be referred to as the Western Rock Lake Reservoir. The only impact from Phase I on this area is a slight improvement in water elevations described in the next section.

C. Western Rock Lake Reservoir

The Western Rock Lake Reservoir is located as outlined in Section V-B and is approximately 2 miles upstream from the refuge dam as shown in Figure 5. The fluctuations in elevation that occur behind this roadway are greater than those occurring at the refuge dam. This prompted the selection of this site as a controlling reservoir in the hydrologic model. The concern at this reservoir is that existing conditions are such that water frequently overtops the roadway or control. Considering the size of the refuge spillway, the remaining area of Rock Lake downstream from this roadway was considered as a single reservoir for modeling purposes.

The data obtained from the HEC-1 hydrologic model indicates that the only impact of the Phase I improvements is on flooding that occurs during snowmelt events. This impact is the result of the lowering of backwater conditions as Rock Lake downstream recedes at a faster rate from its improved outlet conditions. The reduced backwaters result in a reduction in the number of days in which the Western Reservoir is at or below elevation 1530 msl. This reduction ranging from 2 days at 1530 to 6 days at 1528.

The impact of Phase I on reservoir discharges shows only minor increases during snowmelt. These account for the reduction in durations at the lower elevations. The peak discharges and maximum elevations remain unchanged. With the roadway overflow elevation at approximately 1532 msl, the roadway is overtopped on all events, except the 10-year rainfall, and would receive no benefits from Phase I.

D. Rock Lake

The flooding situation near Rock Lake proper is the largest area of consideration. This flooding occurs from backwaters along small inflowing creeks and in low lying areas near the lake, primarily to the west. Approximately 6,000 to 7,000 acres of land are affected during major flood events. These flooded areas are shown on Figure 3. From

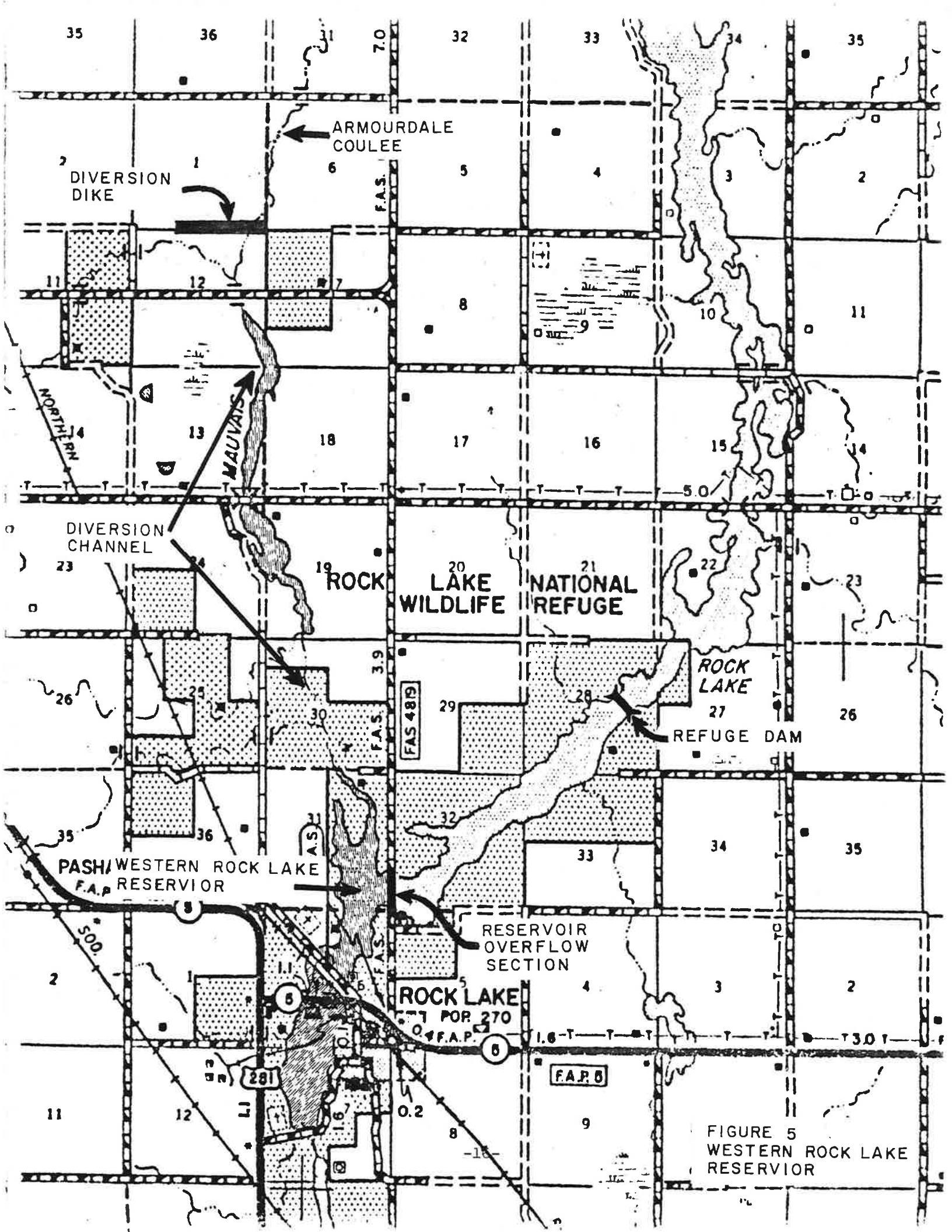


FIGURE 5
WESTERN ROCK LAKE
RESERVIOR

historical records, major flooding begins when the level of the lake reaches approximately 1528.5 msl.

The results from the Phase I improvements appear to be significant (See Appendix C). The time period in which the flooded lands in the Rock Lake area are inundated is reduced on various events and elevations from 3 to 11 days. The effect of the project on the maximum elevation attained by Rock Lake, however, is not significant, with a reduction of only about 0.2 feet. The reason for this is that inflows occur over a relatively short period of time when compared to the capacity of the outlet to remove these floodwaters. The waters flowing into the lake are stored, resulting in the high lake elevations, and then released at a much slower rate. Phase I appears to provide for improved removal conditions, though it does not increase flood protection. The result is that flooding will still occur, however the duration will be reduced. An area-capacity curve for Rock Lake is shown in Figure 6.

The reduction in flood duration appears to be the most important benefit of Phase I. Considering that flooding begins to occur at about 1529 msl level, only minor flooding occurs on the 10-year rainfall event. All other events would result in what could be considered serious flooding. As noted, the major floods occur primarily during spring runoff. Using the 25-year snowmelt as an example, the flood duration is reduced by 7 days. This reduction relating to elevation 1528.5 is illustrated in Figure 7.

A possible problem created with the more efficient removal of waters from Rock Lake is increased peak discharges into Badger Creek. These changes ranging from 22 to 35 percent will be addressed in the next section.

The elevation-discharge curve for Rock Lake was developed using the HEC-2 hydraulic model of Badger Creek from the north end of Rock Lake to the Canadian Border. The HEC-2 model uses cross-sections, slopes, reach lengths, crossings, and given channel conditions to determine the water surface profile along a watercourse.

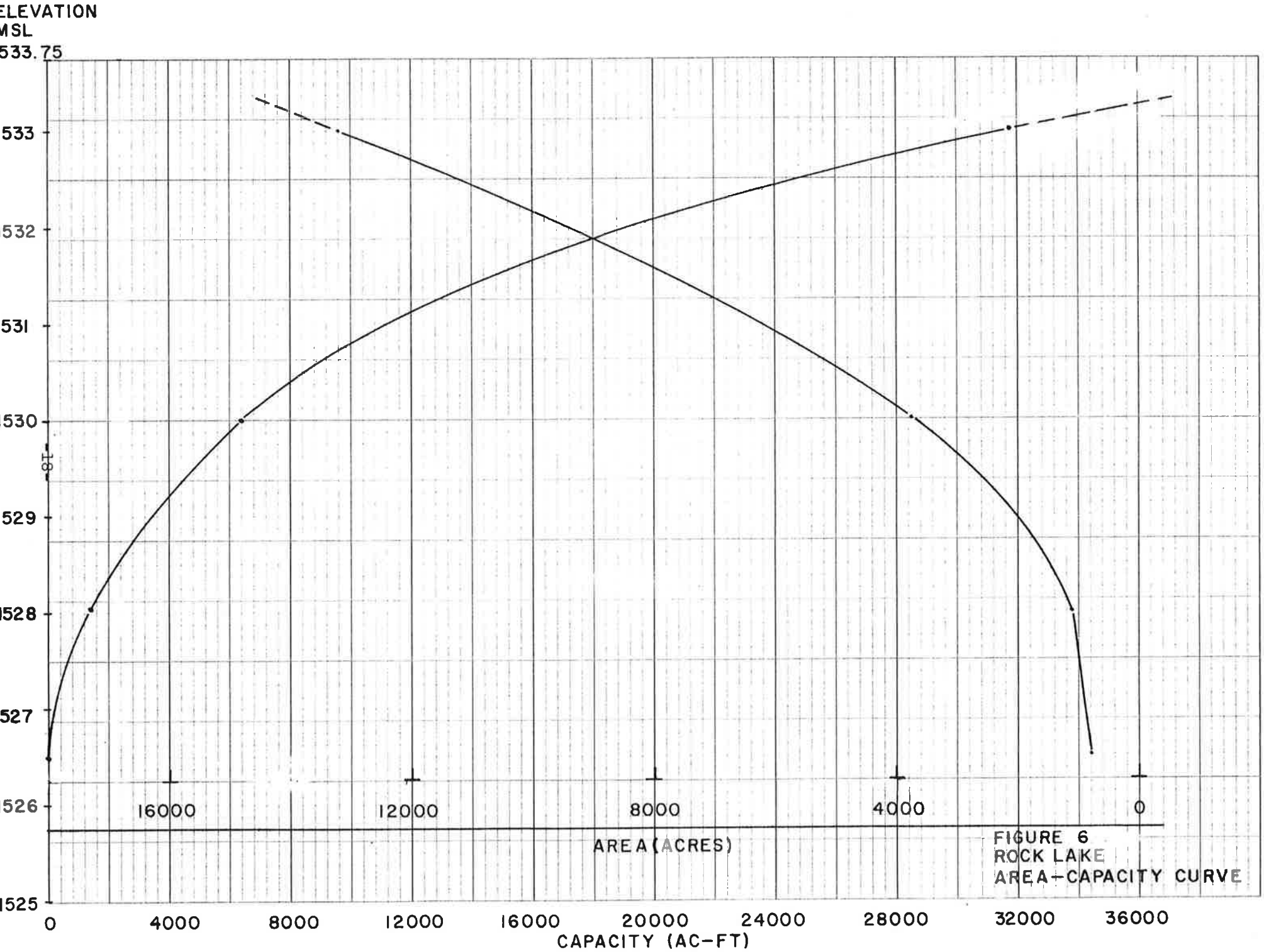
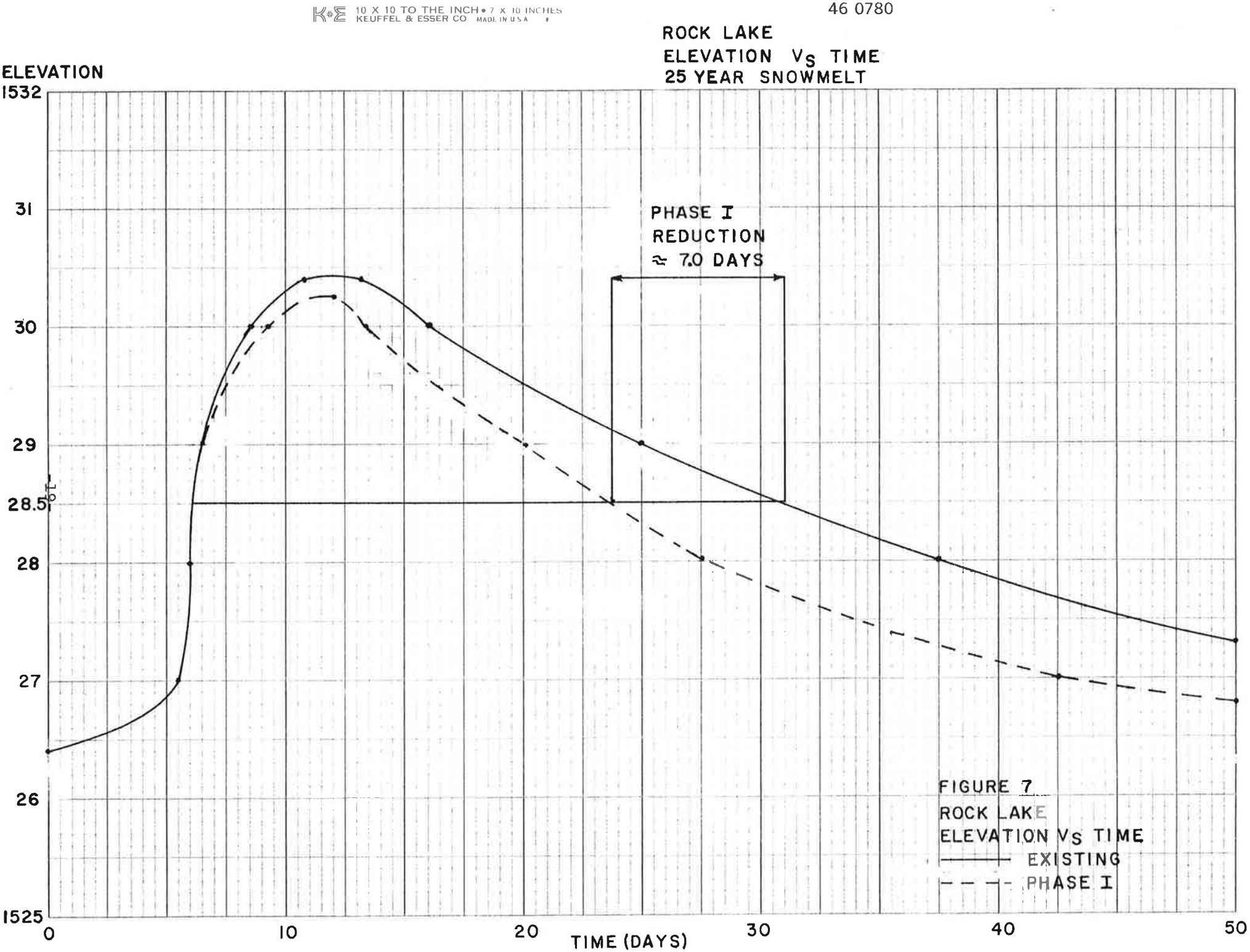


FIGURE 6
ROCK LAKE
AREA-CAPACITY CURVE



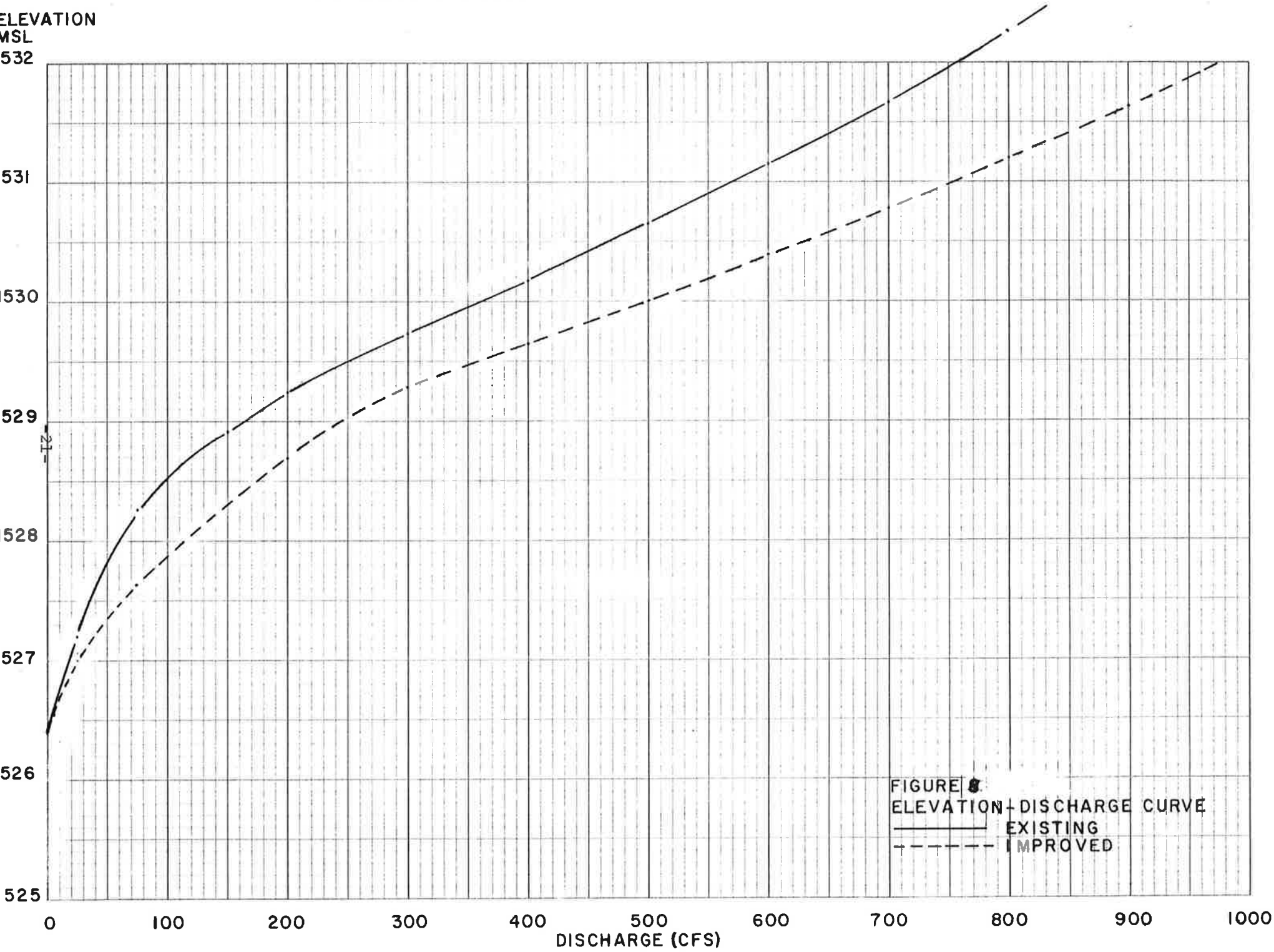
Badger Creek was evaluated for various flows under both existing and improved (Phase I) conditions, to determine the elevations that occur on Rock Lake for a given discharge into Badger Creek. The starting elevation for Rock Lake was set at 1526.4 msl, based on preliminary surveys. The elevation-discharge curves for existing and Phase I conditions shown in Figure 8 illustrates the improved removal efficiency of Badger Creek.

E. Badger Creek

This portion of Badger Creek is approximately seven miles in length, beginning at Rock Lake and proceeding north to the Canadian Border. As outlined in the previous section, Phase I results in increased peaks from Rock Lake into Badger Creek. The HEC-2 model was used to analyze the effects of these increases. A review of this model indicates that even though the peak flows are increased there will be no stage increases. In fact, in some locations the stages are actually reduced by the improved channel conditions. On the larger events, there were no significant changes in the maximum flood elevations from existing conditions.

Another effect of the increased flows is a change in flow durations. Some durations will be reduced and some increased by the removal of a larger volume of water during the increased durations of higher discharges. This is illustrated in Figure 9, which shows the discharge hydrographs for Rock Lake on the 25-year snowmelt.

Badger Creek can carry 120 cfs within its banks to its confluence with Armourdale Coulee, and from 140 cfs downstream to the Canadian Border. There are some low areas that are flooded at this level, however, they are inundated during even small flows. After construction of the Phase I improvements, Badger Creek should handle 140 cfs to the confluence, and 140 cfs to the Canadian border, before similar flooding occurs. Using these in-bank flow capacities, Figure 9 shows Phase I resulting in approximately a 2-day decrease in duration of overbank flow.



ROCK LAKE
DISCHARGE HYDROGRAPH
25 YEAR SNOWMELT

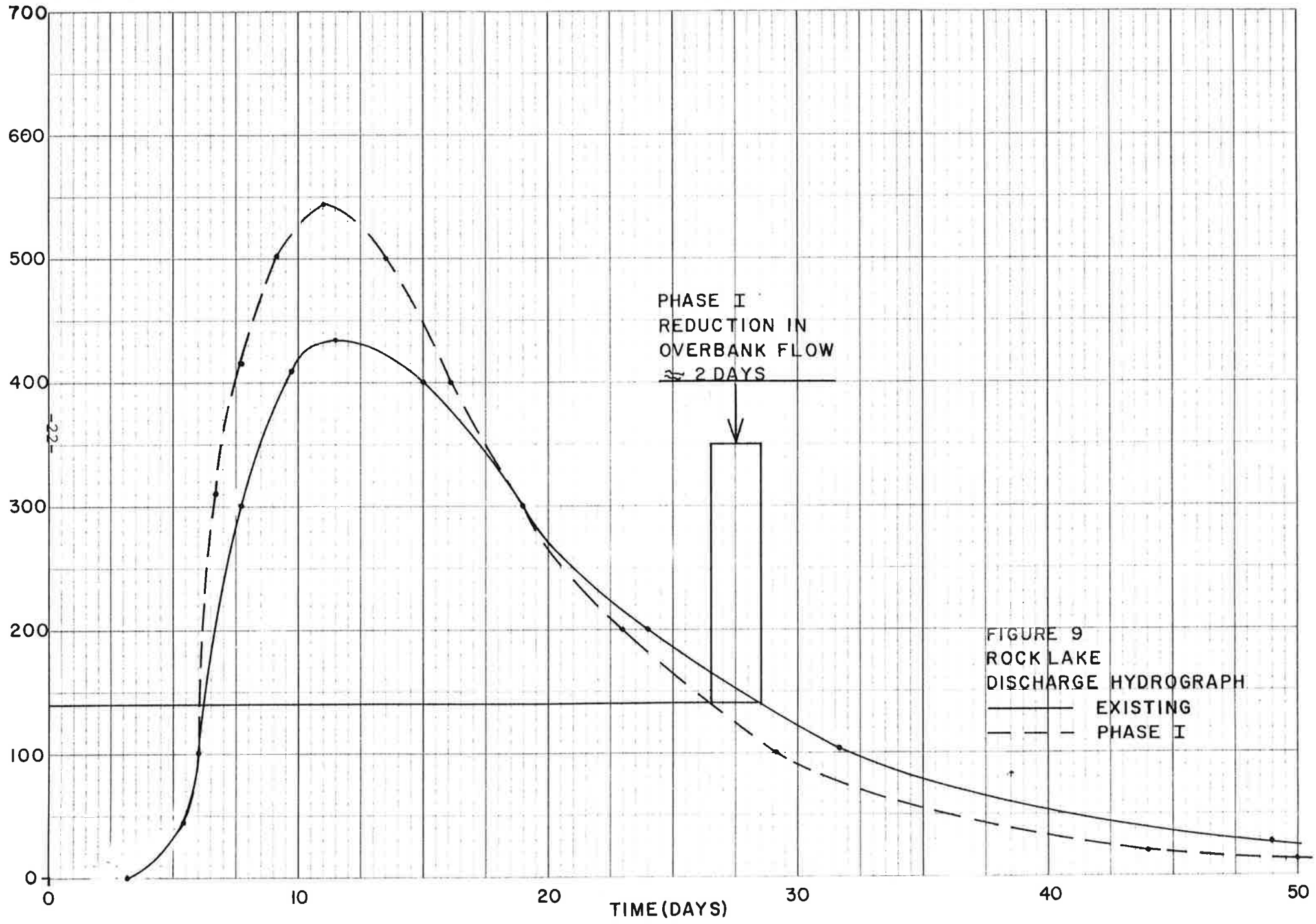


FIGURE 9
ROCK LAKE
DISCHARGE HYDROGRAPH

The major increase in peak flows on Badger Creek occurs only in the area between the north end of Rock Lake and its confluence with the Armourdale Coulee channel. At this point, increases in peak flows decrease to about 6 percent at the Canadian Border (See Appendix C). The impacts along this portion of the creek from the increased peaks and flow durations are not significant. With the improvements in place there are no stage increases and the duration impacts are minimized by improved flow conditions and decreased durations in overbank flow. The changes in the 25-year snowmelt hydrograph at the Canadian Border are illustrated in Figure 10.

F. Canadian Border

Probably the most important concern to be addressed by this project is the impact that Phase I will have on the flows at the Canadian Border. The Canadians have expressed their concern over increased flows and probability of flooding resulting from this project. Their concerns are not limited to Badger Creek, but also include the Pembina River. Recently, the Canadian officials have been willing to discuss the improvements to Badger Creek, if several items were considered. These included a complete study of the Rock Lake Watershed to evaluate the impacts on flows that this project would have. The second is possible improvements to areas along Badger Creek on the Canadian side to improve flood conditions in these areas. At a recent meeting, they anticipated that these improvements would include a channel cleanout of approximately 17,000 feet.

The hydrologic data shows that increases in peak flows from about 6 to 9 percent can be expected from the implementation of Phase I. Due to the timing of the watersheds near this area, the peak flows into Canada are not the direct result of discharges from Rock Lake. The discharges from Rock Lake tend to follow the downstream watershed peaks and have a greater impact on the duration of flows rather than the peaks, as illustrated in Figure 10.

HYDROGRAPH
AT CANADIAN BORDER
25 YEAR SNOWMELT

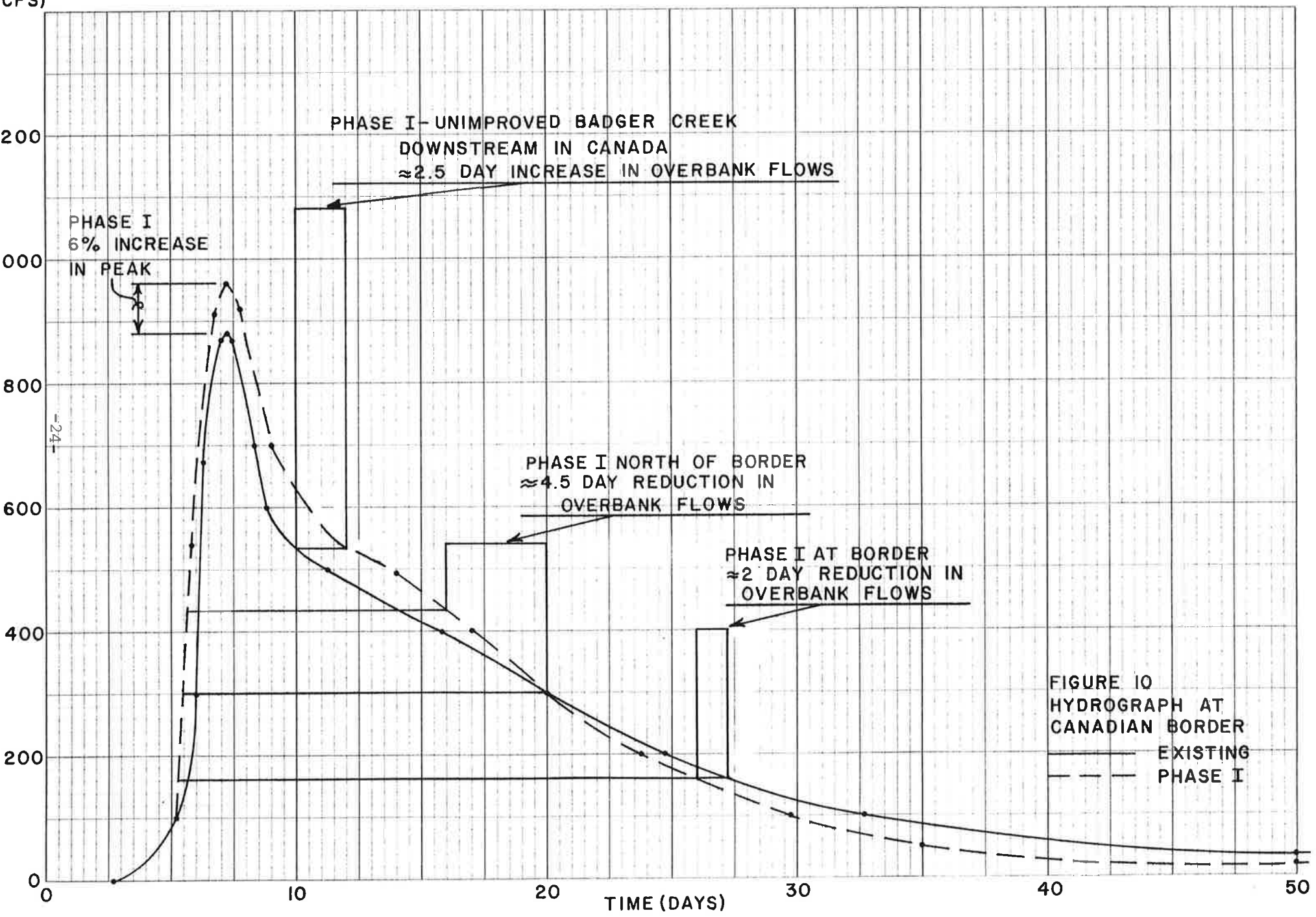


FIGURE 10
HYDROGRAPH AT
CANADIAN BORDER

Considering the channel capacity of 140 cfs through this area, unchanged from Phase I, there is an additional reduction in duration of overbank flow of approximately 2.5 days on the 25-year snowmelt, as compared to Phase I (Figure 13). It should be remembered that Phase I did not impact the peak stages in this area of the creek. The improvements negated the impacts from the increased flows and the total flood duration as stated was actually decreased. The reduction in overbank flow is increased flood protection provided by Phase II. The decrease in total flow duration may also be a benefit in some areas for maintenance or other purposes.

At the point where Badger Creek combines with the newly diverted Armourdale Coulee, the impacts become of some concern. At this location, the peak flows increase 44 percent on snowmelt and 48 percent on rainfall. The 25-year snowmelt hydrograph at the Canadian Border is shown in Figure 14. The increases resulting from the diversion could cause major problems along the creek. These increased peak flows would result in peak flood stage increases of 0.2 to 0.5 feet for a period of two to three days. Without adequate maintenance of the improvements, serious problems could result.

A review of the overbank flow conditions indicates a decrease of an additional 2 days, on the 25-year snowmelt, when compared to Phase I (Figure 14). The impacts to this area will not be an improvement over existing conditions nor those after the Phase I project. The unimproved downstream now become of greater concern than they had been under the small increases in flows resulting from Phase I.

F. Armourdale Coulee

The diversion of Armourdale Coulee into its original channel raises the question of its capacity to carry these flows. A review of existing conditions shows a capacity of 120 to 270 cfs, depending upon where the bank conditions are defined. The bank locations appear to be located at the 120 foot cfs level, however, there is a sharper bank rise occurring near the upper level. The width of the flows is over 900 feet at the

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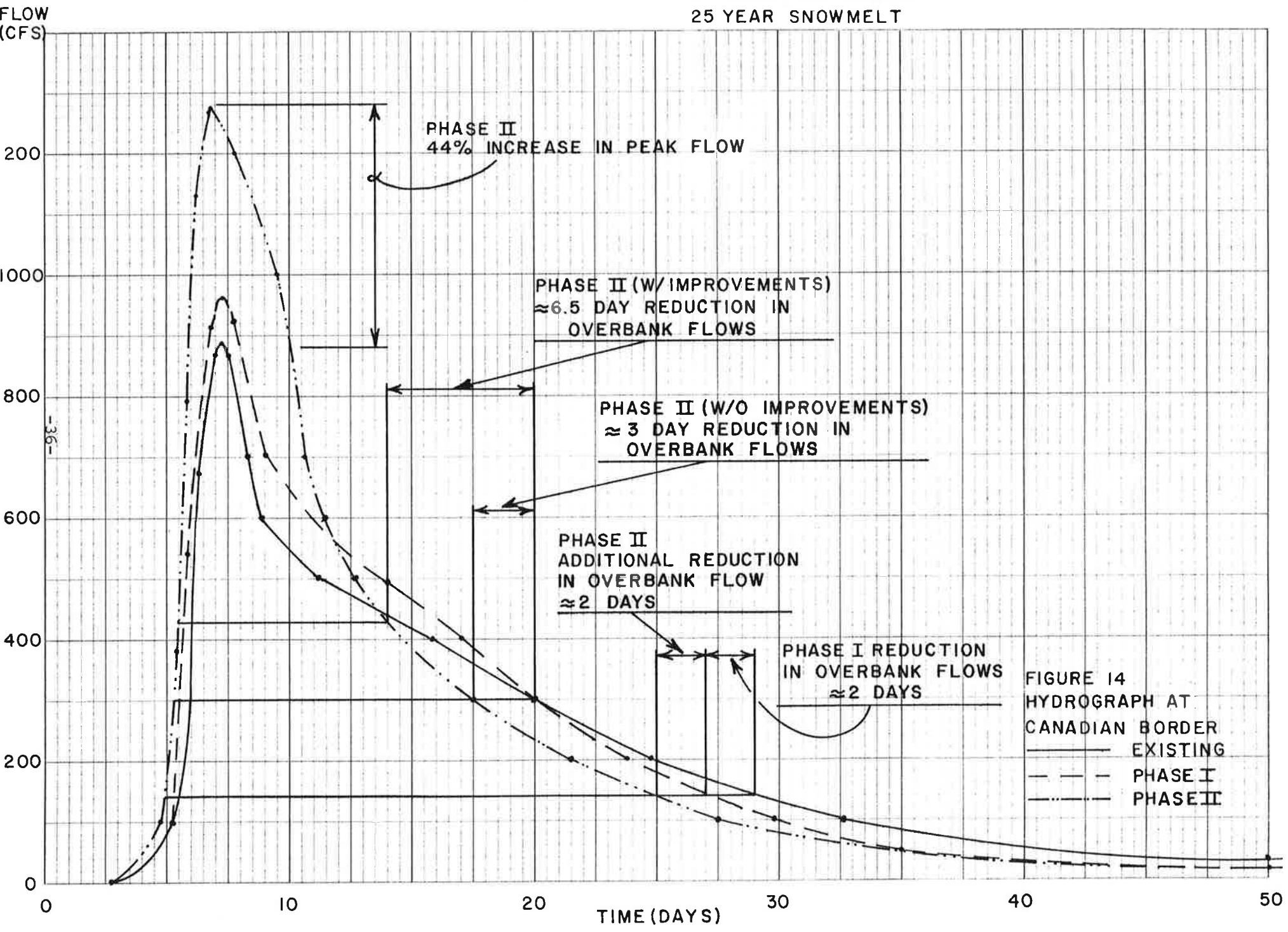


FIGURE 14
HYDROGRAPH AT
CANADIAN BORDER

upper level and is considered excessive. If the channel were improved using the same criteria as that used for Badger Creek, 30-foot bottom width and 2:1 side slopes, the capacity of the creek is improved to around 150 cfs at the lower level to 340 cfs at the upper level.

The hydrologic study indicates that flows from the diversion are in excess of these channel capacities on all events. A summary of these flows is given in Table 2, and reflect the diverted flows and not the peaks that would occur at the confluence with Badger Creek. These flows could be passed through this area, but not without the flooding of a large area along the coulee, presently protected by the existing diversion. There would also be an increase in the duration of flows where now there are only local flows in this channel.

TABLE 2

Peak Flows (cfs) at Point of Diversion
for Armourdale Coulee

Rainfall		Snowmelt
Event	Q(cfs)	Q(cfs)
100	740	560
50	560	430
25	430	330
10	300	-

Reviewing the possible flooding that could occur, it appears as though about 3200 feet of Armourdale Coulee would be affected by increased flooding. This is compared to the 1600 feet presently impacted along the existing diversion channel. Presently, this portion of Armourdale Coulee is not adequate to handle the diversion flows, and without significant improvements would still be inadequate. A portion of the 3200 feet floods under present conditions, Figure 3, and would continue to flood after Phase I, but conditions would be greatly aggravated by Phase II.

Because of the problems that arise with the Phase II project, a detailed cost estimate was not completed. The costs, however, would be comparable on a per mile basis with the Phase I improvements, with the exception of the removal of the existing dike and the construction of a diversion dike to the south.

G. Canadian Border

The most significant impact of Phase II at the Canadian Border is the increase in peak flows. The duration of these flows and their potential for increased flooding and flood stages is of concern.

The snowmelt conditions show a greater impact from flow durations than rainfall with increases of 1 to 3 days of flow over existing peak conditions. This is significant when considering flood potential even on the improved portions of this channel. The flood stages through this area would increase in the range of 0.4 to 0.8 feet, with the improvements. This based on the previously outlined channel capacities. There is a definite need for further information along the Canadian reaches to make a more detailed evaluation of the impacts from Phase II.

The data indicates that without the channel improvements the overbank flow duration would be reduced approximately 3 days, as illustrated in Figure 14. With improvements the duration is reduced by approximately 6.5 days by Phase II as compared to 4.5 days under Phase I. This reduction in duration occurs directly from the increased volume removed during peak flows, Figure 14, which could be more damaging than the improvements from the duration change.

H. Downstream Canadian Impacts

The changes in the overbank flows from the Phase II project for the downstream areas in Canada are given in Table 3. This data shows that in all cases except one, Phase II will result in an increase in the duration of overbank flows. When compared to the impacts from Phase I, Table 1, the changes are that now all of the rainfall events will result

in increased overbank durations whereas, before only the 100 and 50-year rainfall events had this impact. Snowmelt conditions are not affected.

TABLE 3

Rainfall - Snowmelt Overbank Durations
Downstream Badger Creek in Canada 1/
(Approximate Duration in Days)

Event	Rainfall			Snowmelt		
	Existing	Phase II	Difference	Existing	Phase II	Difference
100	3	5	+2	12	11	-1
50	2	4	+2	7	8	+1
25	2	3	+1	4	6	+2
10	0	2	+2	-	-	-

1/ Channel capacity estimated at 575 cfs.

The increases in peaks at this point are considered the same as those at the border. These peaks would result in increased flood stages based on preliminary data, ranging from 1.2 feet on the smaller events to 0.6 feet on the larger events. This is significant increase and until further studies are done along this reach of Badger Creek, the project's impacts remain a problem that need to be considered in more detail.

With the Canadian concerns extending to the Pembina River, the impacts of the Phase II project should be reviewed with a complete model to the Pembina River. The development of an expanded model would include all the necessary data to complete the HEC-1 hydrologic model to the Pembina River and to complete HEC-2 hydraulic model of Badger Creek through this reach, along with gauging information on the Pembina River. The data that is available for this reach of Badger Creek is preliminary in nature and is not sufficient for a more detailed investigation.

VII. SUMMARY

A. Phase I - Summary

The first goal of the Rock Lake Flood Control Association was to improve the flow conditions along Badger Creek. The proposed cleanout of Badger Creek, known as Phase I, consists of the cleaning and re-grading of the creek from Rock Lake to the Canadian Border and several miles into Canada. In 1982, the Association requested the Towner County Water Resource District to establish an assessment district for Badger Creek. This district was voted on and approved in May 1985.

With the creation of this district, the Towner County Board has established a method of financing for the Phase I project. It was the original intent of the investigations agreement to develop preliminary cost estimates, however, the Board has, with the development of the assessment district, determined its own cost estimates. For this reason no estimates were prepared for this report.

Phase I will have little impact in the area along the Armourdale Coulee diversion channel with the exception of a several day decrease in flood duration on snowmelt runoff. The additional drawdown during snowmelt occurs in the lower discharge ranges and is not large enough to affect the flooding of the roadway leading north out of the City of Rock Lake. Therefore, the roadway would receive no benefits from this project. In order to improve the conditions at this roadway, it will probably be necessary to improve the capacity of the culverts; the extent of which would need to be investigated.

The majority of the benefits provided by Phase I occur in the Rock Lake area. The reduction in flood duration is considerable, ranging from 6 to 7 days, based on the 1529 msl flood elevation. The maximum elevations show only minor reductions. This means that the areas currently flooded will continue to be flooded only the duration of the flood will be reduced.

The cleanout of Badger Creek causes increased discharges from Rock Lake. These do not result in significant impacts along the creek considering the Phase I improvements. There would be no increase in peak flood stages, however, some levels would have an extended duration. As a result, upstream from the confluence with Armourdale Coulee there would be a 2 to 4-day reduction in overbank flows.

Below the confluence, the peak discharges increase about 6 percent. When compared to the improved channel conditions to the border, these peaks result in no increase in peak flood stages. The overbank flow durations range from no change to a decrease of 4 days.

The peak discharges that occur at the border are not the result of increased discharges from Rock Lake. The discharges from the lake generally follow the downstream peaks and have a greater influence on the durations. The increases that do occur are more the result of the improvements from the confluence to the border than those leading back to Rock Lake.

At the Canadian Border the impacts from Phase I are similar to those just south of the border. The change in duration of higher flows and increased peaks cause little or no change in flood conditions. Overbank flows are reduced from 1 to 4 days on rainfall, and 5 to 8 days on snowmelt.

The downstream areas in Canada that are unimproved will have only minor impacts from Phase I. Based on preliminary data, the peak stages could be increased by ± 0.1 feet.

The duration of overbank flow in the unimproved reaches would increase in the range of from 1 to 3 days, on various events. A closer review of the channel may indicate that the increase in overbank flows would not result in any downstream impacts. As noted before, as Badger Creek flows into Canada, its channel becomes more and more defined and its capacity increases.

The increased peaks from Phase I do not appear to be as significant as the changes in duration. Also, due to the lack of detailed topographical data in Canada, the peaks on Badger Creek at the end of the improvements proposed by Canada were not computed. For the purposes of this report the flows computed are those that occur at the border. The downstream watershed to the end of the Canadian improvements would add approximately 12 square miles to the total drainage area. If data were obtained for other downstream areas, the HEC-1 hydrologic model could be extended to the Pembina River.

The impacts from Phase I south of the border would be a slight decrease in peak flood stages and an increase in duration of some higher stages. The channel improvements more than compensate for the 6 percent increase in peak flows. With the channel capacity being about 160 cfs, Phase I results in a decrease of approximately 2 days in the duration of overbank flow on the 25-year snowmelt (See Figure 10). With the proposed improvements on the Canadian side, Phase I has even less of an impact on overbank flow as will be addressed later.

The increase in duration of the higher flows results in the maintaining of slightly higher stages for a period of time. These stages are however, lower than what would have occurred under existing conditions. Therefore, their impacts are less significant than they may appear.

As Badger Creek enters Canada, its channel becomes more defined than that south of the border. This increases the in-bank flow capacity from a level of about 300 cfs, under unimproved conditions, to about 425 cfs under improved conditions. Because the larger change in flow capacity, it was necessary to evaluate the overbank flow conditions along this portion of Badger Creek, considering the increased capacity from the improvements. As shown in Figure 10, the reduction in overbank flow is a direct result of the channel improvements. The actual duration of overbank flow is reduced approximately 4.5 days, however, without the improvements, the duration would remain unchanged.

G. Downstream Canadian Impacts

Badger Creek downstream from the proposed Canadian improvements is of concern with the increased flows and peaks. A review of available data shows that the channel slope has increased to about 0.0005 ft/ft as compared to 0.0002 ft/ft up to this point. An analysis of the channel indicates that bank full conditions range from 450 to 520 cfs for a poorly maintained channel. Because of the steeper gradient, the channel conditions are probably improved over the previous areas, and bank full conditions are probably closer to 650 to 700 cfs. Further surveys may be necessary to more clearly define the capacity of this channel in Canada. This could be completed with the review of the proposed improvements in Canada and the continued development of this project.

Considering an average flow capacity of 575 cfs, the 25-year snowmelt conditions would result in a slight increase in duration of overbank flow (See Figure 10). Reviewing the hydrologic model specifically for 575 cfs, the durations changes range from a 1-day reduction, to a 3-day increase. This data is reflected in Table 1. These are not considered significant changes and a closer review of the channel conditions may indicate these flows to be within the channel banks or limited floodplain. Preliminary data indicates that as Badger Creek continues toward the Pembina River, that it continues to increase in size and the gradient improves.

TABLE 1

Rainfall - Snowmelt Overbank Durations
Downstream Badger Creek in Canada 1/
(Approximate Duration in Days)

Rainfall			Snowmelt		Event
Existing	Phase I	Difference	Existing	Phase I	Difference
100	3	6	+3	12	11	1
50	2	3	+1	7	8	+1
25	2	2	0	4	6	+2
10	0	0	0			-

1/ Channel capacity estimated at 575 cfs.

The increases in peaks do not significantly increase the flood stages that occur at this point. The increases of 6 to 9 percent are considered small when compared to the size of the hydrologic model and watersheds from which it was developed. Also, the peaks occurring at this point on Badger Creek, are not the result of the discharges from Rock Lake. The increase in peaks is related to the improvements to the downstream portions of Badger Creek and not those areas near Rock Lake itself.

It is important to realize that the proposed changes are only a cleanout of the existing channel and had the channel been maintained properly over the years, these changes would actually reflect the existing conditions.

VI. ARMOURDALE COULEE DIVERSION

A. Existing Conditions - Phase II

The second major goal of the Rock Lake Flood Control Association was to re-divert Armourdale Coulee back into its original channel; which joins with Badger Coulee about two and one-half miles south of the Canadian Border. In its present state, the coulee has been diverted by the construction of a three-quarter mile long dike approximately 4 to 5 five feet in height. The location of the dike is shown in Figures 2 and 5.

The dike, constructed in 1932 as part of the Rock Lake National Wildlife Refuge, has diverted all flows since then, with the exception of the 1949 spring flood. The thirty-three square mile watershed of Armourdale Coulee that was diverted represents approximately 33 percent of the total watershed and volume presently flowing into the Western Rock Lake Reservoir.

The diversion reviewed in this report will be a complete re-diversion of all Armourdale Coulee flows and will be known as Phase II. This project is considered the second portion of the proposed flood control project for Rock Lake. Therefore, Phase II as compared to the existing conditions is the result of the completion of both Phases I and II. The incremental changes from Phase II over Phase I would require a comparison of the two phases. Some brief comparisons will be made in this report where they are beneficial in describing the impacts from Phase II.

The diversion of Armourdale Coulee would require the removal or opening of the dike to allow flows to pass into the original channel. A problem arising from an attempt for a complete diversion is that after 50 years of diverted flows the southern channel is more defined than the original channel to the north; thus, creating a partial diversion situation similar to what existed prior to the construction of the dike, with the exception that the primary flows would be to the south. A complete diversion would require the diking of the southern channel,

along with improvements to the original northern channel.

With the probability that a complete diversion may not be acceptable, there may be the possibility for construction of a partial diversion. Because of the requirements for evaluating a partial diversion, it was determined that a review of this option was outside the scope of this investigation. A partial diversion is a complex situation that would have to be studied in more detail, and data that is available is not adequate for such a study.

Because the various areas subjected to flooding were previously defined in Section V, only the resulting impacts from the completion of Phase II will be addressed in the following sections.

B. Armourdale Diversion

The diversion of Armourdale Coulee into its original channel will result in a significant improvement to conditions along the existing diversion channel. With a complete diversion, the flows through this area would be reduced to only local inflows. As noted before, however, the diversion would not be complete without the diking of the south channel. The primary cause of flooding in this area is the backwater from the Western Rock Lake Reservoir. The effects of the Phase II project are therefore, reflected in the next section.

C. Western Rock Lake Reservoir

The impacts of the Phase II diversion on the duration of given elevations of the Western Rock Lake Reservoir range from a decrease of 2 to 10 days. The size of decrease being dependent upon the elevation and event (See Appendix C). The primary consideration here is the roadway leading north out of the City of Rock Lake. The Phase II diversion results in this roadway remaining dry through almost a 50-year rainfall and 25-year snowmelt event, whereas under existing conditions it is overtopped on anything greater than a 10-year rainfall. The remaining events show that the durations of the water remaining over this roadway are reduced from 2 to 3 days. This reduction in duration improves the

flooding situation along the diversion channel and around the reservoir. Figure 11 compares the effects of Phase II and Phase I on the 25-year snowmelt. At elevation 1530, Phase II results in approximately a 5.5 day reduction in flood duration. Phase I resulted in a 2-day reduction, but had no impact on the duration of flooding of the roadway.

The changes in maximum elevations obtained on this reservoir range from 0.2 feet to 0.7 feet. Figure 11 shows a 0.45 foot reduction on the 25-year snowmelt. The diversion also results in a significant reduction in the maximum discharges. These range from 21 to 48 percent less than existing conditions.

The peak inflows remaining unchanged from existing conditions indicate that the peaks are not the result of the 1932 diversion of Armourdale Coulee. The diverted flows tend to precede the peaks, reducing the available storage, thus increasing the durations and resultant peak discharges from the reservoir. The reduction in flood duration and reduced discharges is a direct result of the diversion of 33 percent of the watershed and inflows to this reservoir.

C. Rock Lake

As stated previously, flooding on Rock Lake begins at approximately 1529 msl. The decrease in duration of flooding from the completion of Phase II ranges from 1 to 10 days (See Appendix C). A comparison with the impacts from Phase I, Figure 12, shows on the 25-year snowmelt, a reduction in duration of 7 days and with the completion of Phase II, an additional 2.3 days. The general effect of the completion of Phase II, compared to Phase I on the duration of flooding is an additional reduction of approximately 2 to 3 days.

The peak flows from the Western Rock Lake Reservoir reach Rock Lake approximately 1 to 3 days behind the peak stages and discharges on Rock Lake. The volume of water that would be diverted by Phase II under existing conditions now reaches Rock Lake before it reaches peak stage.

46 0780

WESTERN ROCK LAKE RESERVOIR
ELEVATION Vs TIME
25 YEAR SNOWMELT

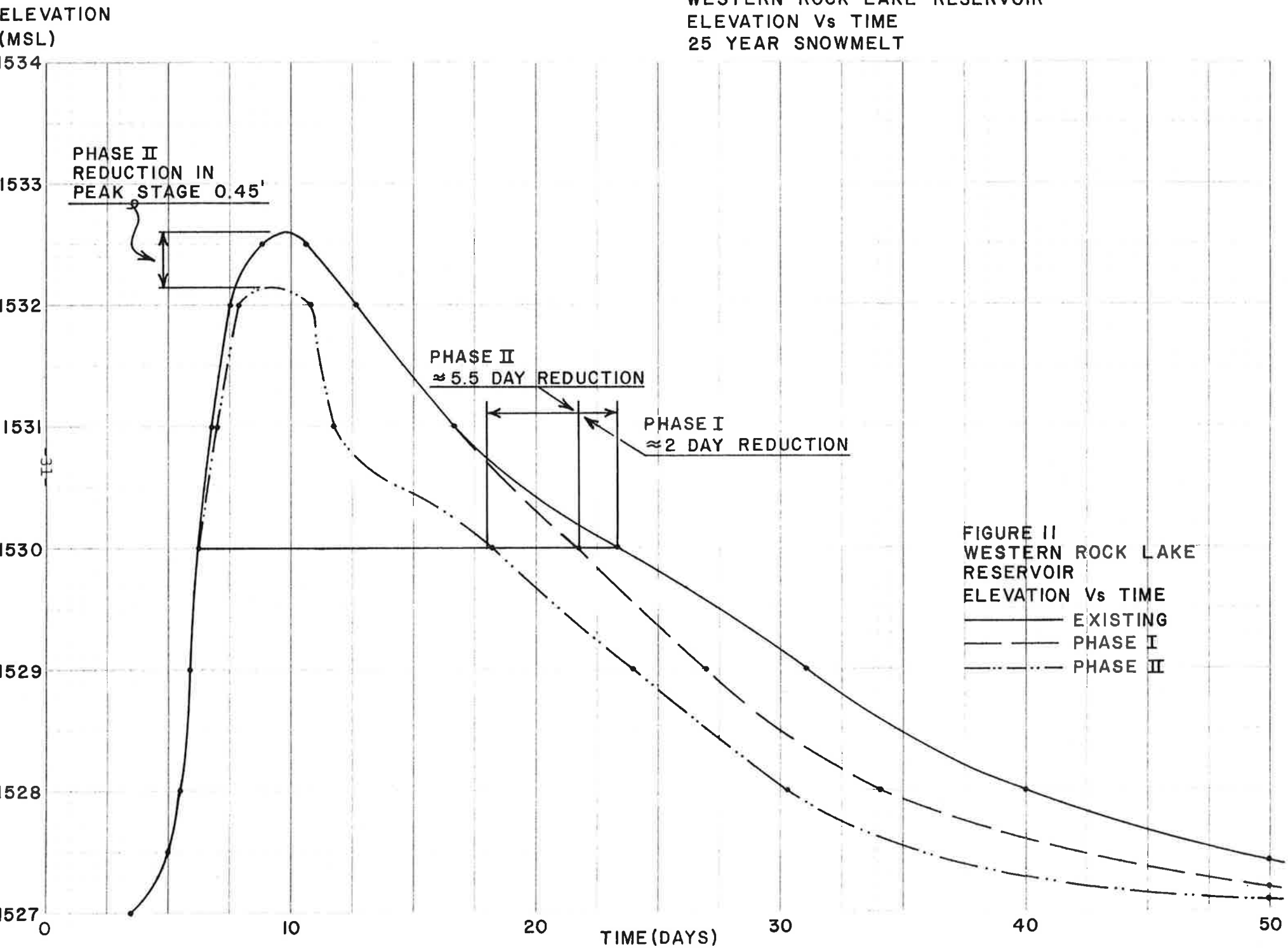
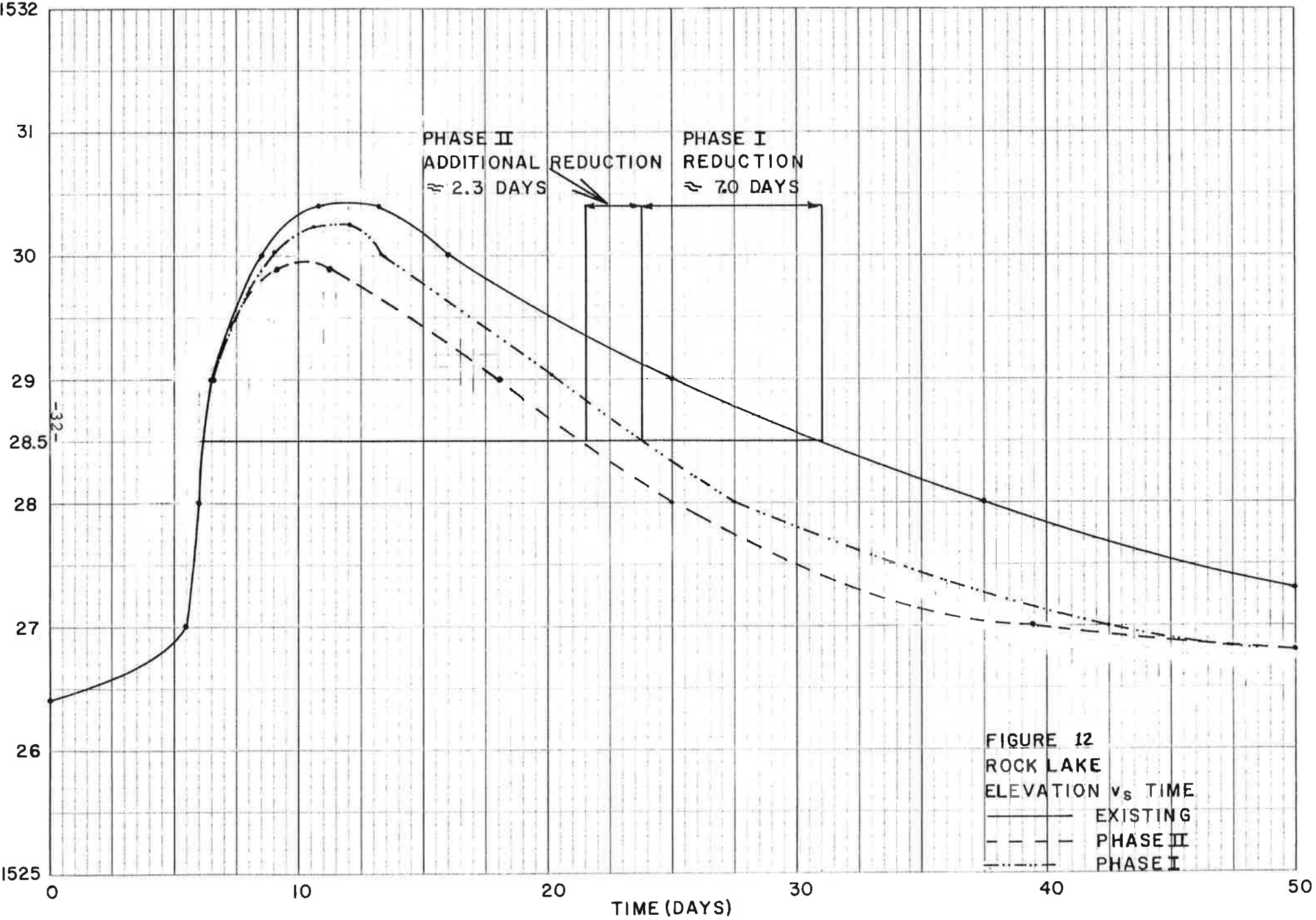


FIGURE 11
WESTERN ROCK LAKE
RESERVOIR
ELEVATION Vs TIME

ROCK LAKE
ELEVATION v_s TIME
25 YEAR SNOWMELT



This diverted watershed represents approximately 17 percent of the total volume of water reaching Rock Lake. The impact of the diversion on these flows can be seen a slight reduction in peak stages ranging from 0.2 to 0.5 feet, which in itself is not significant and is only a minor improvement over Phase I.

Phase II results in increased discharges into Badger Creek ranging from 7 to 41 percent over existing conditions. These increases are generally 50 percent of those from Phase I with the exception of the 25 and 10-year rainfall events. The increases from Phase I ranging from 22 to 35 percent. The effect is that there will be a general reduction in peak discharges into Badger Creek from Phase II. This is illustrated in the 25-year snowmelt hydrographs in Figure 12.

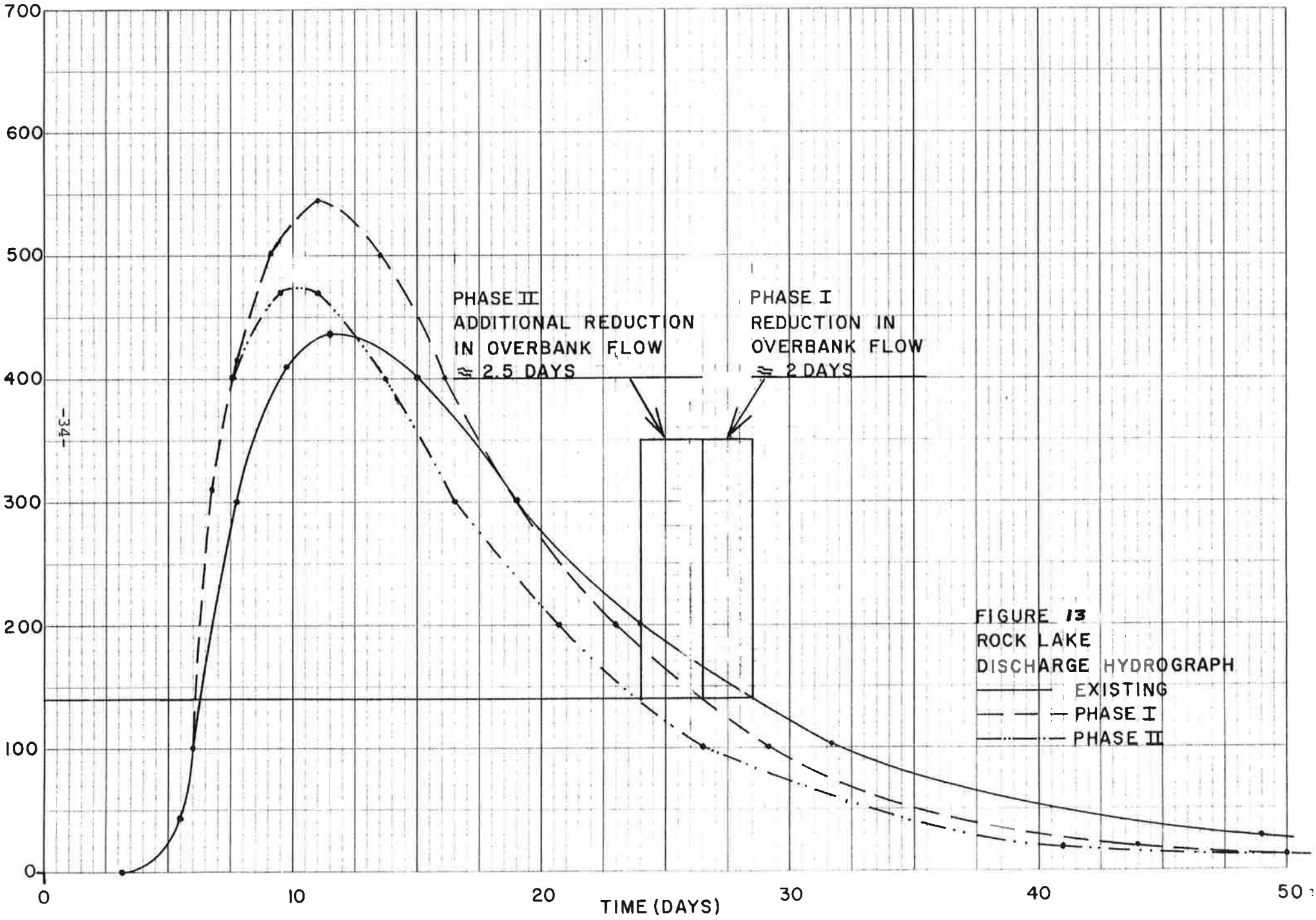
The reduction in volume of water flowing into Rock Lake not only reduces the peak discharges, but results in a reduction in the duration of discharges from the lake. The diverted water is no longer maintaining the elevation of the lake and the levels fall more rapidly. This effect occurs at the lower discharge and elevation ranges.

Under existing conditions, in the lower ranges, Rock Lake remains over elevation 1527 msl for more than fifty days in most cases. After Phase II, as can be seen in Figure 13, this duration decreases to near 40 days. This impact is not significant in the reduction of the initial flood, however, it would provide for additional flood storage in the reduced lake elevation.

D. Badger Creek

The reductions in discharges, into Badger Creek from Phase II over Phase I, result in a decrease in flood stages. This occurs along that portion of the creek from Rock Lake to its confluence with Armourdale Coulee. These stages also show a decrease in duration from those reflected in the completion of Phase I.

ROCK LAKE
DISCHARGE HYDROGRAPH
25 YEAR SNOWMELT



The Phase I project is a proposed cleanout to return Badger Creek to its condition prior to the siltation and growth of vegetation that has occurred over many years. The completion of the project will re-establish what would have been existing conditions had the creek been maintained. Therefore, any impacts from such a project would be those that would have occurred naturally with proper maintenance.

B. Phase II - Summary

The second major goal of the Rock Lake Flood Control Association was to re-establish the flows of Armourdale Coulee back into their original channel. Conceptually, this would reduce the flooding along the present diversion channel and on Rock Lake by reducing the volume of water flowing through the system. Presently, no efforts have been made to develop this project. This investigation report is an initial review of the capability of the original channel to carry the proposed diversion flows, along with the probable impacts of such a project.

The idea is to re-divert all the flows from Armourdale Coulee, presently flowing south, back into the northern channel. This would require the diking of the southern channel. Flows having been diverted for more than fifty years, the southern channel has become more defined and would be the primary channel for flows without the new dike. Because of the problems that would be created by a complete diversion, the project's feasibility remains questionable.

The improvements along the existing diversion channel would be limited. A complete diversion would limit flows through this area to only local runoff. The problem with flooding would still occur, however, since this area is flooded by the backwaters from the Western Rock Lake Reservoir. With the decreased volume of inflow from Phase II, the duration of flooding would be reduced.

A problem created by the diversion is flooding along the original Armourdale Coulee channel. With the capacity of this channel at approximately 150 cfs, with improvements similar to those on Badger Creek,

this channel is not capable of carrying the flows from the diversion. Prior to the initial diversion in 1932 flows would split in the diversion area. The limited capacity of the original channel reflects the split flow situation in that not all the flows from Armourdale Coulee flowed north or the channel would probably be better defined and have a greater capacity.

The flooding of the original channel would affect 3200 feet of channel compared to 1600 feet on the present diversion. The latter being flooded with or without the diversion. The lower portion of the original channel does flood, but Phase I would solve some of this problem. The peaks from this diversion measured just before the confluence with Badger Creek, show an increase of 230 percent. After combining with Badger Creek, the peak increases are reduced to 44 to 48 percent. These peak flows are a serious problem and are a major drawback for a complete diversion plan.

The Western Rock Lake Reservoir will have a decrease in flood duration of from 5 to 8 days at elevation 1529 msl, as a result of Phase II. This in comparison to Phase I which had no impact with the exception of a reduction on the snowmelt events.

The maximum elevations on the Western Reservoir are reduced from 0.2 to 0.7 feet. A direct result of the diversion of 33 percent of the watershed presently contributing to this reservoir. The reduced watershed does not, however, affect the peak inflows. Therefore, the peak inflows do not originate from the present Armourdale Coulee diversion. The diversion flows currently cause higher lake elevations and more frequent overtopping of the roadway. The reduced inflows and lower peak elevations increase the protection of the roadway to about a 50-year rainfall event where before only a 10-year rainfall event would not cause it to flood.

The impact of the Phase II project in the Rock Lake area is best shown by a comparison with Phase I. The addition of Phase II results in an additional 2 to 3-day reduction in flood duration at elevation 1529.

The effect is noted in the lowering of lake levels primarily at the lower discharge and elevation ranges. The more rapid decline in lake elevations is a benefit, providing for additional flood storage.

The peak discharges from Rock Lake on Phase II are only about one-half those resulting from Phase I, with the exception of the 25 and 10-year rainfalls. These improvements over Phase I results in a slight reduction of flood stages on Badger Creek. The total flow duration is reduced primarily at lower flow conditions, causing an additional reduction in overbank flows of two 2 to 3 days. The maximum elevations attained by Rock Lake are not affected by Phase II.

The impact of the diverted Armourdale Coulee flows on Badger Creek at their confluence is an increase in peak flows of 44 to 48 percent. Even with the improvements in place, the flood stages could be increased from 0.2 to 0.5 feet. The overbank flows on Phase II are reduced by one additional day or remain unchanged from Phase I.

At the border the increases in flood stages range from 0.4 to 0.8 feet with the improvements. The overbank flow conditions remain relatively unchanged from Phase I. The peaks that occur here and south of the border are maintained above the pre-project peak levels for 2 to 3 days. This is a direct result of Phase II, as the changes from Phase I were minor.

The main problem with Phase II is its impacts on the Canadian portion of Badger Creek that is unimproved. The increased peaks could cause increased flood stages of from 0.8 feet on large events to 1.2 feet on small events. This type of stage increase, with a 4-day increase in duration over existing peak levels, could cause serious flooding. If this project is to be considered further, there is a need to obtain more detailed information. A complete model to the Pembina River is necessary to evaluate the impacts of the Phase II project. Because of the problems with this project and the need for additional data, the recommendations for Phase II will be limited to suggestions for a complete review of the project's intent.

VIII. RECOMMENDATIONS

A. Phase I

The Phase I project has a variety of benefits. Most of the areas affected by the project will receive benefits. Those areas impacted and not benefitted show impacts that are not significant within the accuracy of the model. The potential problems are small and not considered significant.

With the project proceeding at the local level, it is recommended that the Towner County Water Resource Board continue to work for the completion of this project. After a complete review, there would appear to be no problems created by the project that should prevent its completion.

There are, however, several issues that need to be settled before construction on the remaining portions of the project can begin. The first is to resolve the issue of channel improvements and impacts in Canada. This investigation indicated that the improvements in Canada are an integral part of the Phase I project if it is to work effectively. These improvements would result in a significant benefit to those areas that are to be improved. The areas downstream from the improvements also would not be adversely affected by the construction of this project.

With the moratorium that is currently in place, it is recommended that the Towner County Water Resource Board develop an agreement with local Canadian Government Officials for the construction of the project and the improvements in Canada. A completed copy of this negotiated agreement should be sent to the State Engineer and the North Dakota State Water Commission before construction begins.

The second area that requires negotiation is along Badger Creek from Rock Lake to its confluence with Armourdale Coulee. This area is presently covered by numerous wildlife easements. An agreement should

also be developed with the U.S. Fish and Wildlife Service for work to be completed through these easement areas. The present position of the U.S. Fish and Wildlife Service is that they will not oppose the proposed project if the easements are not violated and a level is established for Rock Lake. If the easements are to be affected, mitigation of the impacts would be necessary.

It is recommended that the Towner County Board pursue the establishment of a level for Rock Lake through the State Engineer.

The Phase I project will provide benefits to those who are pursuing its implementation. The hydrologic models that were developed for this project are available to the local Board for the establishment of a water management plan for the Rock Lake Basin. The data will also be useful to analyze any future changes in the watershed for other projects that may be considered at a later time.

B. Phase II

The Phase II project presents serious problems. There are benefits to some areas, however the impacts in others are significant. The increased flooding and stages along the original Armourdale Coulee channel, and along Badger Creek, are a major problem. The data that is presently available is not adequate to completely evaluate the specific impacts of the Phase II project.

The Phase II project as currently proposed, is not recommended. With the problems of increased flooding it would create and the unknowns that have yet to be considered, the project is not sound and should not be implemented. It is recommended that if the Board still wishes to pursue the option of a diversion that it discuss other alternatives along with the total diversion option. Because the Phase II project is not recommended, no detailed cost estimates were developed. Improvements to the channel similar to those of Phase I, would be comparable in cost.

The primary benefits of the Phase II project are the protection of the existing diversion channel, and reduced impacts on the Western Rock Lake Reservoir. The existing diversion channel does benefit from the diversion though flooding in this reach will still occur from the backwaters of the Western Rock Lake Reservoir. This situation lends itself to the partial diversion alternative that could both reduce the flows in the existing diversion and those diverted into the original channel.

The roadway at the reservoir outlet does benefit from the Phase II project in the form of reduced inflows and volumes. This benefit would be reduced on a partial diversion alternative. Another alternative would be to provide for decreased flood duration on the present diversion channel and the reservoir by increasing the capacity of the culverts through the roadway to accommodate the flows. There may also be a limited benefit in the raising of the roadway to reduce some of the problems. Though this could compound backwater flooding of the diversion channel and the reservoir. The increased culvert sizes could affect the main portion of Rock Lake; the extent of which would need to be investigated.

The impacts on Rock Lake from Phase II are not significant and the changes reflected in a partial diversion would not greatly change the existing conditions after Phase I. The outlet portion of Badger Coulee would also note little or no change. The impacts of a partial diversion alternative would depend upon the amount of the diversion and would need to be evaluated.

The recommended solution for additional flood improvements beyond the implementation of the Phase I project are as follows: First, because of the expense involved in a detailed investigation of a complete or partial diversion it is recommended the Board complete Phase I and then address the need for additional improvements.

Secondly, if they feel improvements are still necessary it is recommended that they give first consideration to improving the capacity of the crossing at the Western Rock Lake Reservoir. This would be a

less costly alternative than the suggested diversions. It is recommended that even if the Board wishes to wait for further improvements that they remove the restrictions to flow that currently exist at this crossing. This alone would improve existing conditions.

As a final option, the Board could consider a complete investigation of the diversion alternatives. As was previously mentioned, this would require the obtaining of a larger amount of data, similar to that gathered for this report, to complete this investigation. This study would also take more time than the other alternatives which could be implemented more quickly and may provide for similar benefits at less expense.

October 7, 1982
SWC Project #1767

APPENDIX A

AGREEMENT

Investigation of Badger Creek
and Armourdale Coulee

I. PARTIES

THIS AGREEMENT is between the North Dakota State Water Commission, hereinafter referred to as the Commission, acting through the State Engineer, Vernon Fahy; and the Towner County Water Resource Board, hereinafter referred to as the Board, acting through its Chairman, Warren Anderson.

II. PROJECT, LOCATION AND PURPOSE

The Board wishes to have a study done of the ability of Badger Creek and the lower reach of Armourdale Coulee to handle flows. The purpose of this investigation is to gather preliminary information to determine what can be done to improve flow conditions along Badger Creek and whether the lower reach of Armourdale Coulee can handle the flows which used to flow in its channel but are now diverted into Rock Lake. Surveys done will be of a preliminary nature. If an alternative materializes, and a set of plans for construction are desired, the surveys would have to be expanded to include more detail.

Surveys along Badger Creek will start at the north outlet to Rock Lake in the NE¼ of Section 28, Township 135 North, Range 66 West. From here it will proceed downstream along the channel until the point where it crosses the U.S.A. - Canadian border. The survey along Armourdale Coulee will start in the NW¼ of Section 12, Township 162 North, Range 67 West where water from the coulee is diverted into Rock Lake. From here

it will proceed downstream along the old channel until it meets with Badger Creek in Section 7, Township 163 North, Range 66 West.

III. PRELIMINARY INVESTIGATION

The Parties agree that further information is necessary concerning the conditions of these channels and their ability to handle various flows. Therefore, the Commission shall conduct an investigation consisting of the following:

1. Hydrologic investigation of the watersheds to determine flows;

2. Establish a baseline along each channel and do field surveys necessary for an evaluation of the problem and a preliminary design;

3. Preliminary design of channels and/or structures that may be found to be necessary to improve flows;

4. A Preliminary Engineering report to evaluate the problem, recommend possible solutions, and provide a detailed cost estimate of any proposed alternative.

IV. DEPOSIT - REFUND

The Board shall deposit a total of $2,000 with the Commission to partially defray the costs of the investigation. Upon receipt of a request from the Board to terminate proceeding further with the preliminary investigation or upon a breach of this agreement by any of the Parties, the Commission shall provide the Board with a statement of all expenses incurred in the investigation and shall refund to the Board any unexpended deposit funds.

V. RIGHTS OF ENTRY

The Board agrees to obtain written permission from any affected

landowners for field investigations by the Commission which are required for the preliminary investigation.

VI. IDEMNIFICATION

The Board hereby accepts responsibility for and holds the Commission harmless from all claims for damage to public or private property, rights or persons arising out of the project and the travel to and from the project site by the Board or any of its subcontractors, agents or employees. In the event such a suit is initiated or judgement entered against the Commission, the Board will indemnify the Commission for any settlement arrived at or judgement satisfied. No indemnification will be required of the Board for claims resulting from negligent acts of the Commission.

VII. CHANGES TO THE AGREEMENT

Changes to any contractual provisions herein will not be effective or binding unless such changes are made in writing, signed by both parties and attached hereto.

OFFICE OF STATE ENGINEER By:	TOWNER COUNTY WATER RESOURCE BOARD By:
VERNON FAHY State Engineer	WARREN ANDERSON Chairman
DATE:	DATE:
WITNESS:	WITNESS:

Pembina, N. D.

APPENDIX B

RESOLUTION 71-4-294

SWC#567 X File 1169
C1-4

Order Prohibiting Drainage Within
The Pembina River Basin

WHEREAS, the Pembina River, an international stream, drains thousands of acres of fertile farmland in Canada and the United States; and

WHEREAS, frequent flooding by the Pembina River has caused the loss of human life and millions of dollars in damage and destroyed crops, roads, bridges and buildings.

NOW, THEREFORE, BE IT RESOLVED that the North Dakota State Water Commission in its meeting held in Pembina, North Dakota, on this 16th day of April, 1971, by virtue of the authority vested in it by Section 61-02-14, North Dakota Century Code, does hereby prohibit and order the cessation of construction of drainage structures within the Pembina River Basin west of Highway No. 32 in North Dakota.

BE IT FURTHER RESOLVED that this Order shall not apply to any legal drainage project designed by engineers employed by any federal, state or local governmental entity which is approved by the State Water Commission.

BE IT FURTHER RESOLVED that this Order shall remain in effect until formally rescinded by the North Dakota State Water Commission.

BE IT FURTHER RESOLVED that a copy of this Order shall be published in a newspaper having general circulation within the Pembina River Basin in North Dakota and copies shall also be forwarded to all County Commissioners, Township Supervisors, Water Management Districts, Soil Conservation Districts and all local, state and federal officials and agencies concerned with or having an interest in or impact upon the water and related natural resources within the Pembina River Basin in North Dakota, and to the Honorable Ed Schreier, Premier of Manitoba, Canada.

FOR THE NORTH DAKOTA STATE WATER COMMISSION:

(SEAL)

William L. Guy

William L. Guy, Governor-Chairman

ATTEST:

Milo W. Hoisveen

Milo W. Hoisveen, Secretary

APPENDIX C

TABLE 1

Western Rock Lake Reservoir - Duration Data

Rainfall Elevation - Duration
(Approximate Duration in Days)

	Existing				Phase I				Difference			
Event (Yr)	100	50	25	10	100	50	25	10	100	50	25	10
Elevation												
>1532	5	4	3	0	5	4	3	0	"No Change"			
>1531	9	8	7	4	9	8	7	4	"No Change"			
>1530	15	14	13	11	15	14	13	11	"No Change"			
>1529	22	22	21	19	22	22	21	19	"No Change"			
>1528	31	31	30	28	31	31	30	28	"No Change"			
>1527	Over 50 Days				Over 50 Days							
Max. El.	1532.8	32.4	32.1	31.3	32.8	32.4	32.1	31.3	"No Change"			

Rainfall Discharge - Duration
(Approximate Duration in Days)

	Existing				Phase I				Difference			
Event (Yr)	100	50	25	10	100	50	25	10	100	50	25	10
Flows (cfs)												
>900	0	0	0	0	0	0	0	0	"No Change"			
>700	1	0	0	0	1	0	0	0	"No Change"			
>500	3	0	0	0	3	0	0	0	"No Change"			
>300	4	3	0	0	4	3	0	0	"No Change"			
>100	10	9	9	5	10	9	9	5	"No Change"			
> 0	Over 50 Days				Over 50 Days							
Peak Flows	700	460	290	140	700	460	290	140	"No Change"			

TABLE 2

Western Rock Lake Reservoir - Duration Data

Rainfall Elevation - Duration
(Approximate Duration in Days)

	Existing				Phase II				Difference			
Event (Yr)	100	50	25	10	100	50	25	10	100	50	25	10
Elevation												
>1532	5	4	3	0	3	1	0	0	-2	-3	-3	0
>1531	9	8	7	4	7	5	3	0	-2	-3	-4	-4
>1530	15	14	13	11	11	10	8	5	-4	-4	-5	-6
>1529	22	22	21	19	17	16	14	11	-5	-6	-7	-8
>1528	31	31	30	28	24	23	21	18	-7	-8	-9	-10
>1527	Over 50 Days				Over 40 Days							
Max. El.	1532.8	32.4	32.1	31.3	1532.5	32.1	31.4	30.5	-0.3	-0.3	-0.7	-0.3

Rainfall Discharge - Duration
(Approximate Duration in Days)

	Existing				Phase II				Difference			
Event (Yr)	100	50	25	10	100	50	25	10	100	50	25	10
Flows (cfs)												
>700	1	0	0	0	0	0	0	0	1	0	0	0
>500	3	0	0	0	0	0	0	0	3	0	0	0
>300	4	3	0	0	2	0	0	0	-2	-3	0	0
>100	10	9	9	5	10	9	7	3	0	0	-2	-2
> 0	Over 50 Days				Over 40 Days							
Peak Flows	700	460	290	140	500	240	160	110	-29%	-48%	-45%	-21%

TABLE 3

Western Rock Lake Reservoir - Duration Data

Snowmelt Elevation - Duration
(Approximate Duration in Days)

Event (Yr)	Existing			Phase I			Difference		
	100	50	25	100	50	25	100	50	25
Elevation									
>1533	3	1	0	3	1	0	0	0	0
>1532	7	7	6	7	7	6	0	0	0
>1531	11	11	10	11	11	10	0	0	0
>1530	18	18	17	16	16	15	-2	-2	-2
>1529	27	27	26	23	22	22	-4	-4	-4
>1528	37	36	35	30	30	29	-7	-6	-6
>1527	Over 50 Days			Over 50 Days					
Max. El.	1533.2	33.0	32.6	1533.2	33.0	32.6	"No Change"		

Snowmelt Discharge - Duration
(Approximate Duration in Days)

Event (Yr)	Existing			Phase I			Difference		
	100	50	25	100	50	25	100	50	25
Flows (cfs)									
>1100	1	0	0	1	0	0	0	0	0
>900	3	0	0	3	0	0	0	0	0
>700	4	2	0	4	2	0	0	0	0
>500	5	4	2	5	4	2	0	0	0
>300	7	6	5	7	6	5	0	0	0
>100	14	11	10	14	13	13	0	+2	+2
> 0	Over 50 Days			Over 50 Days					
Peak Flows	1150	780	560	1150	780	550	0%	0%	-2%

TABLE 4

Western Rock Lake Reservoir - Duration Data
Into Lower Rock Lake

Snowmelt Elevation - Duration
(Approximate Duration in Days)

	Existing			Phase II			Difference		
Event (Yr)	100	50	25	100	50	25	100	50	25
Elevation									
>1533	3	1	0	1	0	0	-2	-1	0
>1532	7	7	6	6	5	3	-1	-2	-3
>1531	11	11	10	9	9	7	-2	-2	-3
>1530	18	18	17	14	13	12	-4	-5	-5
>1529	27	27	26	20	19	18	-7	-8	-8
>1528	37	36	35	27	26	25	-10	-10	-10
>1527	Over 50 Days			Over 50 Days					
Max. El.	1533.2	33.0	32.6	1533.0	32.5	32.2	-0.2	-0.5	-0.4

Snowmelt Discharge - Duration
(Approximate Duration in Days)

	Existing			Phase II			Difference		
Event (Yr)	100	50	25	100	50	25	100	50	25
Flows (cfs)									
>1100	1	0	0	0	0	0	-1	0	0
>900	3	0	0	0	0	0	-3	0	0
>700	4	2	0	1	0	0	-3	-2	0
>500	5	4	2	3	1	0	-2	-3	-2
>300	7	6	5	5	4	0	-2	-2	-5
>100	14	11	10	13	12	11	-1	+1	+1
> 0	Over 50 Days			Over 50 Days					
Peak Flows	1150	780	560	780	510	290	-32%	-48%	-48%

TABLE 5

Rock Lake - Duration Data
Into Badger Creek

Rainfall Elevation - Duration
(Approximate Duration in Days)

	Existing				Phase I				Difference			
Event (Yr)	100	50	25	10	100	50	25	10	100	50	25	10
Elevation												
>1531	0	0	0	0	0	0	0	0	0	0	0	0
>1530	10	3	0	0	7	0	0	0	-3	-3	0	0
>1529	20	16	12	1	14	11	7	0	-6	-5	-4	-1
>1528	32	29	27	23	21	19	17	13	-11	-10	-10	-10
>1527	>50	>50	48	45	39	38	37	34	>-11	>-12	-11	-9
Max. El.	1530.6	30.0	29.5	29.0	30.4	29.8	29.3	28.8	Reduction of Approx. 0.2' on all Events			

Rainfall Discharge - Duration
(Approximate Duration in Days)

	Existing				Phase I				Difference			
Event (Yr)	100	50	25	10	100	50	25	10	100	50	25	10
Flows (cfs)												
>600	0	0	0	0	<1	0	0	0	<+1	0	0	0
>500	0	0	0	0	6	0	0	0	+6	0	0	0
>400	8	0	0	0	10	5	0	0	+2	+5	0	0
>300	13	7	0	0	12	9	5	0	-1	+2	+5	0
>100	25	22	20	14	23	20	18	14	-2	-2	-2	0
> 0	Over 50 Days				Over 50 Days							
Peak Flows	480	370	260	170	610	450	340	230	+27%	+22%	+31%	+35%

TABLE 6

Rock Lake - Duration Data
Into Badger Creek

Rainfall Elevation - Duration
(Approximate Duration in Days)

	Existing				Phase II				Difference			
Event (Yr)	100	50	25	10	100	50	25	10	100	50	25	10
Elevation												
>1531	0	0	0	0	0	0	0	0	0	0	0	0
>1530	10	3	0	0	4	0	0	0	-7	-3	0	0
>1529	20	16	12	1	12	9	5	0	-8	-7	-7	-1
>1528	32	29	27	23	19	17	14	10	-13	-12	-13	-13
>1527	50	50	48	45	35	33	31	28	-15	-17	-17	-17
Max. El.	1530.6	30.0	29.5	29.0	30.3	29.7	29.3	28.9	-0.3	-0.3	-0.2	-0.2

Snowmelt Discharge - Duration
(Approximate Duration in Days)

	Existing				Phase II				Difference			
Event (Yr)	100	50	25	10	100	50	25	10	100	50	25	10
Flows (cfs)												
>500	0	0	0	0	4	0	0	0	+4	0	0	0
>400	8	0	0	0	8	3	0	0	0	+3	0	0
>300	13	7	0	0	10	7	3	0	-3	0	+3	0
>100	25	22	20	14	20	18	16	12	-5	-4	-4	-2
> 0	Over 50 Days				Over 50 Days							
Peak Flows	480	370	260	170	570	430	340	240	+19%	+16%	+31%	+41%

TABLE 7

Rock Lake - Duration Data
Into Badger Creek

Snowmelt Elevation - Discharge
(Approximate Duration in Days)

Event (Yr)	Existing			Phase I			Difference		
	100	50	25	100	50	25	100	50	25
Elevation									
>1531	10	2	0	7	0	0	-3	-2	0
>1530	18	14	8	14	10	5	-4	-4	-3
>1529	27	23	19	20	17	14	-7	-6	-5
>1528	38	35	33	27	24	22	-9	-11	-11
>1527	Over 45 Days			42	40	39			
Max. El.	1531.6	31.0	30.4	1531.4	30.8	30.2	Reduction of Approx. 0.2' on all Events		

Snowmelt Discharge - Duration
(Approximate Duration in Days)

Event (Yr)	Existing			Phase I			Difference		
	100	50	25	100	50	25	100	50	25
Flows (cfs)									
>800	-	-	-	5	0	-	+5	0	-
>700	0	-	-	8	1	-	+8	+1	-
>600	8	0	-	11	6	0	+3	+6	-
>500	12	5	0	14	10	4	+2	+5	+4
>400	17	12	5	16	13	9	-1	+1	+4
>300	20	16	11	19	16	12	-1	0	+1
>100	32	29	25	28	26	23	-4	-3	-2
> 0	Over 50 Days			Over 50 Days					
Peak Flows	680	550	440	850	700	550	+25%	+27%	+25%

TABLE 8

Rock Lake - Duration Data
Into Badger Creek

Snowmelt Elevation - Duration Table
(Approximate Duration in Days)

Event (Yr)	Existing			Phase II			Difference		
	100	50	25	100	50	25	100	50	25
Elevation									
>1531	10	2	0	3	0	0	-7	-2	0
>1530	18	14	8	11	7	0	-7	-7	-8
>1529	27	23	19	17	15	12	-10	-8	-7
>1528	38	35	33	24	22	20	-12	-13	-13
>1527	Over 50 Days			39	37	36	Over 14 Days		
Max. El.	1531.6	31.0	30.4	1531.1	30.5	29.9	Reduced Approximately 0.5 on all Events		

Snowmelt Discharge - Duration
(Approximate Duration in Days)

Event (Yr)	Existing			Phase II			Difference		
	100	50	25	100	50	25	100	50	25
Flows (cfs)									
>700	0	0	0	5	0	0	+5	0	0
>600	8	0	0	8	3	0	0	+3	0
>500	12	5	0	11	7	0	-1	+2	0
>400	17	12	5	13	10	6	-4	-2	+1
>300	20	16	11	16	13	10	-4	-3	-1
>100	32	29	25	25	23	21	-7	-6	-4
> 0	Over 50 Days			Over 50 Days					
Peak Flows	680	550	440	770	620	470	+13%	+13%	+7%

TABLE 9

Rainfall Runoff Durations Into Canada

Phase I Versus Existing
(Approximate Duration in Days)

Event (Yr)	Existing				Phase I				Difference			
	100	50	25	10	100	50	25	10	100	50	25	10
Flows (cfs)												
>1300	0	0	0	0	<1	0	0	0	<1	0	0	0
>1100	1	0	0	0	1	0	0	0	0	0	0	0
>900	2	<1	0	0	2	1	0	0	0	0	0	0
>700	3	2	<1	0	3	2	1	0	0	0	0	0
>500	4	3	2	1	9	3	2	1	+5	0	0	0
>300	15	10	4	2	14	11	7	3	-1	+1	+3	+1
>100	27	24	21	16	24	22	20	16	-3	-2	-1	0
> 0	Over 50 Days				Over 50 Days							
Peak Flows	1290	970	750	520	1370	1030	800	550	6%	6%	6%	6%

TABLE 9B

Rainfall - Duration of Overbank Flows
Badger Creek in Canada (Improved Area)
(Approximate Duration in Days)

Event	Existing Capacity 300 cfs	Phase I Capacity 425 cfs	Difference
100 Year	15	11	-4
50 Year	10	7	-3
25 Year	4	3	-1
10 Year	2	2	0

TABLE 10

Rainfall Runoff Durations Into Canada

Phase II Versus Existing
(Approximate Duration in Days)

Event (Yr)	Existing				Phase II				Difference			
	100	50	25	10	100	50	25	10	100	50	25	10
Flows (cfs)												
>1700	0	0	0	0	< 1	0	0	0	<+1	0	0	0
>1500	0	0	0	0	2	0	0	0	+2	0	0	0
>1300	0	0	0	0	2	<1	0	0	+2	<+1	0	0
>1100	1	0	0	0	2	1	<1	0	+1	+1	<+1	0
>900	2	1	0	0	3	2	1	0	+1	+1	+1	0
>700	3	2	<1	0	4	3	2	1	+1	+1	+1	+1
>500	4	3	2	<1	7	4	3	2	+3	+1	+1	+1
>300	15	10	4	2	12	9	6	4	-3	-1	+2	+2
>100	27	24	21	16	22	19	17	13	-5	-5	-4	-3
> 0	Over 50 Days				Over 50 Days							
Peak Flows	1290	970	750	520	1900	1430	1115	770	48%	48%	48%	48%

TABLE 10B

Rainfall - Duration of Overbank Flows
Badger Creek in Canada (Improved Area)
(Approximate Duration in Days)

Event	Existing Capacity 300 cfs	*Phase II Capacity 425 cfs	Difference
100 year	15	9	-6
50 year	10	5	-5
25 year	4	4	0
10 year	2	3	+1

*Same as for Phase I

TABLE 11

Snowmelt Runoff Durations Into Canada

Phase I Versus Existing
(Approximate Duration in Days)

Event (Yr)	Existing			Phase I			Difference		
	100	50	25	100	50	25	100	50	25
Flows (cfs)									
>1500	<1	0	0	1	0	0	<+1	0	0
>1300	1	0	0	2	0	0	+1	0	0
>1100	3	1	0	3	1	0	0	0	0
>900	4	2	0	7	3	1	+3	+1	+1
>700	8	4	2	11	7	3	+3	+3	+1
>500	15	10	6	15	12	8	0	+2	+2
>300	23	18	14	20	17	14	-3	-1	0
>100	35	30	27	30	27	25	-5	-3	-2
> 0	Over 50 Days			Over 50 Days					
Peak Flows	1500	1160	880	1620	1250	960	8%	8%	9%

TABLE 11B

Snowmelt - Duration of Overbank Flows
Badger Creek in Canada (Improved Area)
(Approximate Duration in Days)

Event	Existing Capacity 300 cfs	Phase I Capacity 425 cfs	Difference
100 Year	23	15	-8
50 Year	18	12	-6
25 Year	14	9	-5

TABLE 12

Snowmelt Runoff Durations Into Canada

Phase II Versus Existing
(Approximate Duration in Days)

Event (Yr)	Existing			Phase II			Difference		
	100	50	25	100	50	25	100	50	25
Flow (cfs)									
>2000	0	0	0	2	0	0	+2	0	0
>1500	< 1	0	0	3	2	0	+2	+2	0
>1300	1	0	0	4	3	0	+3	+3	0
>1100	3	1	0	5	3	2	+2	+2	+2
>900	4	2	0	7	5	3	+3	+3	+3
>700	8	4	2	9	7	5	+1	+3	+3
>500	15	10	6	13	10	7	-2	0	+1
>300	23	18	14	18	15	12	-5	-3	-2
>100	35	30	27	29	25	23	-6	-5	-4
> 0	Over 50 Days			Over 50 Days					
Peak Flows	1500	1160	880	2170	1670	1270	+44%	+44%	+44%

TABLE 12B
Snowmelt - Duration of Overbank Flows
Badger Creek in Canada (Improved Areas)

Event	Existing Capacity 300 cfs	*Phase II Capacity 425 cfs	Difference
100 year	23	15	-8
50 year	18	12	-6
25 year	14	8	-6

*Same as Phase I