THESIS

EX POST FACTO ANALYSIS OF THE SEDGWICK SAND DRAWS PROJECT - A CASE STUDY OF THE SMALL WATERSHED PROGRAM

Submitted by

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WE HEREBY RECOMMEND THAT THE THESIS PREPARED UNDER OUR SUPERVISION BY JASON P. WARD ENTITLED EX POST FACTO ANALYSIS OF THE SEDGWICK SAND DRAWS PROJECT - A CASE STUDY OF THE SMALL WATERSHED PROGRAM BE ACCEPTED AS FULFILLING IN PART REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE.

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ABSTRACT OF THESIS

EX POST FACTO ANALYSIS OF THE SEDGWICK SAND DRAWS PROJECT - A CASE STUDY OF THE SMALL WATERSHED PROGRAM

The Sedgwick Sand Draws Project is a flood control project completed in 1992 to provide floodwater damage protection for agricultural and municipal lands in Sedgwick County, which lies in extreme northeastern Colorado along the South Platte River. Funding and technical support for the project was provided by the U.S. Soil Conservation Service (SCS) under the Watershed Protection and Flood Prevention Act, commonly referred to as The Small Watershed Program. Short duration, high intensity thunderstorms occur in mid to late summer in the upland portions of the Sand Draws Watershed near the Colorado-Nebraska border. Runoff from these storms is channeled into upland sand draws that drain into the developed alluvial floodplain below. Before project average annual floodwater damages were estimated at $220,050.

An ex post facto method was proposed for evaluating the damage reduction benefits of a watershed flood control project. Using economic, hydrologic and engineering principles, damage-frequency curves developed in the proposal phase of a project are used to estimate actual damage reduction benefits. Estimates are made by adjusting the damage-frequency curves to reflect a current economic time base and evaluating damages produced by hydrologic events that have occurred during the period of analysis. Other performance indicators, such as site inspections, historical crop yields, changes in land use, disaster relief application rates, and interviews with local community members are also used in the evaluation.

The ex post facto evaluation principles were applied to the Sand Draws project as a case study. However, lack of information in the SCS Sand Draws proposal required a technique for estimating the original damage-frequency curves. A method for estimating the curves from minimal known information was developed and used for the Sand Draws project. The period of analysis was from completion of the project in June 1992, to the latest date of available data, September 1997. Hydrologic analysis of the watershed identified seven damage producing rainfall events during this period. It was estimated that the project has produced a total of $3,556,628 in damage reduction benefits resulting in average annual benefits of $592,771. Benefit-cost analyses and a look at other performance indicators were also evaluated.

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Chapter 1

INTRODUCTION

1.1 Background

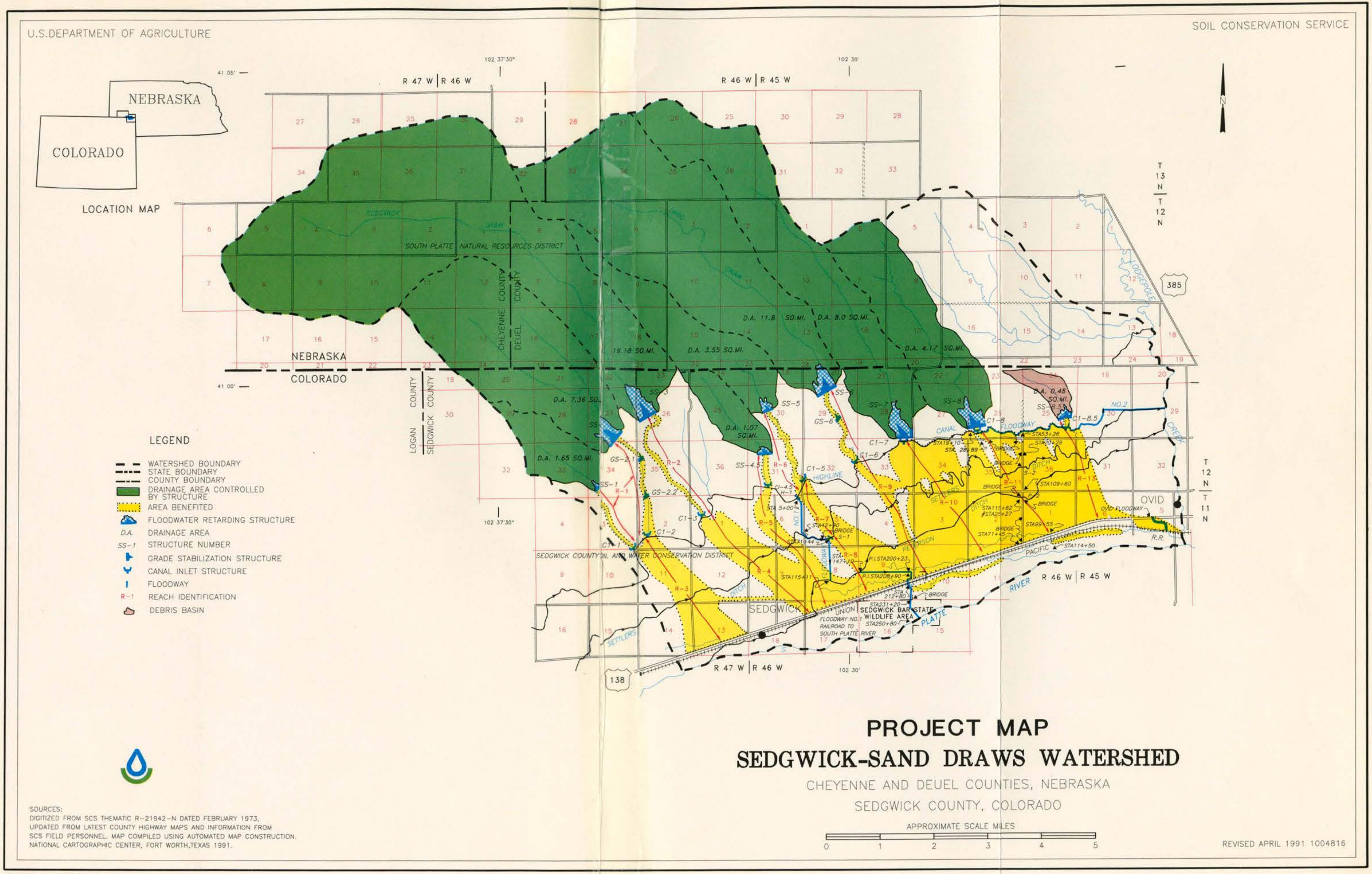
Settlement came to Sedgwick County, Colorado in the mid-1800's with the arrival of homesteaders along the Overland Trail. The existence of the South Platte River and the vast expanse of river bottom land inevitably brought agriculture and ranching to the county and in the 1890's, pioneer settlers brought land under irrigation. In the early 1900's, the Julesburg Irrigation District was formed and Jumbo Reservoir constructed. The Highline Canal was constructed as the reservoir outlet and main feeder canal to the Peterson and Settlers Canals which all supply irrigation water to land within the District (Sedgwick County, 1972).

The majority of agricultural land lies in the lower portion of the watershed below the Highline canal in an alluvial fan created by undulating plains. Ephemeral stream channels are found in the upper portion of the watershed along the Colorado-Nebraska border. The lower portion of the watershed consists of agricultural lands, farmsteads, irrigation canals, county, state and federal roads, the townships of Sedgwick and Ovid, and the Union Pacific Railroad. Flooding frequently occurs in this lower area from runoff produced by high intensity rainfall that drains into the upstream channels. Development in the alluvial fan has cut off natural drainage for these upstream channels and subsequent damage to the lowland areas is frequent. Damaging floods occurred in 1935, 1947, 1948, 1960, 1963, 1964, 1965, 1966, and 1968. Local residents estimate that many other smaller flood flows occurred, although dates and damages were not recalled. In 1975, the estimated average annual floodwater damages were $220,050 for agricultural property and $11,760 for non-agricultural property (SCS, 1975).

Around 1968, the Sedgwick Sand Draws Watershed Conservancy District was formed and application was made to the U.S. Department of Agriculture Soil Conservation Service (SCS) for floodwater protection assistance. The Watershed Protection and Flood Prevention Act (Public Law 83-566) of 1954 allows for local organizations to apply for technical and financial assistance for planning and carrying out watershed projects (SCS, 1992). In 1975, the SCS prepared the Sedgwick Sand Draws Watershed Work Plan and authorized assistance to the district in September, 1976 (SCS, 1975).

The Sedgwick Sand Draws Watershed Project was completed and dedicated on June 12, 1992. Nine floodwater retarding dams, eight miles of floodways and ten irrigation canal inlet structures were constructed to reduce damage from floodwaters The project protects irrigated cropland, roads, railroads, farmsteads and the town of Ovid (Figure 1.1). The nine floodwater retarding dams are class "a" dams as defined by the Soil Conservation Service. Class "a" dams are located in rural or agricultural areas where failure may damage farm buildings, agricultural land, or township and country roads (SCS, 1976). The dams are designed with floodwater storage for the 50-year frequency storm runoff and have sediment storage for the anticipated 100-year accumulation (SCS, 1975). Table 1.1 gives detailed information of each dam, numbered SS-1, SS-2, SS-3, SS-4.5, SS-5, SS-6, SS-7, SS-8, and

Figure 1.1 - Project Map of the Sedgwick Sand Draws Watershed.



USDA-SCS-NATIONAL CARTOGRAPHIC CENTER, FT. WORTH, TX. 1991

Table 1.1 - Structural Data for Floodwater Retarding Dams.

		Structure Number								
Item	Unit	SS-1	SS-2	SS-3	SS-4.5	SS-5	SS-6	SS-7	SS-8	SS-8.5
Drainage Area	square miles	1.65	7.36	19.18	1.07	3.51	11.46	6.47	4.19	0.48
Elev. Bottom of Channel	feet	3740.0	3768.0	3765.0	3707.0	3744.0	3728.0	3677.0	3654.0	3636.0
Elev. Crest of Drawdown	feet	3742.9	3770.5	3766.0	3710.9	3747.3	3729.4	3680.0	3655.5	3638.1
Elev. Principle Spillway at Low Stage	feet	3748.7	NA	NA	3716.3	3760.2	3744.0	NA	NA	NA
Elev. Principle Spillway at High Stage	feet	3756.0	3782.0	3784.5	3724.5	3770.5	3756.2	3695.2	3667.4	3642.0
Elev. Crest of Emergency Spillway	feet	3756.4	3791.2	3799.5	3724.9	3772.7	3758.7	3704.0	3675.2	3646.5
Elev. Top of Dam	feet	3761.4	3796.5	3805.5	3729.9	3777.7	3763.7	3709.0	3680.2	3648.5
Time to Empty Reservoir	days	22.59	10.35	17.73	19.12	31.90	15.48	8.64	6.79	5.25
Time to Empty Sediment Pool	days	12.75	6.83	18.48	15.21	19.90	17.47	6.92	7.01	2.40
Hydrograph Peak	cubic feet per sec	1653.0	3830.4	8164.0	2023.0	1586.9	6031.0	2869.0	1115.6	130.4
Surface Area of Reservoir at Crest of Emergency Spillway	acres	23.46	86.68	148.35	18.20	53.40	123.43	80.96	59.30	11.94
Capacity of Reservoir at Crest of Emergency Spillway	acre-feet	157.6	743.0	2135.6	128.8	561.4	1632.2	805.3	531.8	60.6
Date of Construction Completion	mo.day.yr	12.18.80	NA	01.16.81	11.03.83	12.03.85	11.07.84	10.26.83	06.22.88	04.18.91

SS-8.5. Figure 1.2 is a view looking east across the upstream face of floodwater retarding dam, SS-3, and Figures 1.3 and 1.4 show the inlet tower and outlet works of dam SS-5, respectively. The structures in these photographs are similar to those of all nine dams with the structures varying mainly in size, reflected in the inlet and outlet works.

At the time of this writing the project has been in place for approximately six years. As stated in the Watershed Protection and Flood Prevention Act, upon completion of the project, ownership and responsibility was transferred from the SCS to the sponsoring organizations. Currently, administration and operation and maintenance of the project lie with the Sedgwick Sand Draws Watershed Conservancy District and the Julesburg Irrigation District. Outside of periodic dam inspections required by the Colorado State Engineer's Office, little or no evaluations have been performed since the project's completion.

1.2 Objective

The objective of this thesis is to investigate a method for evaluating the performance of a completed watershed flood control project and applying it to the Sedgwick Sand Draws Project as a case study. Analysis methods used by the SCS along with standard engineering and economic principles are used to accomplish this objective. The results of the evaluation are presented and conclusions are drawn about the performance of the case study.

Figure 1.2 - View looking east across upstream face of floodwater retarding dam SS-3.

Figure 1.3 - Inlet tower on upstream face of floodwater retarding dam SS-5.

Figure 1.4 - Outlet works of floodwater retarding dam SS-5.

Chapter 2

SMALL WATERSHED PROGRAM

2.1 Background

The evolution of watershed protection has its roots in several legislative acts passed by the United States Government. The Flood Control Act of 1936 was the first of such acts followed by The Flood Control Act of 1944 and subsequently the Watershed Protection and Flood Prevention Act of 1954. The latter has come to be known as the Small Watershed Program by which the U.S. Department of Agriculture (USDA) carries out the majority of its flood and erosion control projects. The focus of the program is generally limited to upstream watersheds and includes structural measures and channel modifications for flood control, along with land treatment techniques for soil conservation.

Science, engineering and technology certainly helped shape the Small Watershed Program, but the attitudes of a growing nation equally contributed. It has been recognized throughout the history of agriculture that the stripping and cultivation of uplands contributes to soil erosion. It was observed from early upland development that floods carried infertile sands, depositing them on fertile bottom lands and thereby reducing their productive capacity (Bennett, 1939). The Weeks Act of 1911 authorized the government to purchase forest land to protect these upstream watersheds from soil erosion and flooding. President Franklin D. Roosevelt looked upon forests as beneficial to flood control. By his creation, the Civilian Conservation Corps (CCC) would work on "forestry, the prosecution of soil erosion, flood control and similar projects" (Helms, 1986). The protection of these forest lands became the basis for the national forest system.

The creation of the Soil Erosion Service in 1933 brought an integrated approach to watershed management. Instead of the single focus on forest preservation, emphasis was now placed on the treatment of lands using multiple disciplines of science and engineering. Now, the input from biologists, agronomists, foresters, engineers, and economists were all contributors to the planning of conservation measures on privately owned agricultural land (Berg, 1994). Among the plans for America's farmlands could be found terraces, grassed waterways, contour plowing, strip cropping, longer crop rotations and improved pastures and woodlands with controlled grazing to maintain a healthy ground cover (Helms, 1986). The idea was that this integrated approach to watershed treatment would reduce soil erosion and attenuate flood peaks. These methods are now designated by the Natural Resources Conservation Service as land treatment measures.

In 1935, Congress created the Soil Conservation Service (SCS). A report, "Little Waters: A Study of Headwater Streams and Other Little Waters" sent by president Roosevelt to Congress in 1936, resulted in the Flood Control Act of 1936 (Berg, 1994). The passing of these two congressional actions set forth an organizational approach to watershed protection. However, for many years after, the program was slowed by the organization of internal committees, preliminary field surveys, and the selection of priority watersheds. Ultimately, progress was suspended by the onset of World War II. Near the end of the war, efforts resumed and the USDA recommended eleven watershed projects to be funded under the Flood Control Act of 1944.

The SCS began workplans on these projects as soon as appropriated funding became available. The workplans called for the installation of "small floodwater retaining structures for temporary storage to regulate storm runoff and reduce peak discharges" (USDA, 1949). However, the Flood Control Acts of 1936 and 1944 did not include provisions for structural measures. This was brought to the attention of the Department of Agriculture and prompted an amendment in the program to include such structures. It is worth quoting a portion of the prepared statement of the USDA and SCS to the House Committee on Appropriations: "Our experience to date indicates that the works of improvement originally authorized to be installed by this department in the eleven approved watersheds are inadequate to control the movement of water from the watershed lands until it reaches the points where the Corps of Engineers take over." The passing of this bill had two important results. The SCS now had the authority to include structural measures into watershed management and this set the stage for the passing of the 1954 act.

In August of 1954, Congress passed Public Law 83-566 (P.L. 566), the Watershed Protection and Flood Prevention Act. This act, commonly referred to as The Small Watershed Program, is the authority by which the USDA conducts all of its small watershed projects. Over the years, several amendments have changed the objectives of the program to reflect changes in public interest. The objectives of many of the original projects were to reduce flooding and improve drainage. Today, the program is considered multi-purpose and includes watershed protection, flood prevention, agricultural water management, water based recreation, fish and wildlife habitat improvement, ground water recharge, water quality management, and municipal and industrial water supply (USDA, 1997). The reorganization of the SCS in October, 1994, renamed the Natural Resources Conservation Service (NRCS), also contributed to changes in how small watershed projects are carried out.

2.2 Current Setting

The Watershed Protection and Flood Prevention Act allows for local communities to seek financial and technical assistance to install watershed protection projects on privately owned lands. The act is limited to watersheds not exceeding 250,000 acres. Watershed plans involving an estimated Federal contribution in excess of $5,000,000 for construction, or construction of any single structure having a capacity in excess of 2,500 acre-feet require Congressional approval (USDA, 1998). Projects are initiated by the local sponsoring organizations by application to the local NRCS office or designated state agency. Criteria for accepting applications vary by project but generally include that the watershed must meet the requirements of the law; the local sponsors must indicate willingness to carry out a watershed project; the project must have environmental, economic, and social benefits that exceed the costs for a favorable benefit-cost ratio; and no critical environmental issues exist. After the application is accepted, a plan-environmental impact statement (plan-EIS) is prepared. The plan-EIS must be approved by all parties involved including public review, local and state organizations, and Congress. If Congress approves the plan, the NRCS authorizes federal financial assistance when funds are available. Cost sharing may be required by local organizations under the provisions of P.L. 566.

To date, over 2000 workplans covering 160 million acres in watersheds in every state have been completed or are underway (USDA, 1998). These projects have become an integrated part of the infrastructure in much of rural America. In recent years, Congress has had to address the issue of the growing financial needs of the nation. The result is that all federally funded programs have been cut back in some form. This includes the Small Watershed Program. In 1994, the Clinton Administration proposed to phase out the program. Currently, the program is still in existence, but is facing a backlog of approved projects without available funding. The NRCS is evaluating these projects to reduce the amount of "Federal unfunded commitment" (USDA, 1998). Many of these projects are no longer economically feasible or environmentally sound based on today's standards. Funding obligations in recent years include fiscal year (FY) 1996, $26,323,479; FY 1997, $39,600,00; and FY 1998, $40,000,000 (USDA, 1998).

The uniqueness of the Small Watershed Program lies in its flexibility. The role of the USDA and the NRCS is to provide financial and technical support for small watershed projects. However, responsibility for the success of the project depends on the local sponsoring organization(s). The objectives and design of the project are prepared through cooperation between the federal and local agencies. This insures that local interests are preserved and that the projects meet the desired benefits of the affected communities. The required investment by the community also guarantees that the local people will value the project.

Chapter 3

SAND DRAWS WATERSHED HYDROLOGY

3.1 Watershed Description

The Sand Draws watershed contains approximately 66,714 acres (104.2 square miles), of which 11,000 acres (17.2 square miles) are in Cheyenne County, Nebraska, 24,005 acres (37.5 square miles) are in Deuel County, Nebraska, and 31,709 acres (49.5 square miles) are in Sedgwick County, Colorado (SCS, 1975). The watershed drains into the South Platte River which delineates the southern edge of the watershed. The SCS characterizes the upper portion of the watershed as consisting mainly of flat to gently undulating plains that are dissected towards its southern margins in Nebraska by numerous small, ephemeral watercourses draining southeastward to the tributary drainages in Colorado, the largest of which are Sedgwick Draw and Sand Draw (SCS, 1975). The climate is semi-arid with an average rainfall of 17.01 inches. Storms producing significant hydrologic events in the watershed generally occur in mid to late summer and are characterized as short duration, high-intensity, convective type thunderstorms. The greatest 24-hour amount of precipitation was 5.00 inches recorded at the National Oceanic and Atmospheric Administration rain gage 5 miles south of Sedgwick, CO on May 5, 1969.

The SCS performed a hydrologic analysis of the watershed for the design of the floodwater retarding structures. The analysis was carried out prior to 1975 using national precipitation frequency maps developed by the U.S. Weather Bureau. For comparison and for purposes of evaluating the Sand Draws project, an independent hydrologic analysis was performed. The analysis used historical precipitation records from rain gages located in the proximity of the watershed.

3.2 Soil Conservation Service Design Hydrology

The hydrologic analysis for the design of the floodwater retarding structures was performed by the Soil Conservation Service and is contained in the original work plan for the project (SCS, 1975). The analysis uses methods outlined in Chapter 21, Section 4 of the Soil Conservation Service National Engineering Handbook and Technical Release No. 60 (SCS, 1972, 1976).

Precipitation amounts for floodwater storage and spillway design were determined from precipitation frequency maps from the National Weather Service and Weather Bureau Technical Paper No. 49. One-day (24-hour) precipitation amounts for 2, 5, 10, 25, 50 and 100-year return periods were used in the analysis. To account for the distribution of rainfall over an area, these point precipitation values were converted to areal average precipitation amounts for each subwatershed using standard depth-area curves (U.S. Weather Bureau Technical Paper no. 29). Direct runoff was determined using the SCS curve number method. A curve number was found for each subwatershed based on the soil type and land use for that area. Cross-sections were surveyed throughout the floodplain and used as input for the SCS Water Surface Profile Computer Program to obtain rating curves for each cross-section. This data was used as input for Technical Release No. 20, Hydrology Computer Program, for routing to determine the extent of the floodplain. Hydrographs were developed and used for design of the principle and emergency spillways.

For purposes of this thesis, the data of interest are precipitation amounts. The majority of the data researched were obtained from the Sand Draws work plan and miscellaneous project design notes from the NRSC and State Engineers office in Denver, CO. Unfortunately, the work plan does not contain precipitation amounts corresponding to the various return periods. However, the project design notes do contain precipitation information[1]. Precipitation amounts noted to have been obtained from Weather Bureau Technical Paper No. 49 for the Sand Draws watershed are given in Table 3.1.

Table 3.1 - Weather Bureau Technical Paper No. 49 24-hour precipitation amounts.

Return Period, T (yrs)	24-hour Rainfall (in)
100	4.70
50	4.18
25	3.73
10	3.20
5	2.70
2	2.00

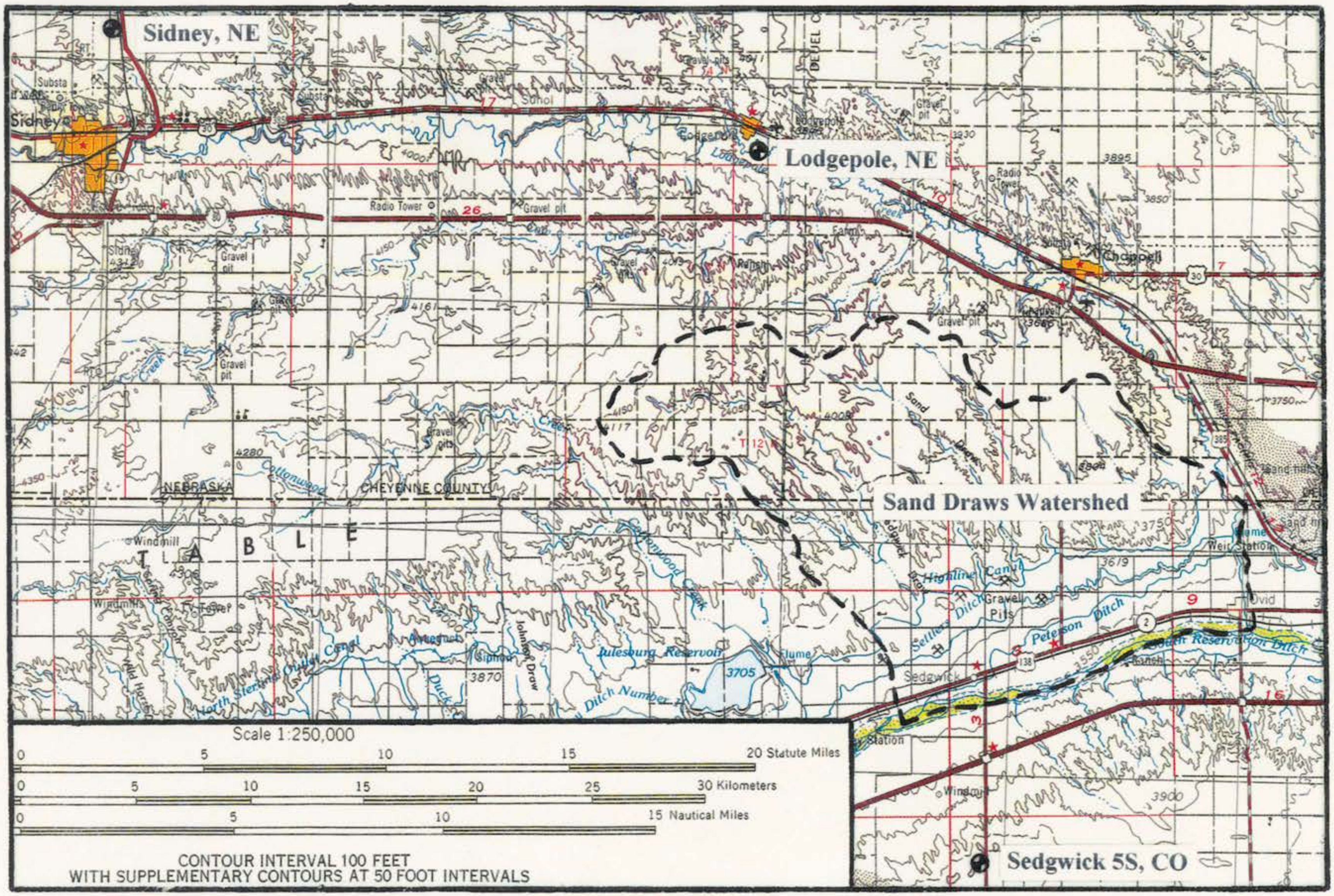
[1] Miscellaneous project design notes were obtained from archives at the NRCS office in Denver, CO and the Colorado Office of the State Engineer. Several dated revisions of notes were found with some that were referenced by both offices. Precipitation amounts were found to vary slightly by subwatershed as well as by dated revision. Approximate precipitation amounts with the latest revision date for subwatershed SS-3, the largest subwatershed, are reported here. These amounts appeared to be the most consistent throughout the research.

3.3 Independent Hydrologic Analysis

Use of National Weather Service publications such as TP-49 was the current accepted method of determining precipitation amounts during the time of the design of the Sand Draws project (1970's). Since then, advances in hydrologic analysis and the availability of a longer period of record have shifted the focus to methods of frequency analysis. Given a record of local precipitation, a statistical analysis can be performed resulting in a frequency curve that plots precipitation versus probability of occurrence. Frequency analysis is becoming a common tool in hydrology because it uses local data in an attempt to accurately predict the rainfall distribution for an area.

An analysis of the precipitation frequency distribution for the Sand Draws Watershed was carried out independently of the work plan. Data were collected from National Oceanic and Atmospheric Administration (NOAA) rainfall gages at Sidney, NE, Lodgepole, NE and Sedgwick, CO. The gages provided reliable 24-hour, daily average precipitation. There are no official rainfall gages located within the watershed. Therefore, the gages were selected based on their proximity to the watershed. Table 3.2 describes the latitude and longitude of each NOAA gage. Locations of the rainfall gages (denoted by the symbol, ◕) in relation to the Sand Draws watershed are shown in Figure 3.1. For reference, the northern edge of the watershed is bordered approximately by latitude N41:04:00, the eastern edge bordered approximately by longitude W102:23:00, the western edge bordered approximately by longitude W102:45:00, and the southern border approximately by latitude N40:55:00.

Figure 3.1 - Rainfall gage locations (denoted by the symbol, ◕) in relation to the Sand Draws Watershed.



Sidney, NE
Lodgepole, NE
Sand Draws Watershed
Sedgwick 5S, CO
Scale 1:250,000
20 Statute Miles
30 Kilometers
15 Nautical Miles
CONTOUR INTERVAL 100 FEET
WITH SUPPLEMENTARY CONTOURS AT 50 FOOT INTERVALS

Table 3.2 - NOAA rainfall gage locations

Gage Name	Years of Record	Approximate Location
Lodgepole, NE Station ID 4900	1949 - 1996 (missing 1978)	Latitude: N41:09:00 Longitude: W102:38:00
Sidney, NE Station ID 7830	1949 -1996	Latitude: N41:13:00 Longitude: W103:01:00
Sedgwick 5S, CO Station ID 7515	1959 - 1996	Latitude: N40:52:00 Longitude: W102:31:00

A frequency analysis was performed on the average of the annual maximums of the NOAA data set. The annual maximum 24-hour precipitation was taken from each of the three NOAA weather stations and averaged for each year of record. From Table 3.2, it can be seen that records for the Sedgwick 5S gage start ten years later than the Sidney and Lodgepole gages. Also, the Lodgepole gage is missing data for 1978. Due to the inconsistent length of record for the three weather stations, a final record of 37 years (1959 - 1996, excluding 1978) was selected for the analysis.

A log-Pearson Type III distribution was fit to the average annual maximum series to determine a relationship between precipitation and return period. For comparison, an Extreme Value Type I distribution was also assumed. Each of these probability distributions are commonly used for hydrologic variables (Chow, 1988). Results of the log-Pearson Type III and Extreme Value Type I distribution for various return periods are shown in Table 3.3 and 3.4, respectively. Appendix A describes details of the analysis.

Table 3.3 - log-Pearson Type III

Return Period, T (yrs)	24-hour Rainfall (in)
50	3.35
25	3.00
10	2.55
5	2.21
2	1.72

Table 3.4 - Extreme Value Type I

Return Period, T (yrs)	24-hour Rainfall (in)
50	3.26
25	2.96
10	2.55
5	2.23
2	1.74

The method of probability plotting was used to determine which distribution fits the precipitation data most appropriately (Chow, 1988). This method linearizes the distribution function and plots the fitted curve against the observed data for comparison. Appendix A contains a description of the method of probability plotting. Figures A.1 and A.2 show the probability plots of the NOAA data for the log-Pearson Type III and the Extreme Value Type I distributions, respectively. It can be seen that both distributions fit the data consistently. However, the log-Pearson Type III distribution appears to fit the data better for longer return periods. For purposes of this thesis, the log-Pearson Type III distribution was selected.

Chapter 4

EX POST FACTO PROJECT EVALUATION

An ex post facto performance evaluation of a watershed flood control project is typically no more than qualitative observations made by the benefactors. A formal quantitative analysis is rarely performed. The major benefit of the project is the reduction of the occurrence of floodwater damages. The benefactors observe the performance of the project based on the quality of the perceived benefits.

The project may perform to the engineered specifications but may not yield a net economic benefit to the community. Typically, engineering and economic analyses are carried out prior to construction to determine the projects net benefits. However, the actual costs and benefits associated with a completed project should be analyzed to determine the actual net benefits. An ex post facto evaluation can provide insight into, and guidelines for, similar future projects.

Following is a proposed ex post facto method for evaluating the performance of a flood control project. An economic analysis can be carried out in a similar manner to the analysis performed prior to selection and construction of project alternatives. The methods of economic discounting, benefit-cost analysis, and flood frequency analysis will be used in a post-project setting. In an ex post facto analysis, actual data as opposed to projected or probable data is used. Basic concepts and an evaluation scheme are introduced in this chapter. Chapter 6 applies these concepts to the Sedgwick Sand Draws case study.

4.1 Economic Discounting

For a flood control project, the benefits and costs normally occur in unequal amounts at different times over the life of the project. For evaluation purposes, it is necessary to convert these streams of costs and benefits, in dollar amounts, to a common time base for the same year. The concept of economic discounting can be used to compute the present worth value of some past amount. The present worth of some past value, P, may be determined using the following equation:

$$PW = P\,(1 + i)^n \tag{4-1}$$

where PW = present worth value;

P = past value;

i = annual discount interest rate;

n = period of analysis in years

Rearranging equation (4-1), the present worth of some future value, F, may be determined as:

$$PW = \frac{F}{(1 + i)^n} \tag{4-2}$$

A principal amount can be evaluated as an annual payment over a length of time using the concept of amortization given by the following equation:

$$A = P \frac{i(1 + i)^n}{(1 + i)^n - 1} \tag{4-3}$$

where: A = amortized annual payment;

P = principal amount;

i = annual discount interest rate;

n = period of analysis in years

4.2 Method of Benefit-Cost Analysis

For proposed watershed projects to be approved by the NRCS, the project must meet the criteria that the economic benefits exceed the costs and have a favorable benefit-cost ratio. For the majority of watershed protection and flood prevention projects, the benefits include floodwater damage reduction, secondary benefits, more intensive land use, and erosion and sedimentation damage reduction. Secondary benefits are usually denoted as increased local income influenced by the project. More intensive land use benefits results from an increase in production of the protected areas. Costs associated with the project are engineering, construction and installation, administration, and operation and maintenance.

A benefit-cost analysis involves comparing the benefits produced by the project to the costs of the project evaluated at an equivalent time base. The benefits can be computed as an expected annual value and the costs amortized over the useful life of the project. An alternative method expresses the benefits and costs as the present worth, discounted algebraic summation of each (James and Lee, 1971). The present worth of annual benefits, PW_b, is:

$$PW_b = \sum_{t=1}^{n} \frac{B_t}{(1 + i)^t} \tag{4-4}$$

The present worth of the costs, PW_c is:

$$PW_c = \sum_{t=1}^{n} \frac{C_t}{(1 + i)^t} \tag{4-5}$$

where: n = period of analysis in years;

i = discount interest rate;

B_t = benefit in year t;

C_t = cost in year t

The benefit-cost ratio is then computed by taking the ratio of PW_b to PW_c.

4.3 Floodwater Damage Reduction Benefits

The primary benefits of watershed flood control projects come from the reduction of floodwater damage due to the installation of floodwater retarding structures. The evaluation of floodwater damages and the reduction of damages are most commonly found by the frequency method. The frequency method involves the establishment of relationships between the physical and economic flood characteristics and the probable frequency of flood occurrence (SCS, 1964).

The physical appraisal involves establishing the relationships of the physical characteristics of floods to the frequency of their occurrence. These associations, generally expressed by means of graphs, include the following:

1. Runoff related to frequency of occurrence.
2. Runoff versus discharge.
3. Discharge versus frequency.
4. Discharge versus flood stage.
5. Flood stage versus area flooded.

The economic appraisal involves establishing and relating monetary values to the physical flood characteristics and to the frequency of their occurrence. These include the following:

1. Area flooded versus damage.
2. Flood stage versus damage.
3. Discharge versus damage.
4. Damage versus frequency of occurrence.

The last relationship is commonly referred to as the damage-frequency function. By plotting the damages versus the flood frequency of occurrence, an expected annual damage can be computed as the summation of the probability weighted estimates of damage. The expected annual damage may be easily computed as the area under the curve. Damage-frequency curves can be generated for with and without project conditions. The expected annual floodwater damage reduction benefits are then computed by taking the difference in the area under the without project and the with project damage-frequency curves.

4.4 Ex Post Facto Analysis

For completed watershed projects, there are currently no standard methods for evaluating their performance. Proposed NRCS watershed projects rely heavily on a favorable benefit-cost ratio for determining if the project is economically justified. The ratio is usually computed using the expected annual benefits and the amortized cost of the project. The expected annual benefits are primarily from floodwater damage reduction and are computed based on the frequency method.

For proposed projects, the benefits and costs are the values that are expected in the future if the project is installed. Equations (4-4) and (4-5) use the concept of present worth to bring these expected future values backwards in time to a pre-project time base. For completed projects, the actual cost and the actual benefits may be known at any given time in the past from project completion to present. Equation (4-1) can be used to bring a value in the past forward to a present time. Using this concept in equations (4-4) and (4-5) gives:

$$PW_b^{'} = \sum_{t=0}^{n} B_t \, (1 + i)^t \tag{4-6}$$

and

$$PW_c^{'} = \sum_{t=0}^{n} C_t \, (1 + i)^t \tag{4-7}$$

where: $PW_b^{'}$ = present worth of benefits;

$PW_c^{'}$ = present worth of costs

Note that the summation is now evaluated from zero to n to take into account the present year, year zero. If the annual costs of the project are equal in value to the amortized total cost, then equation (4-7) may be replaced by:

$$PW_c' = \sum_{t=0}^{n} C_t \qquad (4\text{-}8)$$

From equations (4-6) and (4-7), a benefit-cost ratio could be computed at any time from project completion to the present. Many conclusions could be drawn from this depending upon the point in time the analysis is made. For flood control projects an ex post facto benefit-cost analysis may not be possible or practical until enough time has passed for significant, flood producing, hydrologic events to occur.

For many completed projects, the actual value of benefits that have occurred may not be accurately known. As an approximation, damage-frequency curves developed in the proposal phase can be brought forward in time using the present worth discounting method. Note that this can only be done assuming that no major changes in land use have occurred since the development of the original curves. Using this technique, damage-frequency curves can be generated for any given year in the project life in terms of present worth values. Since these curves are probability distribution functions, each benefit has an associated exceedance probability. For a hydrologic event with a return period, and therefore an exceedance probability, an associated benefit value can be found.

4.5 Additional Performance Indicators

An economic analysis using concepts of damage-frequency curves and benefit-cost ratios provides a measure of the monetary benefits derived from a project. Within these results are contained individual indicators that can be observed independently to provide supporting information on project performance. For flood prevention projects where agricultural damage reduction is the primary benefit, several indicators can be identified. Trends in increased crop yield, more intensive land use, and a decreased rate in disaster relief applications are a few of these indicators.

Crop yields vary from year to year depending upon factors such as climate, crop management practices, and unforseen acts of God. In a pre-project setting, there may not be apparent trends in crop yields. However, in the years following installation of the project, reduction of floodwater damages could increase annual yields. In analyzing yields, care should be taken to insure that increased yields are from the reduction of floodwater damages and not that of better management practices.

The reduction of the frequency of flooding, has a two-fold beneficial effect. First, it reduces the occurrence of flood damages. Second, it will stimulate increased production in the protected areas (Kuiper, 1965). The benefit of more intensive land use can result from the project by stimulating cultivation of land that was previously periodically flooded. The effects of the project on more intensive land use can be determined by observations of land use and analysis of the number of cultivated acres in the floodplain before and after project installation.

Chapter 5

SEDGWICK SAND DRAWS DAMAGE-FREQUENCY CURVES

The primary source of information for evaluating the Sand Draws project is from the SCS Sedgwick Sand Draws Watershed Work Plan (SCS, 1975). The work plan is a detailed overview of the project compiled in the proposal phase. Although complete, the document lacks certain important information required for an ex post facto analysis. Minimal information is given pertaining to damage-frequency curves developed for the project.

An extensive search for the original damage-frequency curves and other relevant data was undertaken during research for this thesis. Organizations and individuals associated with the Sand Draws project were contacted and interviewed. After an exhaustive search for the data, it was concluded that the original damage-frequency curves were lost or destroyed. One alternative to using the original data is to collect and analyze current data to produce new damage-frequency curves. However, this would require extensive field surveys and economic analyses that are beyond the scope of this thesis. Another alternative is to use the available data in the SCS work plan and data obtained through research to approximate the original damage-frequency curves.

5.1 1975 Time Base Damage-Frequency Curves

The SCS Sand Draws work plan reports that damage-frequency curves were developed in 1975 for use in the design of the project. Damage-frequency curves were developed for agricultural lands and for other categories affected by floodwater damages.

5.1.1 Agricultural Lands Damage-Frequency Curve

The work plan contains reliable information on the number of acres flooded with and without project conditions for irrigated and non-irrigated lands by storm frequency. Non-irrigated and irrigated lands are those considered lying above and below the Highline Canal, respectively. For development of the agricultural lands damage-frequency curve, only irrigated lands will be considered. The portion and relative value of non-irrigated lands in the floodplain is a small fraction of the total agricultural production subject to floodwater damage. The work plan also reports the estimated expected annual floodwater damages found from the area under the damage-frequency curve. Unfortunately, the work plan does not contain the actual damage-frequency curve or the damage in dollars associated with each storm frequency.

The work plan provides with and without project expected annual flood damages associated with agriculture to be estimated at $53,680 and $208,550, respectively. This is the area under the with and without project damage-frequency curves for a 1975 time base. The number of irrigated acres flooded by the 2, 5, 10 and 100-year storm return periods are also known (Table 5.1). The work plan states that damages are estimated to begin at the

Table 5.1 - Acres flooded with and without project conditions for irrigated agricultural lands.

Return Period, T (years)	Probability of Occurrence, (1 / T)	Without Project Acres Flooded	With Project Acres Flooded
100	0.01	5,124	2,554
10	0.1	3,775	1,548
5	0.2	3,325	1,429
2	0.5	2,809	1,256
1.8	0.55	0	0

2-year frequency storm. To reflect this, a return period of 1.8 years (0.55 probability of occurrence) with zero damages has been added. The additional return period adds minimal area and completes the curve for more accurate computations. A plot of the number of acres damaged versus the probability of occurrence is shown in Figure 5.1.

The computed areas under the with and without project curves are 794.7 acres and 1800.5 acres, respectively. These values correspond to the estimated expected annual acres damaged for with and without project conditions. Therefore, the estimated damage in dollars per flooded acre of land can be computed as:

without project conditions:

$$\frac{\textit{average annual flood damage in dollars}}{\textit{average annual number of acres damaged}} = \frac{\$208{,}550}{1800.5\ \textit{acres}} = \$115.83\ \textit{per flood damaged acre}$$

with project conditions:

$$\frac{\textit{average annual flood damage in dollars}}{\textit{average annual number of acres damaged}} = \frac{\$53{,}680}{794.7\ \textit{acres}} = \$67.55\ \textit{per flood damaged acre}$$

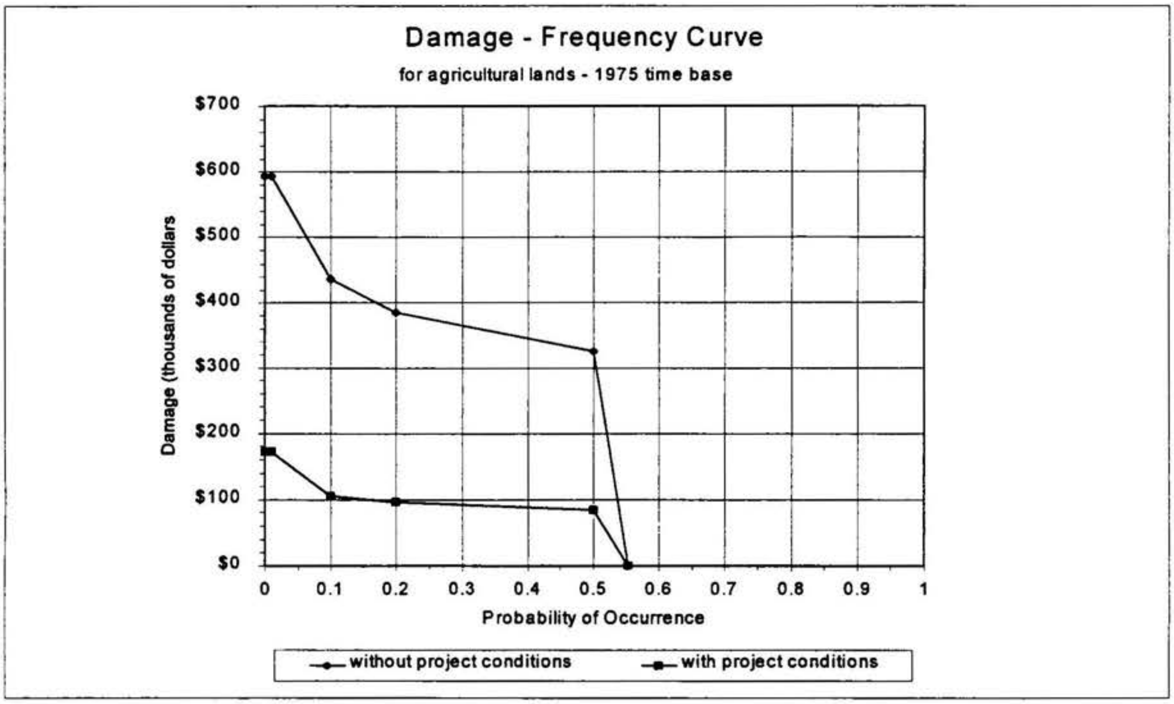


Figure 5.1 - Acres damaged frequency curve for agricultural lands.

These values are for a 1975 time base and are considered the damageable value per acre (DVPA) due to flooding for irrigated agricultural lands. The work plan states that the original DVPA values were computed using the value of land and the degree of inundation. A composite acre value was determined based on current percent crop use, yield and market values. The DVPA values were then computed using the composite acre value multiplied by percent damage loss factors that take into account the depth of inundation and month of flooding (SCS, 1975).

The damage in dollars for each return period can now be computed by multiplying the acres flooded times the damageable value per acre. The results can be plotted as an approximated damage-frequency curve for irrigated agricultural lands. Table 5.2 and Figure 5.2 show the approximated damage-frequency curves for with and without project conditions. Each curve was developed using the five available data points and assuming a linear relationship between points.

Table 5.2 - Agricultural land damage-frequency curve approximation, 1975 time base.

Return Period, T (years)	Probability of Occurrence, (1 / T)	Without Project Damage	With Project Damage
100	0.01	$593,504	$172,518
10	0.1	$437,251	$104,565
5	0.2	$385,129	$96,526
2	0.5	$325,361	$84,841
1.8	0.55	$0	$0

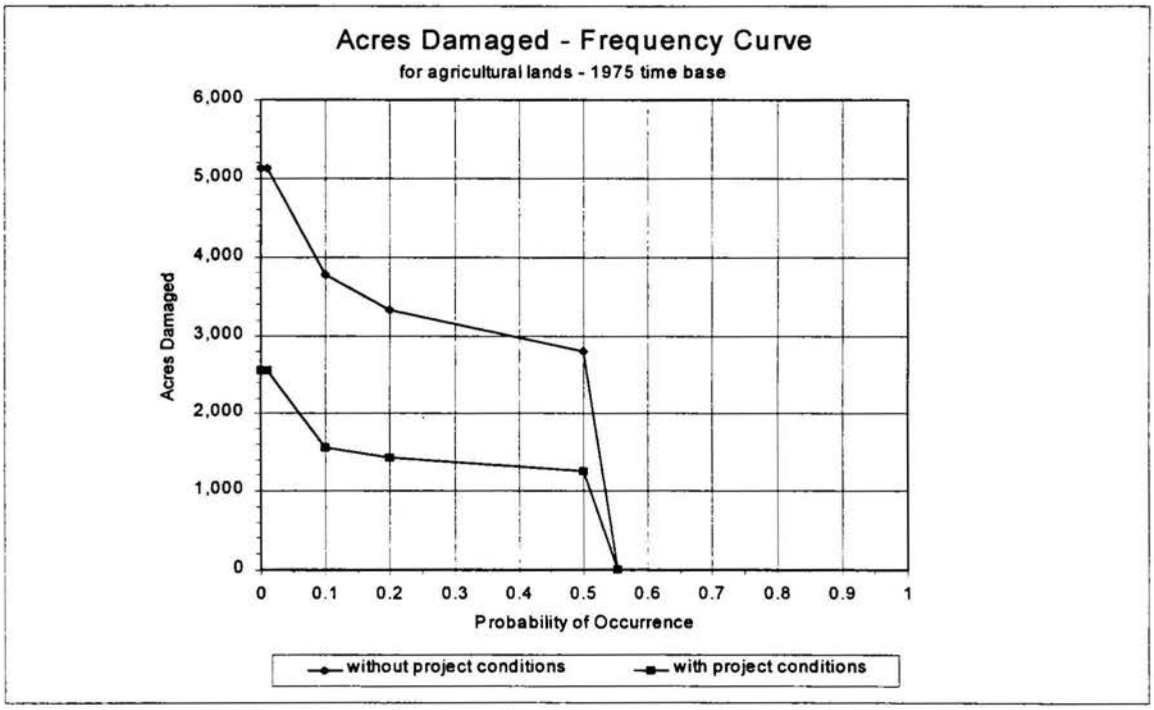


Figure 5.2 - Agricultural land damage-frequency curve approximation, 1975 time base.

5.1.2 Other category damage-frequency curves

The work plan states that damage-frequency curves were also developed for the categories of other agricultural, non-agricultural, sediment and erosion, and indirect damages. Other agricultural damages include damage to fences, field roads, farm machinery, irrigation equipment and ditches, livestock, and debris cleanup. Non-agricultural damages account for damages to roads, bridges, railroad property, and residential and commercial properties in the town of Ovid. Also included in this category are damages to the Julesburg Irrigation District properties consisting mainly of breaching of the Highline Canal and subsequent delay of irrigation water delivery. Sediment damage is primarily from sheet and rill erosion. Deposition occurs on the floodplain, necessitating the cleaning of canals and ditches and re-leveling affected cropland. Indirect damages include losses which result from flooding even though the property involved was not flooded. Examples of indirect damages include local power outages and redirection of traffic due to road closure. Indirect damages were calculated to be 10 percent of direct damages for agricultural and 20 percent for nonagricultural (SCS, 1975).

The SCS work plan provides the with and without project expected annual damages for each of these categories. As with the agricultural land information, the original damage-frequency curves are not contained in the work plan. However, curves for these categories may be approximated using the damage-frequency curve developed for agricultural lands.

If the same set of return periods (1.8, 2, 5, 10, and 100 year) are used in the analysis of each category, then it may be assumed that the shape and geometric proportioning of all of the damage-frequency curves remains the same. The only change for each category will be the ordinate values of damage in dollars for a given probability. This assumption can be made because all of the damage-frequency curves are probability distribution functions based on the same hydraulic analysis. The agricultural lands damage-frequency curve was approximated using the five return periods and assuming a linear relationship between points on the curve. The expected annual damages are computed by summing up five individual areas under the curve as illustrated in Figure 5.3.

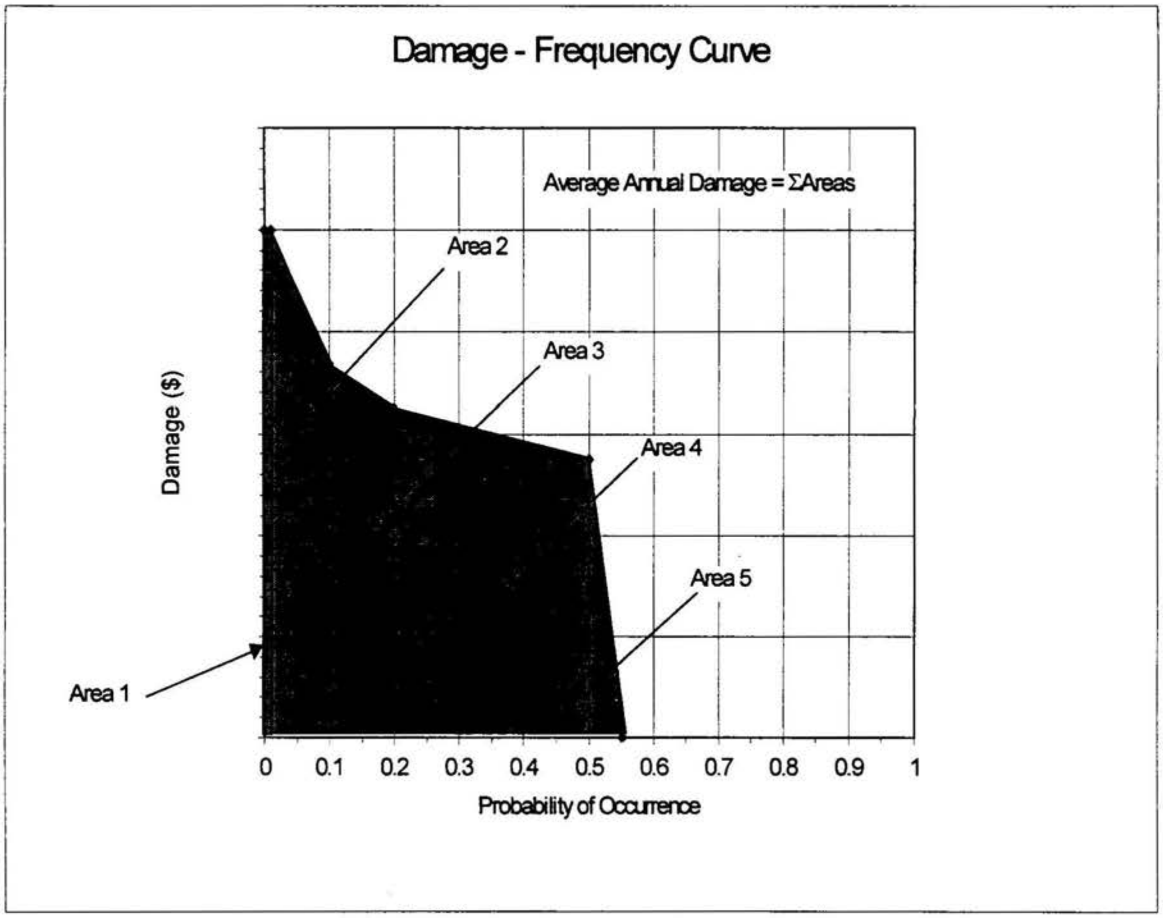


Figure 5.3 - Area under the damage-frequency curve computation.

For the agricultural lands damage-frequency curve, each of the five areas can be computed. The proportion of an individual area to the total area, given the symbol N_i, can be computed by the ratio of each area, A_i, to the total area, A_t. Values of N_i for each area computed from the 1975 agricultural lands damage-frequency curve are given in Table 5.3.

Table 5.3 - Individual area proportion.

Area	A_i without project	A_i with project	N_i without project (A_t = \$208,550)	N_i with project (A_t = \$53,680)
1	\$5,935	\$1,725	0.028	0.032
2	\$46,384	\$12,469	0.222	0.232
3	\$41,119	\$10,055	0.197	0.187
4	\$106,574	\$27,205	0.511	0.507
5	\$8,538	\$2,226	0.041	0.041

Since geometric proportioning is assumed to remain the same for all damage-frequency curves, the value of N_i remains constant. The individual areas of the damage-frequency curves for the remaining categories can now be computed by multiplying the expected annual damages (area under the curve) by N_i. The ordinates of the damage-frequency curves can be computed using the equations describing the area under the curve for each individual area. With known points on the abscissa (probability of occurrence) and the individual areas under the curve known, the ordinates can be computed. An algorithm of the ordinate computations is presented in Appendix B. The 1975 time base damage-frequency curves for agricultural, other agricultural, non-agricultural, sediment and erosion, and indirect damages are also given in Appendix B.

5.2 Future time base damage-frequency curves

The Sedgwick Sand Draws project was completed in June of 1992. At the time of this writing, hydrologic and economic data are available through 1997. Therefore, for the ex post facto analysis, damage-frequency curves must be developed for the years 1992 to 1997. The 1975 agricultural lands damage-frequency curve may be brought forward in time using current land use and crop values. The damage-frequency curves for the remaining categories may be brought forward in time using economic discounting techniques.

5.2.1 Agricultural lands damage-frequency curve

To evaluate agricultural damages at a future time, the 1975 time base agricultural lands damage-frequency curve must be converted to present values. Current composite acre values for the Sand Draws floodplain can be computed based on the Colorado Agricultural Statistics annual reports published by the Colorado Department of Agriculture. The composite acre value is a weighted value based on the percentage of the number of acres harvested, yield per acre, and marketing year average price for each crop. Composite acre values were computed for the Sand Draws floodplain using data for Sedgwick County from the Colorado Agricultural Statistics. It is assumed here that the value for the entire county is representative of the Sand Draws floodplain. This assumption is deemed valid since the majority of the irrigated lands in Sedgwick County lie within the Sand Draws floodplain.

Also, the crops harvested for the county are all crops that are harvested in the floodplain. Composite acre values of irrigated lands for 1992-1997 are given in Table 5.4. Details of the composite acre computations are given in Appendix C.

Table 5.4 - Composite acre value for Sedgwick County, 1992 - 1997.

Year	Composite Acre Value (dollars per acre)
1992	$284.13
1993	$331.66
1994	$397.25
1995	$393.68
1996	$401.71
1997	$389.65

Development of the 1975 agricultural lands damage-frequency curve resulted in a without and with project conditions DVPA values of $115.83 and $67.55, respectively. These values are the approximate amount of damage per acre of flooded agricultural land and take into account the different land uses and the depth of flooding in the floodplain. They are a direct proportion of the composite acre value of land based on 1975 crop use, yield and market values.

A damageable value correction factor (DVCF) can be defined as the ratio of the 1975 DVPA value to the 1975 composite acre value. A composite acre of land in Sedgwick County in 1975 is valued at $275.70 per acre (Appendix C). The with and without project DVCF's are given in Table 5.5.

Table 5.5 - Damageable value correction factor.

1975 w/o project DVPA	1975 w/ project DVPA	1975 Composite Acre Value	w/o project DVCF	w/ project DVCF
$115.83	$67.55	$275.70	0.420	0.245

Assuming that the DVCF remains constant, a DVPA value can be computed for any year. The DVPA for any given year is the composite acre value for that year multiplied times the DVCF. The with and without project DVPA values for 1992 - 1997 are given in Table 5.6.

Table 5.6 - Damageable value per acre, 1992 - 1997.

Year	Composite Acre Value	w/o project DVPA	w project DVPA
1992	$284.13	$119.37	$69.61
1993	$331.66	$139.34	$81.26
1994	$397.25	$166.89	$97.33
1995	$393.68	$165.39	$96.45
1996	$401.71	$168.77	$98.42
1997	$389.65	$163.70	$95.47

The ordinates of the 1992 through 1997 agricultural lands damage-frequency curves can now be constructed by multiplying the corresponding DVPA value times the acres flooded in Table 5.1. The agricultural lands damage-frequency curves for 1992-1997 are given in Appendix D.

5.2.2 Other category damage-frequency curves

The 1975 damage-frequency curves for the categories of other agricultural, non-agricultural, sediment and erosion, and indirect damages can be brought forward in time using economic discounting and the techniques described earlier for development of the original curves. The 1975 expected annual damages can be discounted to a future common time base using equation (4-1). Note that the 1975 damage value is denoted as P in equation (4-1) since the common time base is in the future. The ordinate values can then be computed using the individual area technique described earlier and in Appendix B.

The discount interest rate used in equation (4-1) must be selected dependent on the year of analysis. Discount interest rates used by the Federal Reserve System of the United States are used in the analysis (Federal Reserve Bank, 1998). Historic monthly interest rates were averaged to obtain an average annual interest rate. An arithmetic average of annual interest rates from 1975 to the date of interest is used in the present worth analysis. The average year to date discount interest rates are given in Table 5.7. Annual average interest rates from 1975 to 1997 are given in Appendix E. Damage-frequency curves for 1992-97 are given in Appendix D.

Table 5.7 - Average discount interest rate.

Year	Average year to date discount interest rate
1992	7.61%
1993	7.37%
1994	7.18%
1995	7.08%
1996	6.99%
1997	6.90%

Chapter 6

SEDGWICK SAND DRAWS EX POST FACTO EVALUATION

Concepts of the ex post facto evaluation procedure presented in Chapter 4 are next applied to the Sedgwick Sand Draws Watershed project. The period of analysis covers the years from the time of completion of the project in June, 1992, through 1997. Hydrologic events in the watershed are used in conjunction with damage-frequency curves, developed in Chapter 5, to estimate floodwater damages and project benefits incurred during the period of analysis. The effects of rainfall distribution return periods are addressed, the costs of the project are identified, and benefit-cost ratios are examined. Interpretation of results, a look at other performance indicators and site inspections are also discussed.

6.1 1992-1997 Hydrology

Rainfall events that have occurred within the period of analysis must be identified in order to determine benefits derived from the project. Data are selected from the three NOAA rainfall gages described in Chapter 3 and from an additional NOAA gage in Big Springs, NE. The rainfall distributions, also outlined in Chapter 3, will be used in the analysis to determine the return period and probability of occurrence for each event. For comparison, the SCS TP-40 distribution and the log-Pearson distribution will both be investigated.

6.1.1 Assumptions

Selecting data to be used in the ex post facto analysis requires several assumptions to be made. The derivation of the damage-frequency curves developed in Chapter 5 use the assumption that floodwater damages begin at the 2-year return period. Therefore, it must be assumed that storms greater than the 2-year storm produce floodwaters resulting in damages to property. Records of actual damages during the period of analysis are unavailable, therefore, it must be assumed that unreported damages did occur.

The original hydrologic analysis performed by the SCS used the runoff curve number method to determine direct runoff. This runoff was routed through the floodplain for use in the frequency method to develop the damage-frequency curves. An assumption made in the curve number method was that the antecedent soil moisture content in the watershed is always at average conditions. The antecedent moisture content is known to have a significant effect on both the volume and rate of runoff (McCuen, 1989). If heavy or light rainfall has occurred in the past few days saturating the soil, a storm less than the 2-year frequency could possibly produce runoff and floodwaters resulting in damage. Without a more rigorous analysis, it must be assumed that the antecedent soil moisture content during the period of analysis is always at average conditions. Therefore, storms less than the 2-year frequency occurring over consecutive days are not considered in the evaluation. It must also be assumed that point precipitation values at a single gage occurred uniformly over the watershed. This allows the use of damage-frequency curves for point precipitation values occurring at any of the four gages.

For the ex post facto analysis, it is possible that a storm event greater than the 2-year frequency may appear at more than one gage for the same 24-hour period. In this case, the largest reported event will be used in the analysis. It is also possible that storm events greater than the 2-year frequency may occur at multiple times during the same year of analysis. In this case, the damage frequency analysis would show damages and benefits for each consecutive storm assuming normal conditions prior to the each event. This may not reflect the actual conditions since damages from the first storm of the year may not have been recovered and consecutive storms would, in reality, cause less damage. Therefore, for years with multiple damage producing storms, the arithmetic average of the damage reduction benefits will be used.

6.1.2 Hydrologic Events

Rainfall gages at Sidney, NE, Lodgepole, NE, Big Springs, NE, and Sedgwick, CO, were analyzed for 24-hour precipitation amounts greater than the 2-year return period. The 2-year storm for the SCS TP-40 and log-Pearson distributions are 2.00 and 1.72 inches, respectively. A total of eight events matching this criteria occurred over the period of analysis. The dates listed with gage name and precipitation amount are shown in Table 6.1.

The dates of each of these events were researched further to support using them in the ex post facto analysis. Local newspapers were referenced for precipitation amounts and reports of flooding. The Julesburg Advocate from Julesburg, CO, Sidney Telegraph from Sidney, NE, and Chappell Register from Chappell, NE, were three newspapers referenced. All of the dates listed reported significant amounts of rainfall

Table 6.1 - Rainfall events greater than 2-year storm, 1992-1997.

Date	Rainfall Gage	24-hour Rainfall (in)
6/15/92	Sedgwick, CO	2.69
6/27/92	Sedgwick, CO	1.74
5/9/95	Sidney, NE	2.92
6/4/95	Lodgepole, NE	3.15
7/15/95	Sedgwick, NE	2.93
9/19/96	Lodgepole, NE	2.52
9/19/96	Big Springs, NE	1.90
6/2/97	Sidney, NE	2.32

and/or localized flooding. For the event on 9/19/96, the greater of the two gage reports, 2.52 inches, will be used. The events and their associated return periods that are used in the analysis are listed in Table 6.2. The return periods for each storm were linearly interpolated from the SCS TP-49 and log-Pearson distributions.

Table 6.2 - Rainfall events greater than 2-year storm, 1992-1997.

Date	Rainfall Gage	24-hour Rainfall (in)	Return Period, (yrs) SCS TP-49	Return Period, (yrs) log-Pearson
6/15/92	Sedgwick, CO	2.69	5.0	14.7
6/27/92	Sedgwick, CO	1.74	<2	2.1
5/9/95	Sidney, NE	2.92	7.2	22.3
6/4/95	Lodgepole, NE	3.15	9.5	35.7
7/15/95	Sedgwick, NE	2.93	7.3	22.7
9/19/96	Lodgepole, NE	2.52	4.2	9.6
6/2/97	Sidney, NE	2.32	3.4	6.6

6.2 Project Costs

The costs of the project must be identified for use in the benefit-cost analysis. The 1975 SCS work plan estimated the total cost for installation of the structural measures at \$3,994,040. The actual project costs in 1992 are available from the NRCS and total \$13,930,821. Amortized over the expected useful life of the project, (100 years, SCS 1975) at 3.25 percent interest (1992 discount interest rate of the Federal Reserve Bank, 1998), the annual costs are estimated at \$472,025. The project costs take into account construction, engineering services, project administration, land rights, and other related costs. With the exception of land rights, these costs are completely covered under P.L. 566. Cost incurred to the Julesburg Irrigation District are only those associated with land right purchases, totaling \$163,026. This amount was loaned to the district under three separate loans by the Northern Colorado Water Conservancy District (JID, 1998).

6.3 Ex Post Facto Analysis

6.3.1 Floodwater Damage Reduction Benefits

The procedures outlined in Chapter 4, the hydrologic data, and the costs can now be used to estimate the floodwater damages and project benefits that have incurred since completion of the project. Damages resulting from a given rainfall event with and without project conditions can be estimated using the 1992-1997 damage-frequency curves. Floodwater damage reduction benefits are computed as the difference between estimated damages without and estimated damages with the project in place. Note that a total of five damage categories are used to determine damage reduction benefits for each event. Damage-frequency curves are given for agricultural lands, other agricultural, non-agricultural, sediment and erosion, and indirect damages (reference Appendix D). The damage reduction benefits for a given rainfall event are the summation of the benefits obtain in each category. Floodwater damage reduction benefits for the identified storms are given in Table 6.3 and 6.4. For comparison, the results are shown assuming both the SCS TP-49 and the log-Pearson rainfall distributions.

It can be seen from the results, that the selection of rainfall distribution affects the estimated amount of damages and, therefore, benefits. Using the log-Pearson Type III distribution results in a difference of $479,241 or a 15 percent increase in damage reduction benefits. This increase is due to the lower probabilities of occurrence (longer return periods) predicted by the log-Pearson Type III distribution.

The development of the log-Pearson Type III distribution in Chapter 3 uses historical data from the local rainfall gages to predict the distribution. The SCS TP-49 distribution is interpolated from isohyetal maps developed for the western United States from the Continental Divide to the 103rd meridian. It would appear that the log-Pearson distribution would reflect a more accurate picture of the watershed hydrology. Indeed, it is the opinion of the author that it does. However, the damage-frequency curves, developed in Chapter 4, are created from SCS TP-49 return periods versus acres flooded data from the work plan. The number of acres flooded for a given return period corresponds to a precipitation amount given by the SCS TP-49 distribution. To use the log-Pearson distribution would require that the return periods be adjusted to reflect the same number of acres flooded for the same

Table 6.3 - Damage reduction benefits assuming the SCS TP-49 rainfall distribution.

			Without Project Damages		With Project Damages		Damage Reduction Benefits	
Date	24-hour Rainfall (in)	Return Period, T (yrs)	Each Event	Average	Each Event	Average	Each Event	Average
6/15/92	2.69	5.0	$844,310	$844,310	$206,319	$206,319	$637,991	$637,991
5/9/95	2.92	7.2	$1,143,215		$271,774		$871,440	
6/4/95	3.15	9.5	$1,191,267	$1,160,139	$279,016	$274,324	$912,250	$885,813
7/15/95	2.93	7.3	$1,145,934		$272,184		$873,749	
9/19/96	2.52	4.2	$1,072,804	$1,072,804	$263,771	$263,771	$809,033	$809,033
6/2/97	2.32	3.4	$1,048,214	$1,048,214	$259,357	$259,357	$788,857	$788,857
		TOTAL		$4,125,467		$1,003,771		$3,121,694

Table 6.4 - Damage reduction benefits assuming a log-Pearson Type III rainfall distribution.

Date	24-hour Rainfall (in)	Return Period, T (yrs)	Without Project Damages		With Project Damages		Damage Reduction Benefits	
			Each Event	Average	Each Event	Average	Each Event	Average
6/15/92	2.69	14.7	$1,080,648	$903,590	$275,042	$229,457	$805,605	$674,133
6/27/92	1.74	2.1	$726,532		$183,871		$542,661	
5/9/95	2.92	22.3	$1,461,646		$391,862		$1,069,784	
6/4/95	3.15	35.7	$1,541,498	$1,489,308	$425,798	$403,618	$1,115,700	$1,085,690
7/15/95	2.93	22.7	$1,464,780		$393,194		$1,071,586	
9/19/96	2.52	9.6	$1,234,596	$1,234,596	$288,977	$288,977	$945,619	$945,619
6/2/97	2.32	6.6	$1,176,359	$1,176,359	$280,866	$280,866	$895,493	$895,493
		TOTAL		$4,803,853		$1,202,918		$3,600,935

recipitation amount. This could be done and new damage-frequency curves developed. However, the results would be the same as the SCS TP-49 results shown in Table 6.3.

Therefore, the SCS TP-49 rainfall distribution is more appropriate for use with the damage-frequency curves in Chapter 4. The damage estimates in Table 6.3 are the reported results for this thesis.

6.3.2 Benefit-Cost Ratio

A cumulative, common time-based benefit-cost ratio can be determined using equations (4-6) and (4-7) for the period of analysis, 1992-1997. Using the 1997 discount interest rate of 5 percent and a constant amortized cost of $472,025, a 1997 time-based benefit-cost ratio of 1.26 is found. Computation of the benefit-cost ratio is illustrated in Table 6.5.

6.4 Interpretation of Results

The above analysis estimates the amount of damages that occurred with the project in place and damages that may have occurred without the project. The results may be further analyzed to interpret the performance of the project. The computed benefit-cost ratio is the ratio of the cumulative adjusted benefits and costs of the project for 1997. It should be noted that this ratio will change from year to year. For example, in 1993 and 1994, no rainfall

Table 6.5 - Time-base adjusted benefit (SCS TP-49 rainfall distribution).

Year	Total Benefit, B_t (from Table 6.3)	year, t	Adjusted 1997 time-base benefit $B_t (1 + i)^t$	Amortized cost, C_t
1992	$637,991	5	$890,642	$472,025
1993	$0	4	$0	$472,025
1994	$0	3	$0	$472,025
1995	$885,813	2	$1,012,273	$472,025
1996	$809,033	1	$864,856	$472,025
1997	$788,857	0	$788,857	$472,025
	Cumulative		$PW_b' = \Sigma B_t (1 + i)^t =$ $3,556,628	$PW_c' = \Sigma C_t =$ $2,832,150

Interest rate, $i = 6.9\%$
Period of analysis, n = 5

$$Benefit\text{-}cost\ ratio = \frac{PW_b'}{PW_c'} = \frac{\$3,556,628}{\$2,832,150} = 1.26$$

events greater than the 2-year storm occurred in the area. Therefore, for those two years, the individual year benefit-cost ratio was zero. However, the cumulative adjusted benefit-cost ratio for 1994 is 0.52. This is due to benefits incurred in 1992. Care should be taken in selecting the frame of reference for interpreting the benefit-cost ratio. Individual year and cumulative adjusted benefit-cost ratios are shown in Table 6.6.

Table 6.6 - Benefit-cost ratio (SCS TP-49 rainfall distribution).

Year	Total Benefit, B_t	year, t	Amortized cost, C_t	Individual year benefit-cost ratio	Discount Interest rate	Cumulative, adjusted benefit-cost ratio
92	$637,991	5	$472,025	1.41	7.61	1.35
93	$0	4	$472,025	0.00	7.37	0.73
94	$0	3	$472,025	0.00	7.18	0.52
95	$885,813	2	$472,025	1.88	7.08	0.88
96	$809,033	1	$472,025	1.71	6.99	1.10
97	$788,857	0	$472,025	1.67	6.90	1.26

The benefit-cost ratios analyzed thus far have pertained to the entire cost of the project. The majority of this cost was paid for by congressional appropriations by the United States Government under P.L. 566. However, there were costs incurred by the Julesburg Irrigation District for land easements totaling $163,026. This amount was loaned to the district in three separate loans of $33,000, $63,026, and $67,000 at 2.0, 5.0, and 2.0 percent interest, respectively. Each loan has a 40 year term resulting in a combined amortized annual payment of $7,329. For comparison, the benefit-cost ratios were computed with the Julesburg Irrigation District costs alone. Table 6.7 presents the results in the same manner as Table 6.6. As can be seen from the results, the Julesburg Irrigation District has benefitted up to 81 times their annual costs.

Table 6.7 - Benefit-cost ratio for Julesburg Irrigation District (SCS TP-49 distribution).

Year	Total Benefit, B_t	year, t	Amortized cost, C_t	Individual year benefit-cost ratio	Discount Interest rate	Cumulative, adjusted benefit-cost ratio
92	$637,991	5	$7,329	87.05	7.61	87.05
93	$0	4	$7,329	0.00	7.37	46.73
94	$0	3	$7,329	0.00	7.18	33.33
95	$885,813	2	$7,329	120.86	7.08	56.94
96	$809,033	1	$7,329	110.39	6.99	70.75
97	$788,857	0	$7,329	107.64	6.90	80.88

The algebraic mean of the time-base adjusted benefits for the period of analysis results in average annual benefits of $592,771. For the entire project, the amortized costs of the principle amount are $472,025 per year (assuming a 1992 discount interest rate). For the Julesburg Irrigation District alone, the annual payments to the project are $7,329. Therefore, at present, the average annual benefits exceed the annual costs as reflected in the benefit-cost ratios of Table 6.6 and 6.7. This clearly shows that, during the period of analysis, the project has been an economic benefit. However, the results will vary as the length of the period of analysis increases. To conclusively prove that the project has long term economic benefits, this analysis would, ideally, have to be performed at the end of the project's intended life.

6.5 Additional Performance Indicators

In addition to evaluating the benefits of the Sand Draws project using the frequency method, other indicators may be used to measure the project's performance. Historical trends in crop yields, changes in land use, flood relief application rates, and interviews with local landowners are all indicators that may measure performance.

The Sand Draws project was completed in June 1992. However, construction started in approximately 1979 and progressed over the years. During this time, some structures were completed and fully functional while others were still under construction. It is possible that areas in the floodplain could have felt benefits from completed structures, while other areas were still unprotected. Analyzing agricultural trends could reflect the project's benefits as early as the completion of the first structure in 1980. In the economic analysis, variation in crop yields are reflected in the derivation of the composite acre value. However, the composite acre value takes into account prevailing market values which are independent of the project. Analyzing trends in crop yields can provide conclusions of the affect of the project on agricultural production independently of market values.

Trends in crop yields were followed for Sedgwick County using data provided by the Colorado Agricultural Statistics Service. County statistics were used because accurate and continuous data of yields strictly within the floodplain are unavailable. Average annual crop yields for irrigated corn, winter wheat, alfalfa hay, and dry beans were tracked from 1975 to 1997. As a control group, the same yields were tracked for adjacent Logan County, Colorado. It is assumed that Logan County has agricultural practices and a climate similar to Sedgwick County. Trends for the indicated crops are shown in Figures 6.1, 6.2, 6.3, and 6.4. Trends for the total number of irrigated harvested acres is shown in Figure 6.5. The number of harvested acres could also indicate a change in land use. Again, in the economic analysis, this benefit is reflected in the composite acre value. However, changes in land use can provide another measure of project performance.

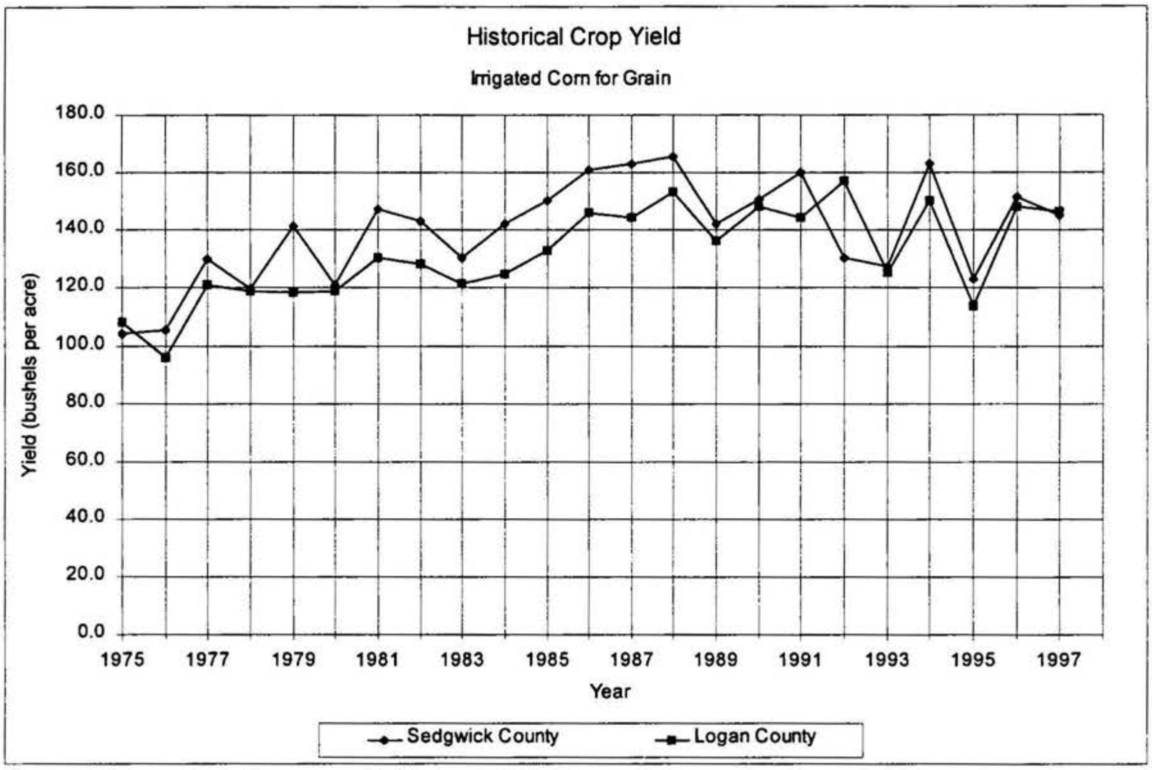


Figure 6.1 - Historical crop yield for irrigated corn for grain.

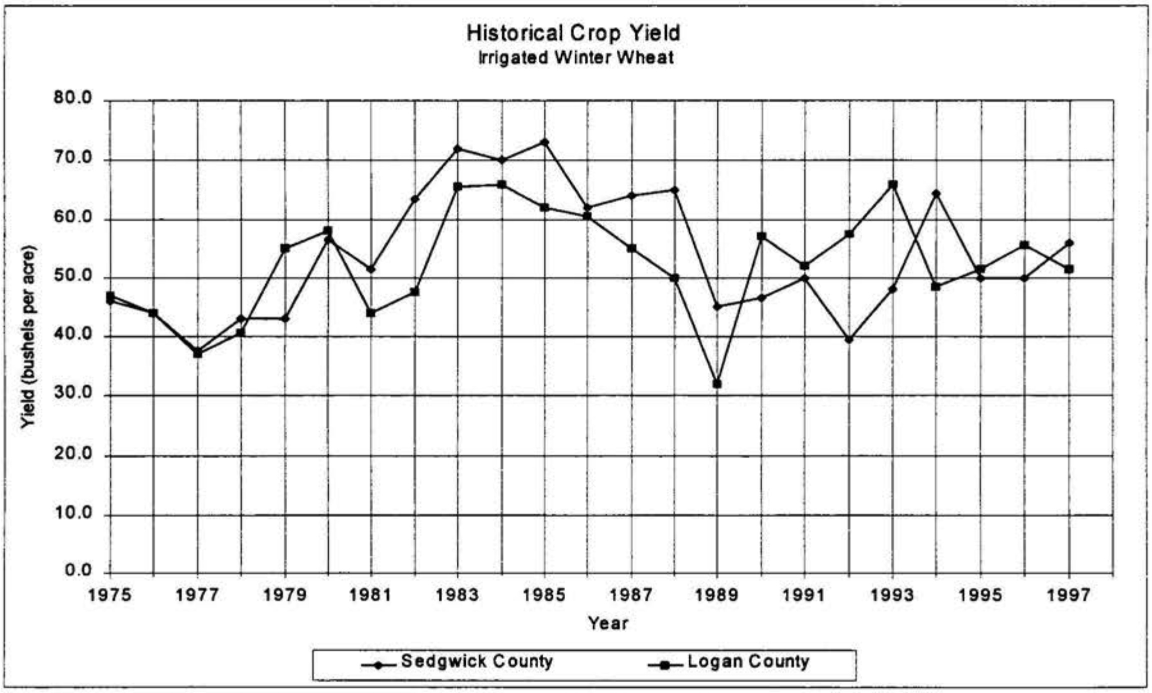


Figure 6.2 - Historical crop yield for irrigated winter wheat.

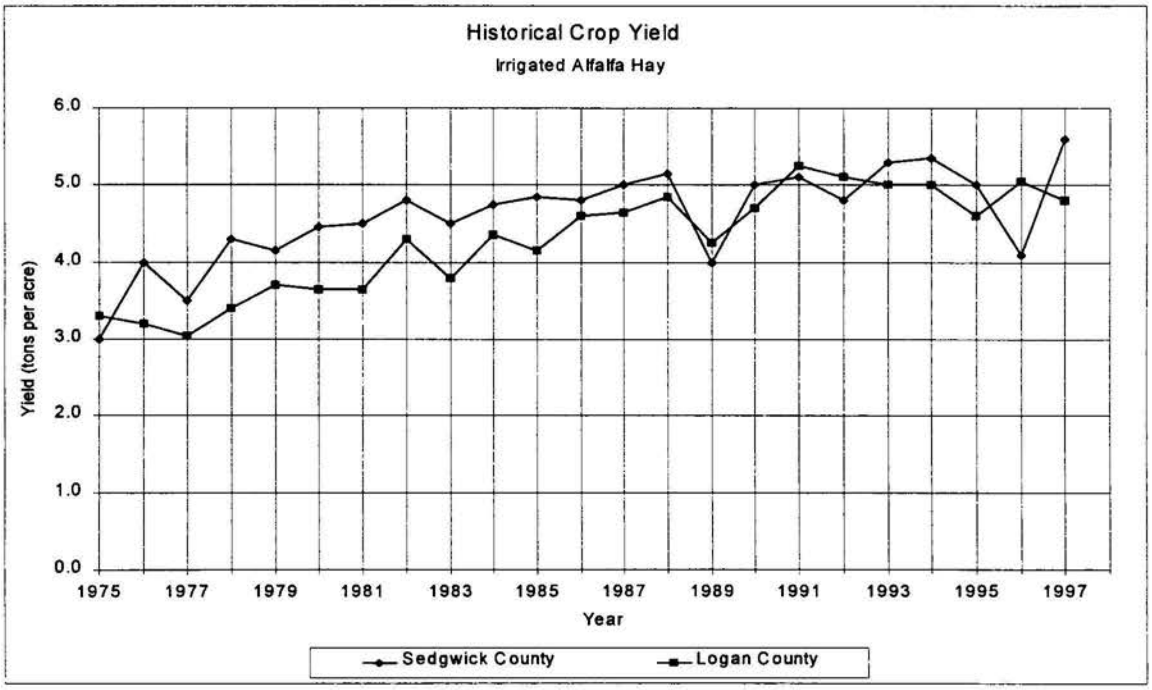


Figure 6.3 - Historical crop yield for irrigated alfalfa hay.

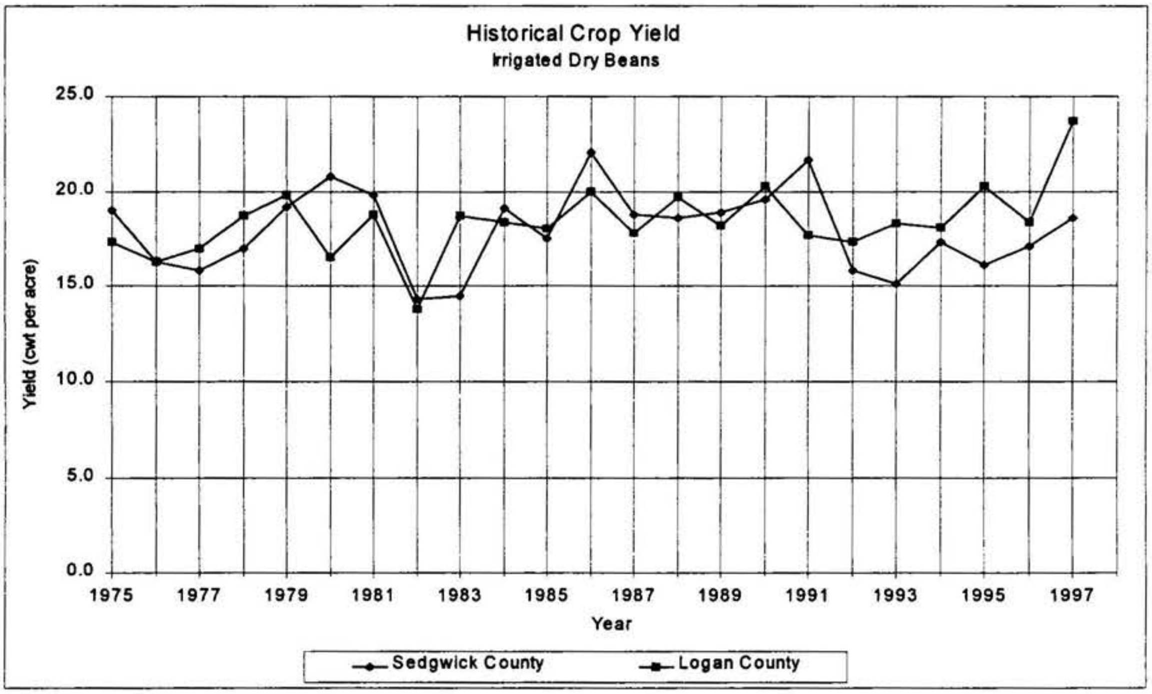


Figure 6.4 - Historical crop yield for irrigated dry beans.

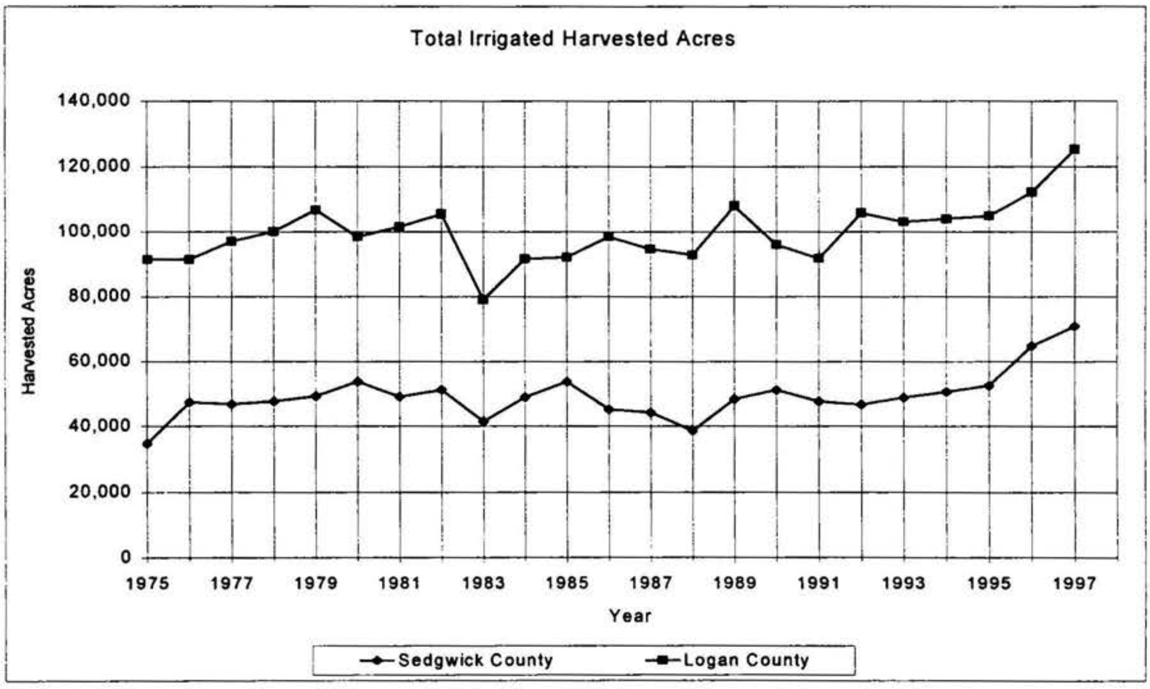


Figure 6.5 - Historical total irrigated harvested acres.

The figures show that there is no apparent deviation of the trend lines from each other showing no obvious effect of the project on county crop yields. Upon further investigation, it was found that it is inaccurate to use these figures to interpret project benefits. Crop yield data from the Colorado Agricultural Statistics Service reports the number of units harvested over the number of acres harvested, not the total number of acres planted. Therefore, if a parcel of land is damaged by floods and not harvested, the crop yield data would not reflect damages from floodwaters. The data would have to be the yield over the original acres planted to reflect a benefit. However, it is beneficial to note that the data is similar to that of nearby Logan County which, therefore, supports the validity and use of the Sedgwick County data for composite acre values.

Though crop yield records do not reflect project benefits, it was observed from field trips to the floodplain and interviews with Julesburg Irrigation District officials that there is an increase in the number of agricultural acres protected from floodwaters. Land was observed to be cultivated and harvested below and up to the downstream base of several structures (Figure 6.6). Whether or not this land was used for agriculture before the project was installed was not obtained. However, prevention of crop losses from flooding would inherently increase the yield on that land.

An attempt was made to track the historical rate of applications made for flood relief. The Sedgwick County Farm Service Agency was contacted for this information. The agency enacted a flood relief program only once since the completion of the project for an unrelated flood event along the South Platte River.

Figure 6.6 - View looking east across downstream face of dam SS-3 showing winter wheat crop at base of dam.

Interviews with local community members gave an indication of how the public perceives the benefits of the project. Opinions concerning construction of the project were sought out with no intention of quantifying the benefits. Local landowners, Wallace McClary and Kish Otsuka, indicated their support for the project (McClary, 1997, Otsuka, 1998). Both Mr. McClary and Mr. Otsuka experienced flooding on their properties prior to construction of the Sand Draw dams and indicated they have directly benefitted from the project. Mr. Larry Frame, manager of the Julesburg Irrigation District, also indicated support of the project (Frame, 1997).

Losses prior to the project included periodic breaching and sedimentation of the Highline Canal along with other damage to District property. With the Sand Draws project in operation, these damages have essentially ceased. It was noted that during the proposal phase of the project there were minor disputes with certain landowners over easement purchases. However, these disputes were quickly resolved. It was indicated by all parties interviewed that there is general approval of the project throughout the community. Most notably was the fact that the community received the project with minimal cost under the Small Watershed Program. Most of the landowners in the floodplain were present prior to the project and have experienced flooding first hand and flood mitigation at little or no cost is perceived as a tremendous benefit.

6.6 Site Inspection

An inspection of the structural measures was performed on June 30, 1998. The inspection consisted of site visits to each of the nine floodwater retarding structures. Notes, photographs and videotape recordings were taken at each site. Observations and notes at each site followed an inspection sheet prepared specifically for this project. The completed inspection sheets are contained in Appendix F. The inspection focused on the general conditions of six items; the upstream slope, downstream slope, abutments, emergency spillway, principle spillway and outlet works. Particular attention was given to any signs of structural degradation that would comprise the integrity of the structures. This included such things as surface erosion, excessive vegetative growth, cracking, excessive debris, and the condition of inlet and outlet structures. Each item was given a condition of good, acceptable or poor as defined by the following:

Observed Condition	Description
GOOD	Near new appearance, no threat to safety of the dam.
ACCEPTABLE	Surfaces irregular or otherwise not in new condition, no threat to safety of the dam.
POOR	Conditions observed appear to threaten safety of the dam.

All of the structures are classified in good condition. Structures SS-1, SS-3, and SS-4.5 have outlet works that are classified as acceptable condition. This is mainly due to erosion and/or sedimentation around the plunge pool area of the outlet works. These are minor problems and pose no threat to the safety of the dams.

An issue that seemed to be inconsistent is the access of cattle grazing onto the structures. Structures SS-1, 2, 3, 5, 6, and 7 allowed grazing directly on the dam and around the principle spillway. All of these structures had fences around them that had either a cattle access point or area where the fence was destroyed. Structures where grazing was allowed had short grasses and structures without grazing had tall grasses covering the slopes and crest. Neither condition seemed to have advantage over the other. Outside of the difference in grass height, the presence of cattle did not appear to have a negative impact on the structural integrity of the dams.

Structure SS-3 appeared to have the most activity of passing flood events. The drainage area of SS-3 is the largest of the nine drainage areas in the watershed. An accumulation of sediment was developing in the retarding area and very little vegetation appeared in the pool area as opposed to the other structures. On June 10, 1998, during the research for this thesis, a storm produced runoff that was detained in the pool area of SS-3 and SS-6. This storm provided a first hand account of an active structure. A site visit was made on June 11, 1998 to document and photograph the structure. Figure 6.7 shows dam SS-3 under dry conditions on Dec 4, 1997. Figures 6.8 and 6.9 show photographs of dam SS-3 on June 11, 1998 after a storm has occurred.

Figure 6.7 - Dam SS-3 under dry conditions on Dec 4, 1997.

Figure 6.8 - Dam SS-3 after storm on June 11, 1998.

Figure 6.9 - Outlet works of Dam SS-3 after storm on June 11, 1998.

Chapter 7

SUMMARY AND CONCLUSIONS

7.1 Summary

A method was proposed for evaluating the damage reduction benefits of a completed watershed flood control project. The ex post facto analysis uses principles from economics, hydrology, and engineering to develop damage-frequency curves and investigates supporting performance indicators such as site inspections, historical crop yields, changes in land use, flood relief applications, and interviews with local community members. The period of analysis for an evaluation is selected as the period of time from project completion to the present, or the latest date of available information. If available, damage-frequency curves developed in the project proposal phase are adjusted in time to reflect the future period of analysis. Known damage producing hydrologic events, as defined by the damage-frequency curves, are then applied to the curves to estimate damages prevented and benefits provided by the project. Benefit-cost ratios are then determined from known annual costs and benefits.

The ex post facto method was applied to the Sedgwick Sand Draws case study for evaluation of current damage reduction benefits. Normally, damage-frequency curves are available from the proposal phase of a flood control project. However, for the Sand Draws project, only partial information of the original damage-frequency curves was available. In the interest of cost and time, a technique for estimating the full 1975 time base damage-frequency curves was developed. Using economic discounting, current agricultural data, and assuming that geometric proportioning of the curves was preserved throughout time, damage-frequency curves were developed for the period of analysis. A hydrologic analysis of the Sand Draws watershed was performed in order to identify damage producing storm events and to determine, therefore, floodwater damage reduction benefits. In addition, benefit-cost analyses and a look at other performance indicators were also carried out.

In the hydrologic analysis of the Sand Draws watershed, a log-Pearson Type III rainfall distribution was found to fit the local rain gage data. Also available for the watershed was the Soil Conservation Service rainfall distribution, SCS TP-49. For comparison, both distributions were used in the ex post facto analysis. The results showed a difference of approximately 15 percent in damage reduction benefits. The reason for this is the lower probabilities of occurrence (longer return periods) predicted by the log-Pearson distribution. It was concluded that, because of methods used in construction of the damage frequency curves, the SCS TP-49 distribution was more appropriate here. If a separate, more rigorous investigation was carried out where new damage-frequency curves were developed, it is predicted that the log-Pearson distribution would be more accurate.

7.2 Conclusions

The period of analysis selected for the Sand Draws case study is from completion of the project in June 1992, to the latest date of available data, September 31, 1997. The hydrologic analysis, using the SCS TP-49 distribution, identified six rainfall events that occurred during this period and could be used in the evaluation. Given this information, it was found that the Sand Draws project produced an estimated $3,556,628 in damage reduction benefits resulting in average annual benefits of $592,771. A current, cumulative benefit-cost ratio of 1.26 was computed using the amortized total cost for the project. It should be noted that the results are dependent on the period of analysis and will vary from year to year. At present, the project is seen as an economic benefit. However, to conclusively prove that the project has long term economic benefits, the period of analysis would have to be over the intended life of the project.

Other performance indicators such as crop yield records and flood relief application rates did not show definitive results. Available crop yield data was shown to be in an incorrect format to reflect project benefits and flood relief application rates were unavailable. However, interviews with local community members indicated support of the project. From field trip observations, it was apparent that there is an increase in the number of agricultural acres protected from floodwaters. Also, site inspection results indicated all of the structures to be in good working condition.

This case study of the Small Watershed Program shows an example of a successful flood control project. The Sand Draws project is a good example of how the program was intended to work. Funding and technical support for construction of the project were provided by the SCS and, after completion, turned over to the supporting organizations. In the six years since its completion, the project has performed adequately and the community has benefitted. The selected case study does, however, raise the question of whether or not a project of this magnitude could be carried out in today's political and financial environment. The Small Watershed Program is still in existence, but is under financial uncertainty and has changed its focus from structural to nonstructural means of flood control.

Analyzing the damage reduction benefits of a flood control project, ex post facto, quantifies the performance of the project and is beneficial in the planning of new projects. The method used here for the Sand Draws case study allows for quantification of the benefits of a project when original damage-frequency curves are not available. The method could be used for many flood control projects, however, it is particularly suited for those projects carried out under the Small Watershed Program.

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BIBLIOGRAPHY

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APPENDIX A

PRECIPITATION FREQUENCY ANALYSIS

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PRECIPITATION FREQUENCY ANALYSIS

Frequency Distributions

As noted in chapter 3, the average annual maximum precipitation records from three NOAA weather stations were selected for the hydrologic analysis of the Sedgwick Sand Draws Watershed.

The data were assumed to take the form of either a log-Pearson Type III distribution or an Extreme Value Type I distribution. Both distributions use the frequency factor equation proposed by Chow (1988):

$$x_T = \bar{x} + K_T s \qquad \text{(A-1)}$$

where: x_T = magnitude of the 24-hour precipitation event for a given return period, T (yrs);

$\bar{x}$ = mean value of the sample data set;

K_T = frequency factor;

s = standard deviation of the sample data set

The following outlines the procedures used for fitting the data to the assumed distributions.

Extreme Value Type I Distribution

1. Calculate the standard deviation, s, and mean, $\bar{x}$, of the average annual maximum precipitation from the three weather stations.

2. Calculate K_T given by the expression:

$$K_T = -\frac{\sqrt{6}}{\pi}(0.5772 + \ln[\ln(\frac{T}{T-1})]) \tag{A-2}$$

3. Using equation (A-1), calculate x_T for the desired return period.

log - Pearson Type III Distribution

1. Take the base 10 logarithms of the average annual maximum precipitation from the three weather stations, y = log(x).

2. Calculate the standard deviation, s, the mean, $\bar{y}$, and the skewness coefficient, C_s of the logarithms of the data. C_s is given by the equation:

$$C_s = \frac{n \sum_{i=1}^{n} (x_i - \bar{x})^3}{(n - 1)(n - 2)\, s^3} \tag{A-3}$$

where: n = number of observed data points

3. Calculate K_T given by the expression:

$$K_T = z + (z^2-1)k + \frac{1}{3}(z^3-6z)k^2 - (z^2-1)k^3 + zk^4 + \frac{1}{3}k^5 \tag{A-4}$$

where: $k = C_s / 6$

z = the standard normal variable given by:

$$z = w - \frac{2.515517 + 0.802853w + 0.010328w^2}{1 + .432788w + 0.189269w^2 + 0.001308w^3} \qquad \text{(A-5)}$$

where: w is an intermediate variable dependent on the return period, T, calculated as:

$$w = [\ln(\frac{1}{p^2})]^{1/2} \qquad \text{(A-6)}$$

where: p is the exceedance probability, $p = 1/T$

4. Calculate y_T for the desired return period using equation (A-1) in the form:

$$y_T = \bar{y} + K_T s \qquad \text{(A-7)}$$

5. Calculate the antilog of y_T to determine x_T.

Probability Plotting

To check that a probability distribution fits the precipitation data, the method of probability plotting is used (Chow, 1988). This method linearizes the distribution function and the observed data may then be plotted against the fitted curve for comparison.

First, the data are ranked in order by descending magnitude.

Next, calculate the probability plotting positions for the data. The plotting position refers to the probability value assigned to each piece of data to be plotted (Chow, 1988). The plotting position for the ranked data is given by the exceedance probability in the form:

$$p = \frac{m - b}{n + 1 - 2b} \qquad \text{(A-8)}$$

where: m = rank of a value in a list ordered by descending magnitude.

n = total number of data points

b = parameter based on the assumed distribution. For a log-Pearson Type III distribution, b = 3/8 and for an Extreme Value Type I distribution, b = 0.44 (Chow, 1988).

The observed data is then used to calculate the fitted distribution using equation (A-1). The distribution is then plotted along with the observed data using the standard normal variable as the horizontal axis to linearize the plot. This plot is used to compare the goodness of fit between the observed data and the assumed distribution. Figures A.1 and A.2 show the probability plots for the log-Pearson and the Extreme Value distributions, respectively.

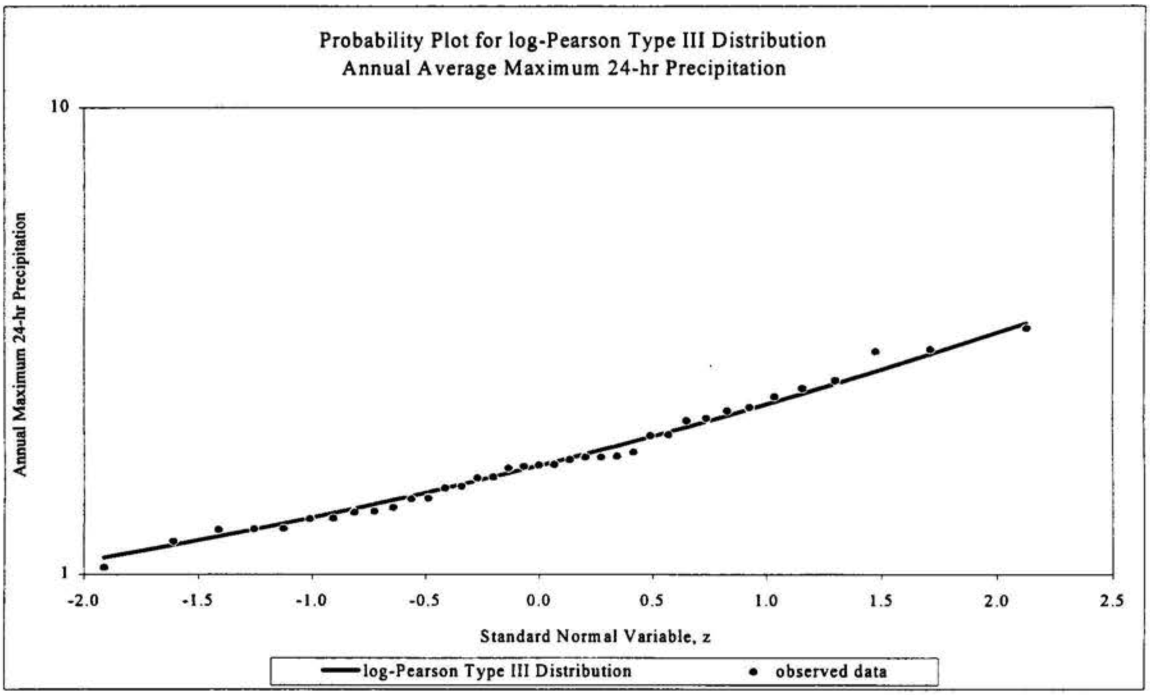


Figure A.1 - Probability plot for log-Pearson Type III distribution.

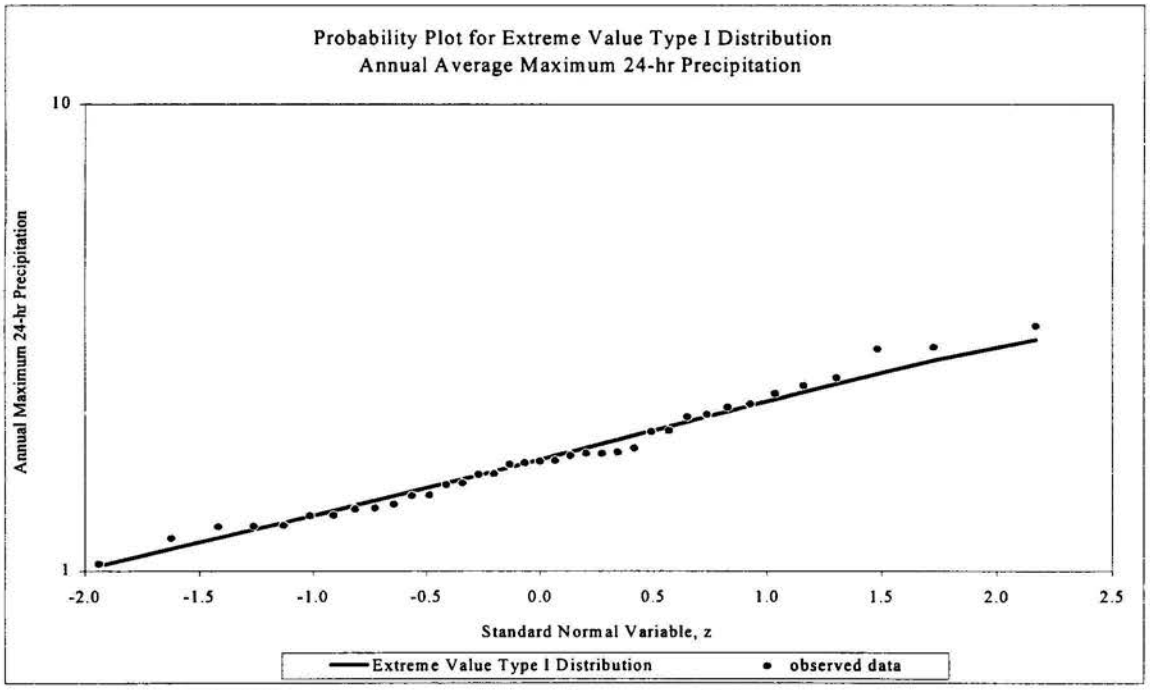


Figure A.2 - Probability plot for Extreme Value Type I Distribution.

APPENDIX B

1975 DAMAGE-FREQUENCY CURVES

APPENDIX B

DEVELOPMENT OF THE 1975 DAMAGE-FREQUENCY CURVES FOR OTHER CATEGORIES

The damage frequency curves for the categories of other agricultural, non-agricultural, sediment and erosion, and indirect damages are derived based on the shape and geometric proportioning of the 1975 agricultural lands damage-frequency curve developed in Chapter 5. The following is an algorithm for computing the ordinates of the 1975 damage-frequency curves for these categories.

1. The agricultural lands damage-frequency curve can be shown in general using the symbol p for the abscissa values and D for the ordinate values as presented in Figure B.1. The values p_1, p_2, p_3, p_4, and p_5 represent the value of the 100, 10, 5, 2, and 1.8 year return periods. The values of D_1, D_2, D_3, D_4, and D_5, represent the corresponding unknown damage values.

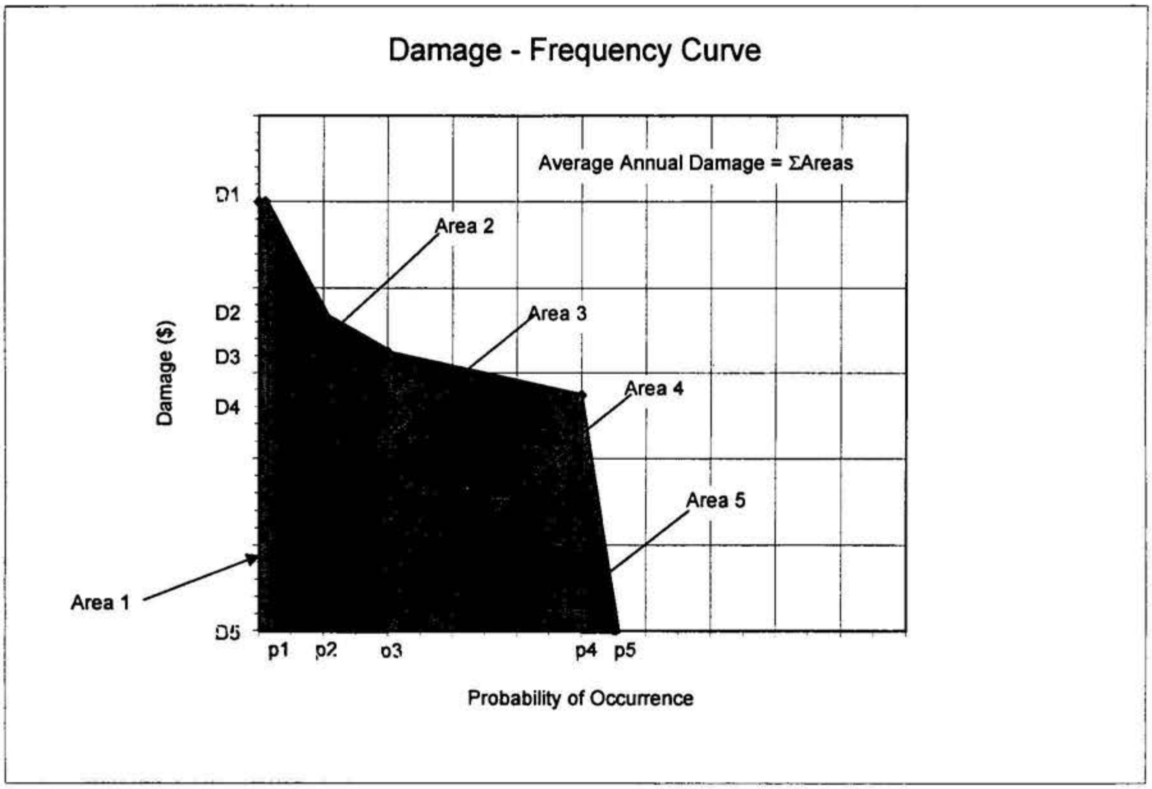


Figure B.1 - Area under the damage-frequency curve computation.

2. Using the definition of N_i defined in Chapter 5, each individual area can be written as:

$$A_1 = N_1 (A_t) \quad \text{(B-1)}$$

$$A_2 = N_2 (A_t) \quad \text{(B-2)}$$

$$A_3 = N_3 (A_t) \quad \text{(B-3)}$$

$$A_4 = N_4 (A_t) \quad \text{(B-4)}$$

$$A_5 = N_5 (A_t) \quad \text{(B-5)}$$

where: A_t = the total area under the curve, or the expected annual damages.

3. The individual areas may also be described by the following equations assuming a linear distribution between points:

$$A_1 = p_1 D_1 \quad \text{(B-6)}$$

$$A_2 = 0.5 (p_2 - p_1) (D_1 - D_2) + (p_2 - p_1) D_2 \quad \text{(B-7)}$$

$$A_3 = 0.5 (p_3 - p_2) (D_2 - D_3) + (p_3 - p_2) D_3 \quad \text{(B-8)}$$

$$A_2 = 0.5 (p_4 - p_3) (D_3 - D_4) + (p_4 - p_3) D_4 \quad \text{(B-9)}$$

$$A_5 = 0.5 (p_5 - p_4) D_4 \quad \text{(B-10)}$$

4. Solving equations (B-1) through (B-10) simultaneously for D_1, D_2, D_3, and D_4 gives:

$$D_1 = \frac{N_1 (A_t)}{p_1} \quad \text{(B-11)}$$

$$D_2 = \frac{2 N_2 (A_t)}{(p_2 - p_1)} - D_1 \quad \text{(B-12)}$$

$$D_3 = \frac{2 N_3 (A_t)}{(p_3 - p_2)} - D_2 \quad \text{(B-13)}$$

$$D_4 = \frac{2 N_4 (A_t)}{(p_4 - p_3)} - D_3 \quad \text{(B-14)}$$

$$D_5 = 0 \quad \text{(B-15)}$$

5. For the 1975 damage-frequency curves the expected annual damages, A_t, are known from the SCS work plan and are given in Table B.1. Using equations (B-

11) through (B-15), the 1975 damage-frequency curves can be constructed for the categories of other agricultural, non-agricultural, sediment and erosion, and indirect damages. The derived damage-frequency curves are given in Figures B.2 through B.4.

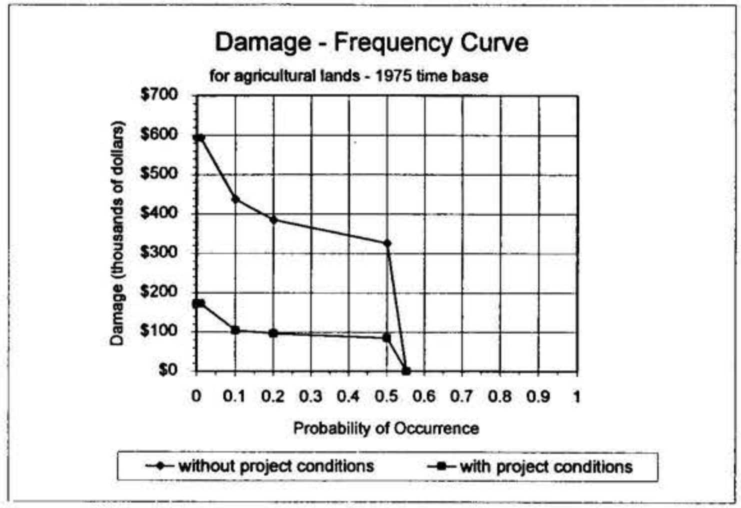
Table B.1 - 1975 Expected Annual Damages.

Category	Expected Annual Damages, A_t	
	w/o project	w/ project
other agricultural	\$11,500	\$4,750
non-agricultural	\$11,760	\$1,930
sediment and erosion	\$11,370	\$4,220
indirect damages	\$35,120	\$6,200

Damage-Frequency Curve - Irrigated Agricultural Lands
1975 time base

Damageable Value Per Acre	
w/o project	w/ project
$115.83	$67.55

Return Period (years)	Probability of Occurrence	w/o project Damages	w/ project Damages
100	0.01	$593,504	$172,518
10	0.10	$437,251	$104,565
5	0.20	$385,129	$96,526
2	0.50	$325,361	$84,841
1.81	0.55	$0	$0



Damage-Frequency Curve - Other Agricultural
1975 time base

Average annual damages from SCS work plan	
w/o project	w/ project
$11,370	$4,220

Return Period (years)	Probability of Occurrence	w/o project N	w/ project N	w/o project Damages	w/ project Damages
100	0.01	0.028	0.032	$32,727	$15,266
10	0.10	0.222	0.232	$24,111	$9,253
5	0.20	0.197	0.187	$21,237	$8,541
2	0.50	0.511	0.507	$17,941	$7,507
1.81	0.55	0.041	0.041	$0	$0

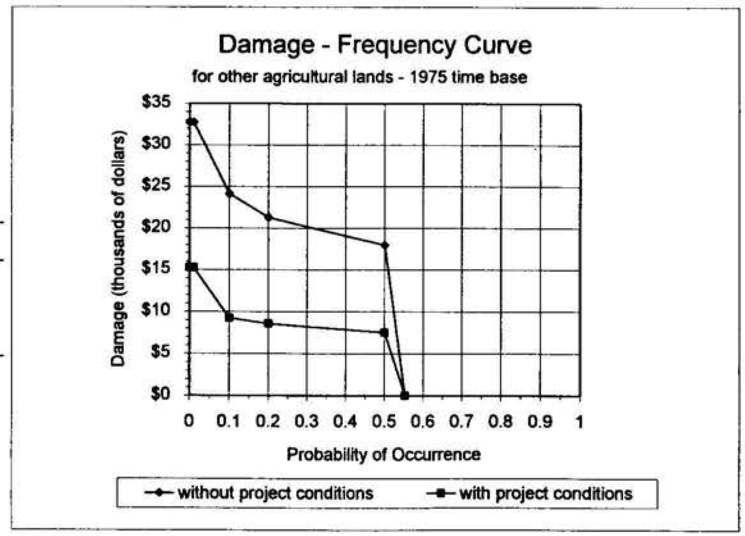
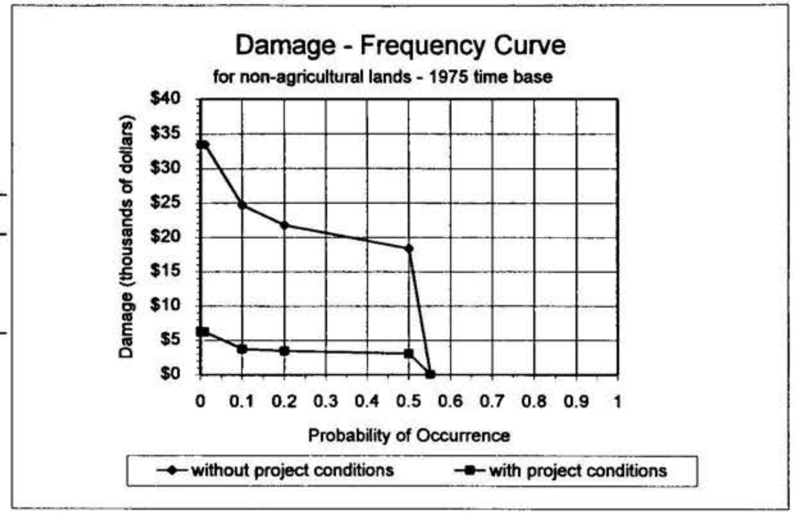


Figure B.2 -1975 time base damage-frequency curves for Agricultural and Other Agricultural.

Damage-Frequency Curve - Non-agricultural
1975 time base

Average annual damages from SCS work plan	
w/o project	w/ project
$11,760	$1,930

Return Period (years)	Probability of Occurrence	w/o project N	w/ project N	w/o project Damages	w/ project Damages
100	0.01	0.028	0.032	$33,467	$6,203
10	0.10	0.222	0.232	$24,656	$3,759
5	0.20	0.197	0.187	$21,717	$3,470
2	0.50	0.511	0.507	$18,347	$3,050
1.81	0.55	0.041	0.041	$0	$0



Damage-Frequency Curve - Sediment & Erosion
1975 time base

Average annual damages from SCS work plan	
w/o project	w/ project
$11,370	$4,220

Return Period (years)	Probability of Occurrence	w/o project N	w/ project N	w/o project Damages	w/ project Damages
100	0.01	0.028	0.032	$32,357	$13,562
10	0.10	0.222	0.232	$23,839	$8,220
5	0.20	0.197	0.187	$20,997	$7,588
2	0.50	0.511	0.507	$17,738	$6,670
1.81	0.55	0.041	0.041	$0	$0

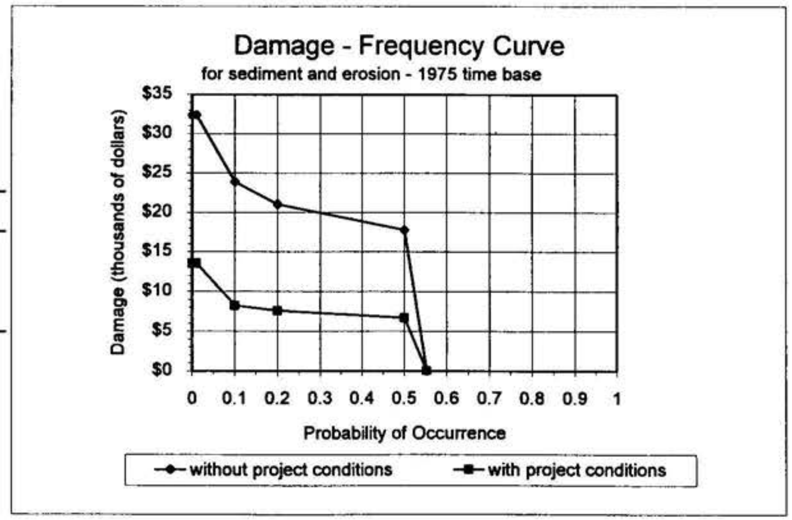


Figure B.3 -1975 time base damage-frequency curves for Non-agricultural and Sediment and Erosion.

Damage-Frequency Curve - Indirect Damages
1975 time base

Average annual damages from SCS work plan	
w/o project	w/ project
$35,120	$6,200

Return Period (years)	Probability of Occurrence	w/o project N	w/ project N	w/o project Damages	w/ project Damages
100	0.01	0.028	0.032	$99,947	$19,926
10	0.10	0.222	0.232	$73,634	$12,077
5	0.20	0.197	0.187	$64,856	$11,149
2	0.50	0.511	0.507	$54,791	$9,799
1.81	0.55	0.041	0.041	$0	$0

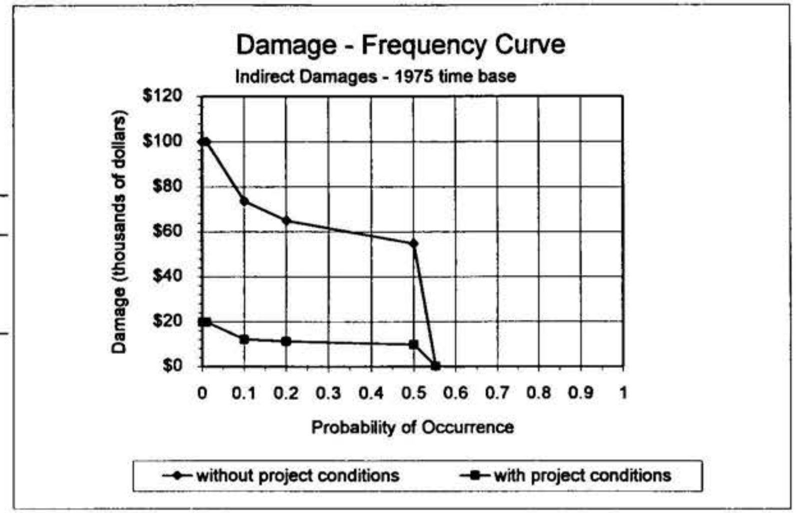


Figure B.4 -1975 time base damage-frequency curves for Indirect Damages.

APPENDIX C

COMPOSITE ACRE VALUES

Table C.1 - 1975 Sedgwick County composite acre value.

Source: Colorado Agricultural Statistics (CAS) - 1981

Crop	Acreage planted Acres	Unit	Irrigated Acreage harvested Acres	Irrigated Yield per acre	Irrigated Production	Non-irrigated Acreage harvested Acres	Non-irrigated Yield per acre	Non-irrigated Production	Total Acreage harvested Acres	Total Yield per acre	Total Production
Winter Wheat	79,500	bushel	500	46.00	23,000	75,500	36.00	2,718,000	76,000	36.00	2,741,000
Spring Wheat	800	bushel	400	54.50	21,800	200	20.00	4,000	600	43.00	25,800
Corn for Grain	21,000	bushel	14,500	104.00	1,508,000	2,000	17.00	34,000	16,500	93.50	1,542,000
Corn for Silage		ton							4,100	15.00	61,000
Barley	1,500	bushel	300	59.00	17,700	1,200	23.00	27,600	1,500	30.00	45,300
Oats	2,100	bushel	400	60.00	24,000	1,500	52.00	78,000	1,900	53.50	102,000
Sorghum for Grain	2,300	bushel				400	15.00	6,000	400	15.00	6,000
Sunflowers, Oil		pound									
Sunflowers, Non-oil		pound									
Sugar Beets	3,100	ton							3,100	17.20	53,200
Dry Beans	7,600	pound	7,000	1,900.00	133,000	500	340.00	1,700	7,500	1,800.00	134,700
Alfalfa Hay		ton	2,600	3.00		1,400	3.00		4,000	3.00	12,000
Other Hay		ton	1,900	1.90		4,600	1.90		6,500	1.90	12,200
Total Planted Acreage	111,700										

Total Harvested Acreage 122,100 acres
Total Irrigated Harvested Acreage 34,800 (includes all corn for silage and sugar beets)
Total Non-Irrigated Harvested Acreage 87,300 (includes all sunflower)

Composite Acre - Irrigated Only

CAS Marketing Year Average Prices

Crop	Acreage harvested Acres	Percent of Total Harvested Acreage	Unit	Yield per Acre	Marketing Year Average Prices dollars / unit	Weighted per Acre Value	
Irrigated Winter Wheat	500	1.4	bushel	46.0	3.24	2.14	
Irrigated Spring Wheat	400	1.1	bushel	54.5	3.23	2.02	
Irrigated Corn for Grain	14,500	41.7	bushel	104.0	2.62	113.53	
Corn for Silage	4,100	11.8	ton	15.0	19.50	34.46	estimated
Irrigated Barley	300	0.9	bushel	59.0	2.64	1.34	
Irrigated Oats	400	1.1	bushel	60.0	1.85	1.28	
Irrigated Sorghum for Grain	0	0.0	bushel	0.0	2.34	0.00	
Sugar Beets	3,100	8.9	ton	17.2	28.70	43.97	
Irrigated Dry Beans	7,000	20.1	cwt	19.0	15.50	59.24	
Irrigated Alflafa Hay	2,600	7.5	ton	3.0	54.00	12.10	
Irrigated Other Hay	1,900	5.5	ton	1.90	54.00	5.60	
Total Harvested Acreage	34,800	100.0		**Total Composite Acre Value =**		**275.70**	

Table C.2 - 1992 Sedgwick County composite acre value.

Source: Colorado Agricultural Statistics (CAS) - 1995

Crop	Acreage planted Acres	Unit	Irrigated: Acreage harvested Acres	Irrigated: Yield per acre	Irrigated: Production	Non-irrigated: Acreage harvested Acres	Non-irrigated: Yield per acre	Non-irrigated: Production	Total: Acreage harvested Acres	Total: Yield per acre	Total: Production
Winter Wheat	78,000	bushel	1,900	39.50	75,000	63,100	27.50	1,725,000	65,000	27.50	1,800,000
Spring Wheat	300	bushel				200	30.00	6,000	200	30.00	6,000
Corn for Grain	44,300	bushel	34,000	130.00	4,420,000	9,000	60.00	540,000	43,000	115.50	4,960,000
Corn for Silage		ton							900	19.00	17,000
Barley	1,000	bushel				500	30.00	15,000	500	30.00	15,000
Oats	3,100	bushel	100	90.00	9,000	600	43.50	26,000	700	50.00	35,000
Sorghum for Grain	600	bushel									
Sunflowers, Oil	3,300	pound							3,300	1,320.00	4,350,000
Sunflowers, Non-oil	1,300	pound							1,200	1,625.00	1,950,000
Sugar Beets		ton									
Dry Beans	5,200	pound	4,800	1,580.00	7,600	400	1,000.00	4,000	5,200	1,540.00	80,000
Alfalfa Hay		ton	4,000	4.80	19,200				4,000	4.80	19,200
Other Hay		ton	1,000	2.40	2,400	2,100	2.00	4,200	3,100	2.15	6,600
Total Planted Acreage	136,200										

Total Harvested Acreage	127,100 acres
Total Irrigated Harvested Acreage	46,700 (includes all corn for silage and sugar beets)
Total Non-Irrigated Harvested Acreage	80,400 (includes all sunflower)

Composite Acre - Irrigated Only

CAS Marketing Year Average Prices

Crop	Acreage harvested Acres	Percent of Total Harvested Acreage	Unit	Yield per Acre	Marketing Year Average Prices dollars / unit	Weighted per Acre Value
Irrigated Winter Wheat	1,900	4.1	bushel	39.5	3.15	5.06
Irrigated Spring Wheat	0	0.0	bushel	0.0	3.00	0.00
Irrigated Corn for Grain	34,000	72.8	bushel	130.0	2.23	211.06
Corn for Silage	900	1.9	ton	19.0	19.10	6.99
Irrigated Barley	0	0.0	bushel	0.0	2.57	0.00
Irrigated Oats	100	0.2	bushel	90.0	1.70	0.33
Irrigated Sorghum for Grain	0	0.0	bushel	0.0	1.92	0.00
Sugar Beets	0	0.0	ton	0.0	39.50	0.00
Irrigated Dry Beans	4,800	10.3	cwt	15.8	19.00	30.86
Irrigated Alflafa Hay	4,000	8.6	ton	4.8	64.50	26.52
Irrigated Other Hay	1,000	2.1	ton	2.40	64.50	3.31
Total Harvested Acreage	46,700	100.0		**Total Composite Acre Value =**		**284.13**

Table C.3 - 1993 Sedgwick County composite acre value.

Source: Colorado Agricultural Statistics (CAS) - 1995

Crop	Acreage planted Acres	Unit	Irrigated Acreage harvested Acres	Irrigated Yield per acre	Irrigated Production	Non-irrigated Acreage harvested Acres	Non-irrigated Yield per acre	Non-irrigated Production	Total Acreage harvested Acres	Total Yield per acre	Total Production
Winter Wheat	84,100	bushel	2,500	48.00	120,000	77,500	43.00	3,330,000	80,000	43.00	3,450,000
Spring Wheat	100	bushel				100	30.00	3,000	100	30.00	3,000
Corn for Grain	41,900	bushel	34,000	127.00	4,320,000	7,000	53.00	370,000	41,000	114.50	4,690,000
Corn for Silage		ton							700	20.00	14,000
Barley		bushel									
Oats	2,100	bushel	100	80.00	8,000	500	44.00	22,000	600	50.00	30,000
Sorghum for Grain	600	bushel									
Sunflowers, Oil	3,100	pound							3,100	1,275.00	3,960,000
Sunflowers, Non-oil	1,400	pound							1,300	1,355.00	1,760,000
Sugar Beets		ton									
Dry Beans	6,700	pound	5,900	1,510.00	89,000	500	800.00	4,000	6,400	1,450.00	93,000
Alfalfa Hay		ton	5,000	5.30	26,500				5,000	5.30	26,500
Other Hay		ton	700	1.85	1,300	600	2.00	1,200	1,300	1.90	2,500
Total Planted Acreage	139,300										

Total Harvested Acreage 139,500 acres
Total Irrigated Harvested Acreage 48,900 (includes all corn for silage and sugar beets)
Total Non-Irrigated Harvested Acreage 90,600 (includes all sunflower)

Composite Acre - Irrigated Only
CAS Marketing Year Average Prices

Crop	Acreage harvested Acres	Percent of Total Harvested Acreage	Unit	Yield per Acre	Marketing Year Average Prices dollars / unit	Weighted per Acre Value
Irrigated Winter Wheat	2,500	5.1	bushel	48.0	3.21	7.88
Irrigated Spring Wheat	0	0.0	bushel	0.0	2.83	0.00
Irrigated Corn for Grain	34,000	69.5	bushel	127.0	2.65	234.00
Corn for Silage	700	1.4	ton	20.0	19.90	5.70
Irrigated Barley	0	0.0	bushel	0.0	2.93	0.00
Irrigated Oats	100	0.2	bushel	80.0	1.82	0.30
Irrigated Sorghum for Grain	0	0.0	bushel	0.0	2.50	0.00
Sugar Beets	0	0.0	ton	0.0	38.40	0.00
Irrigated Dry Beans	5,900	12.1	cwt	15.1	27.00	49.19
Irrigated Alflafa Hay	5,000	10.2	ton	5.3	77.00	41.73
Irrigated Other Hay	700	1.4	ton	1.85	77.00	2.04
Total Harvested Acreage	48,900	100.0		**Total Composite Acre Value =**		**340.83**

Table C.4 - 1994 Sedgwick County composite acre value.

Source: Colorado Agricultural Statistics (CAS) - 1995

			Irrigated			Non-irrigated			Total		
Crop	Acreage planted Acres	Unit	Acreage harvested Acres	Yield per acre	Production	Acreage harvested Acres	Yield per acre	Production	Acreage harvested Acres	Yield per acre	Production
Winter Wheat	95,000	bushel	1,400	64.50	90,000	83,600	29.00	2,445,000	85,000	30.00	2,535,000
Spring Wheat		bushel									
Corn for Grain	45,400	bushel	35,000	163.00	5,705,000	9,000	41.00	370,000	44,000	138.00	6,075,000
Corn for Silage		ton							1,000	21.50	21,500
Barley		bushel									
Oats	1,800	bushel				800	35.00	28,000	800	35.00	28,000
Sorghum for Grain	400	bushel									
Sunflowers, Oil	3,100	pound							3,000	1,035.00	3,100,000
Sunflowers, Non-oil	1,000	pound							1,000	680.00	680,000
Sugar Beets	160	ton							160	24.40	3,900
Dry Beans	7,800	pound	7,000	1,730.00	121,000	500	1,200.00	6,000	7,500	1,690.00	127,000
Alfalfa Hay		ton	5,500	5.35	29,500				5,500	5.35	29,500
Other Hay		ton	600	1.35	800	400	1.25	500	1,000	1.30	1,300
Total Planted Acreage	154,100										

Total Harvested Acreage	148,960	acres
Total Irrigated Harvested Acreage	50,660	(includes all corn for silage and sugar beets)
Total Non-Irrigated Harvested Acreage	98,300	(includes all sunflower)

Composite Acre - Irrigated Only

CAS Marketing Year Average Prices

Crop	Acreage harvested Acres	Percent of Total Harvested Acreage	Unit	Yield per Acre	Marketing Year Average Prices dollars / unit	Weighted per Acre Value
Irrigated Winter Wheat	1,400	2.8	bushel	64.5	3.50	6.24
Irrigated Spring Wheat	0	0.0	bushel	0.0	3.35	0.00
Irrigated Corn for Grain	35,000	69.1	bushel	163.0	2.40	270.27
Corn for Silage	1,000	2.0	ton	21.5	21.40	9.08
Irrigated Barley	0	0.0	bushel	0.0	2.70	0.00
Irrigated Oats	0	0.0	bushel	0.0	1.85	0.00
Irrigated Sorghum for Grain	0	0.0	bushel	0.0	2.02	0.00
Sugar Beets	160	0.3	ton	24.4	35.70	2.75
Irrigated Dry Beans	7,000	13.8	cwt	17.3	16.60	39.68
Irrigated Alflafa Hay	5,500	10.9	ton	5.4	90.50	52.57
Irrigated Other Hay	600	1.2	ton	1.35	90.50	1.45
Total Harvested Acreage	50,660	100.0		**Total Composite Acre Value =**		**382.04**

Table C.5 - 1995 Sedgwick County composite acre value.

Source: Colorado Agricultural Statistics (CAS) - 1996

			Irrigated			Non-irrigated			Total		
Crop	Acreage planted Acres	Unit	Acreage harvested Acres	Yield per acre	Production	Acreage harvested Acres	Yield per acre	Production	Acreage harvested Acres	Yield per acre	Production
Winter Wheat	88,000	bushel	2,000	50.00	100,000	81,000	42.50	3,435,000	83,000	42.50	3,535,000
Spring Wheat		bushel									
Corn for Grain	50,500	bushel	37,000	123.00	4,545,000	11,000	40.00	440,000	48,000	104.00	4,985,000
Corn for Silage		ton							800	20.00	16,000
Barley	1,600	bushel	300	85.00	25,500	1,100	29.00	32,000	1,400	41.00	57,500
Oats	2,800	bushel				800	37.50	30,000	800	37.50	30,000
Sorghum for Grain		bushel									
Sunflowers, Oil	2,500	pound							2,500	680.00	1,700,000
Sunflowers, Non-oil	2,200	pound							2,000	920.00	1,840,000
Sugar Beets		ton									
Dry Beans	6,600	pound	5,700	1,610.00	92,000	300	1,330.00	4,000	6,000	1,600.00	96,000
Alfalfa Hay		ton	6,000	5.00	30,000				6,000	5.00	30,000
Other Hay		ton	800	2.75	2,200	600	1.35	800	1,400	2.15	3,000
Total Planted Acreage	154,200										

Total Harvested Acreage 151,900 acres
Total Irrigated Harvested Acreage 52,600 (includes all corn for silage and sugar beets)
Total Non-Irrigated Harvested Acreage 99,300 (includes all sunflower)

Composite Acre - Irrigated Only
CAS Marketing Year Average Prices

Crop	Acreage harvested Acres	Percent of Total Harvested Acreage	Unit	Yield per Acre	Marketing Year Average Prices dollars / unit	Weighted per Acre Value
Irrigated Winter Wheat	2,000	3.8	bushel	50.0	4.60	8.75
Irrigated Spring Wheat	0	0.0	bushel	0.0	4.30	0.00
Irrigated Corn for Grain	37,000	70.3	bushel	123.0	3.40	294.17
Corn for Silage	800	1.5	ton	20.0	22.00	6.69
Irrigated Barley	300	0.6	bushel	85.0	3.00	1.45
Irrigated Oats	0	0.0	bushel	0.0	1.95	0.00
Irrigated Sorghum for Grain	0	0.0	bushel	0.0	3.22	0.00
Sugar Beets	0	0.0	ton	0.0	35.40	0.00
Irrigated Dry Beans	5,700	10.8	cwt	16.1	16.30	28.44
Irrigated Alflafa Hay	6,000	11.4	ton	5.0	88.50	50.48
Irrigated Other Hay	800	1.5	ton	2.75	88.50	3.70
Total Harvested Acreage	52,600	100.0		**Total Composite Acre Value =**		**393.68**

Table C.6 - 1996 Sedgwick County composite acre value.

Source: Colorado Agricultural Statistics (CAS) - 1997

			Irrigated			Non-irrigated			Total		
Crop	Acreage planted Acres	Unit	Acreage harvested Acres	Yield per acre	Production	Acreage harvested Acres	Yield per acre	Production	Acreage harvested Acres	Yield per acre	Production
Winter Wheat	96,000	bushel	3,000	50.00	150,000	78,000	40.50	3,160,000	81,000	41.00	3,310,000
Spring Wheat		bushel	0	0.00	0	0	0.00	0	0	0.00	0
Corn for Grain	63,000	bushel	48,500	151.50	7,340,000	12,500	76.50	955,000	61,000	136.00	8,295,000
Corn for Silage		ton							900	16.50	15,000
Barley	2,400	bushel				2,400	33.00	79,000	2,400	33.00	79,000
Oats	1,400	bushel				1,000	20.00	20,000	1,000	20.00	20,000
Sorghum for Grain		bushel									
Sunflowers, Oil	800	pound							800	1,225.00	980,000
Sunflowers, Non-oil	500	pound							500	1,000.00	500,000
Sugar Beets	60	ton							60	20.00	1,200
Dry Beans	5,000	pound	4,500	1,710.00	77,000	300	1,330.00	4,000	4,800	1,690.00	81,000
Alfalfa Hay		ton	7,000	4.10	28,800				7,000	4.10	28,800
Other Hay		ton	900	2.80	2,500	500	1.60	800	1,400	2.35	3,300
Total Planted Acreage	169,100										

Total Harvested Acreage 160,860 acres
Total Irrigated Harvested Acreage 64,860 (includes all corn for silage and sugar beets)
Total Non-Irrigated Harvested Acreage 96,000 (includes all sunflower)

Composite Acre - Irrigated Only
CAS Marketing Year Average Prices

Crop	Acreage harvested Acres	Percent of Total Harvested Acreage	Unit	Yield per Acre	Marketing Year Average Prices dollars / unit	Weighted per Acre Value
Irrigated Winter Wheat	3,000	4.6	bushel	50.0	4.15	9.60
Irrigated Spring Wheat	0	0.0	bushel	0.0	3.65	0.00
Irrigated Corn for Grain	48,500	74.8	bushel	151.5	2.75	311.54
Corn for Silage	900	1.4	ton	16.5	24.00	5.49
Irrigated Barley	0	0.0	bushel	0.0	3.05	0.00
Irrigated Oats	0	0.0	bushel	0.0	2.20	0.00
Irrigated Sorghum for Grain	0	0.0	bushel	0.0	2.50	0.00
Sugar Beets	60	0.1	ton	20.0	35.40	0.65
Irrigated Dry Beans	4,500	6.9	cwt	17.1	24.80	29.42
Irrigated Alflafa Hay	7,000	10.8	ton	4.1	93.50	41.37
Irrigated Other Hay	900	1.4	ton	2.80	93.50	3.63
Total Harvested Acreage	64,860	100.0		**Total Composite Acre Value =**		**401.71**

Table C.7 - 1997 Sedgwick County composite acre value.

Source: Colorado Agricultural Statistics (CAS) - 1998

			Irrigated			Non-irrigated			Total		
Crop	Acreage planted Acres	Unit	Acreage harvested Acres	Yield per acre	Production	Acreage harvested Acres	Yield per acre	Production	Acreage harvested Acres	Yield per acre	Production
Winter Wheat	103,500	bushel	5,000	56.00	280,000	80,000	35.00	2,800,000	85,000	36.00	3,080,000
Spring Wheat		bushel									
Corn for Grain	74,300	bushel	52,000	145.00	7,550,000	21,000	66.50	1,400,000	73,000	122.50	8,950,000
Corn for Silage		ton							1,000	20.00	20,000
Barley	1,700	bushel				1,500	30.50	46,000	1,500	30.50	46,000
Oats	1,300	bushel				700	55.50	39,000	700	55.50	39,000
Sorghum for Grain		bushel									
Sunflowers, Oil	2,000	pound							1,900	1,265.00	2,400,000
Sunflowers, Non-oil	2,900	pound							2,800	960.00	2,690,000
Sugar Beets	2,180	ton							2,120	19.10	40,500
Dry Beans	4,700	pound	3,500	1,860.00	65,000	500	600.00	3,000	4,000	1,700.00	68,000
Alfalfa Hay		ton	5,000	5.60	28,000				5,000	5.60	28,000
Other Hay		ton	2,300	2.15	5,000	1,200	1.40	1,700	3,500	1.90	6,700
Total Planted Acreage	190,400										

Total Harvested Acreage	180,520	acres
Total Irrigated Harvested Acreage	70,920	(includes all corn for silage and sugar beets)
Total Non-Irrigated Harvested Acreage	109,600	(includes all sunflower)

Composite Acre - Irrigated Only

CAS Marketing Year Average Prices

Crop	Acreage harvested Acres	Percent of Total Harvested Acreage	Unit	Yield per Acre	Marketing Year Average Prices dollars / unit	Weighted per Acre Value
Irrigated Winter Wheat	5,000	7.1	bushel	56.0	3.25	12.83
Irrigated Spring Wheat	0	0.0	bushel	0.0	3.30	0.00
Irrigated Corn for Grain	52,000	73.3	bushel	145.0	2.65	281.74
Corn for Silage	1,000	1.4	ton	20.0	24.00	6.77
Irrigated Barley	0	0.0	bushel	0.0	3.05	0.00
Irrigated Oats	0	0.0	bushel	0.0	2.00	0.00
Irrigated Sorghum for Grain	0	0.0	bushel	0.0	2.25	0.00
Sugar Beets	2,120	3.0	ton	19.1	40.00	22.84
Irrigated Dry Beans	3,500	4.9	cwt	18.6	19.20	17.62
Irrigated Alflafa Hay	5,000	7.1	ton	5.6	103.00	40.67
Irrigated Other Hay	2,300	3.2	ton	2.15	103.00	7.18
Total Harvested Acreage	70,920	100.0		**Total Composite Acre Value =**		**389.65**

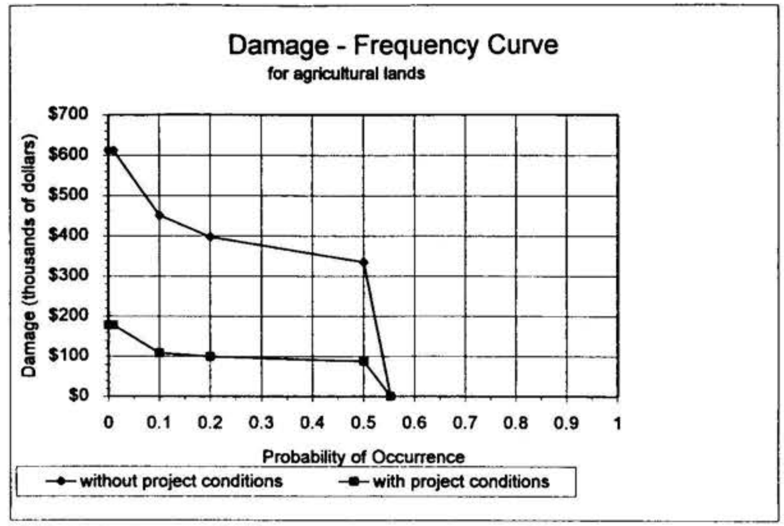
APPENDIX D

1992 - 1997 DAMAGE FREQUENCY CURVES

Damage-Frequency Curve - Irrigated Agricultural Lands
1992 time base

Damageable Value Per Acre	
w/o project	w/ project
$119.37	$69.61

Return Period (years)	Probability of Occurrence	Without Project Acres Flooded	Without Project Damage in Dollar	With Project Acres Flooded	With Project Damage in Dollars
100	0.01	5,124	$611,651	2554	$177,793
10	0.1	3,775	$450,621	1548	$107,762
5	0.2	3,325	$396,905	1429	$99,478
2	0.5	2,809	$335,310	1256	$87,435
1.8	0.55	0	$0	0	$0



Damage-Frequency Curve -Other Agricultural
1992 time base

Expected Annual Damages	
w/o project	w/ project
$40,012.21	$16,526.78

Return Period (years)	Probability of Occurrence	w/o project N	w/ project N	w/o project Damages	w/ project Damages
100	0.01	0.0285	0.0321	$113,869	$53,114
10	0.1	0.2224	0.2323	$83,891	$32,193
5	0.2	0.1972	0.1873	$73,890	$29,718
2	0.5	0.5110	0.5068	$62,424	$26,120
1.8	0.55	0.0409	0.0415	$0	$0

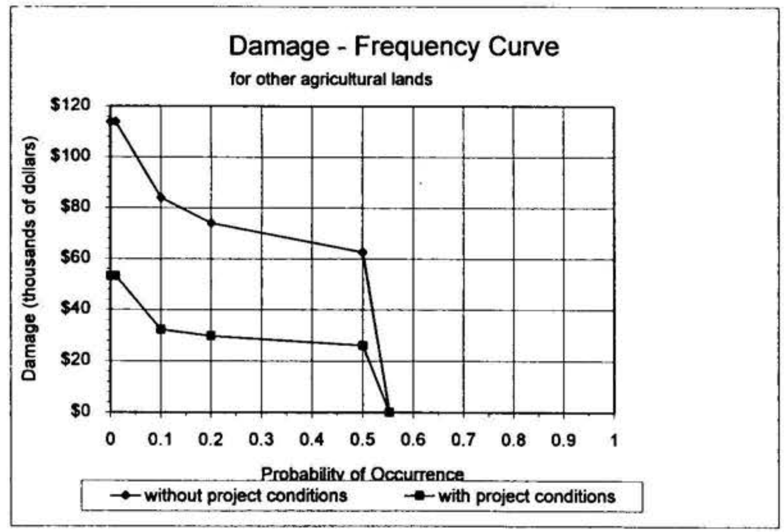
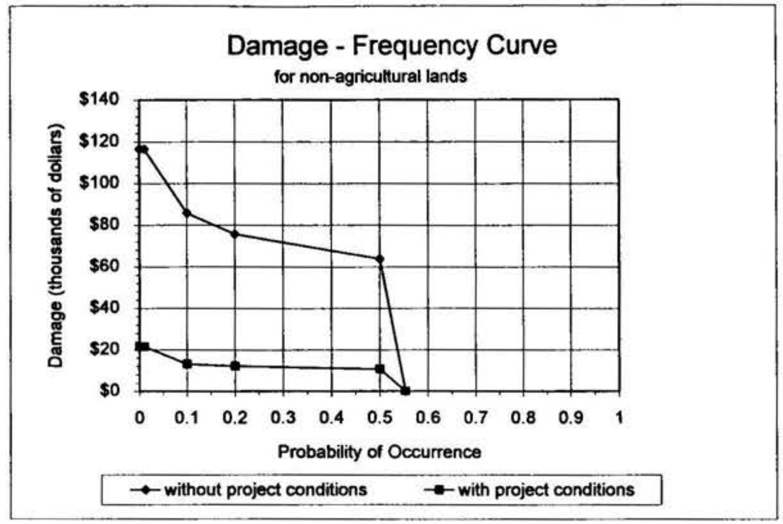


Figure D.1 - 1992 time base damage-frequency curves for Agricultural and Other-agricultural.

Damage-Frequency Curve - Non-Agricultural
1992 time base

Expected Annual Damages	
w/o project	w/ project
$40,916.84	$6,715.09

Return Period (years)	Probability of Occurrence	w/o project N	w/ project N	w/o project Damages	w/ project Damages
100	0.01	0.0285	0.0321	$116,443	$21,581
10	0.1	0.2224	0.2323	$85,787	$13,081
5	0.2	0.1972	0.1873	$75,561	$12,075
2	0.5	0.5110	0.5068	$63,835	$10,613
1.8	0.55	0.0409	0.0415	$0	$0



Damage-Frequency Curve - Sediment and Erosion
1992 time base

Expected Annual Damages	
w/o project	w/ project
$39,559.90	$14,682.74

Return Period (years)	Probability of Occurrence	w/o project N	w/ project N	w/o project Damages	w/ project Damages
100	0.01	0.0285	0.0321	$112,582	$47,188
10	0.1	0.2224	0.2323	$82,942	$28,601
5	0.2	0.1972	0.1873	$73,055	$26,402
2	0.5	0.5110	0.5068	$61,718	$23,206
1.8	0.55	0.0409	0.0415	$0	$0

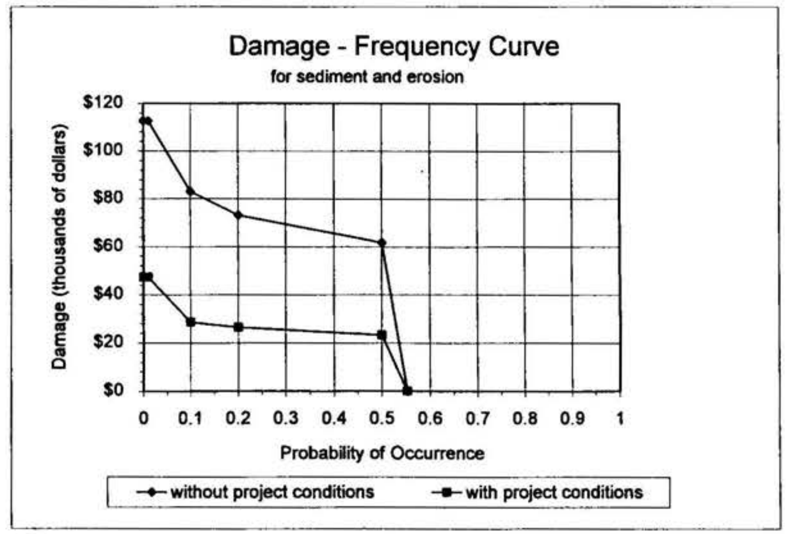
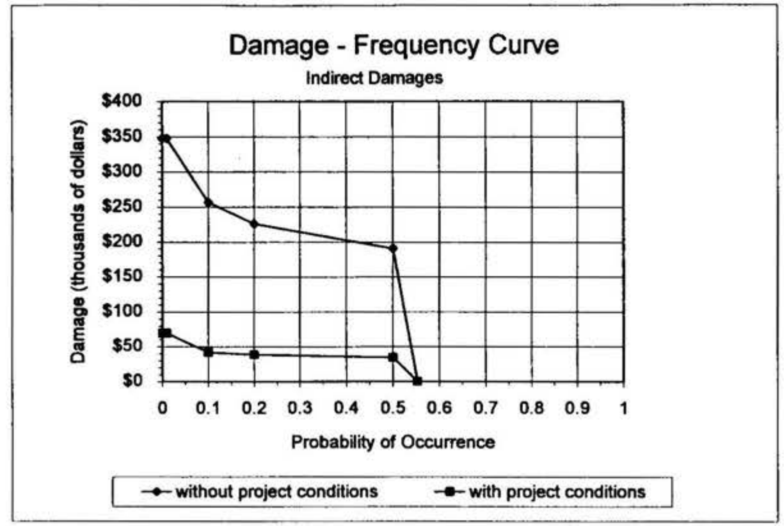


Figure D.2 - 1992 time base damage-frequency curves for Non-agricultural and Sediment and Erosion.

Damage Frequency Curve - Indirect Damages
1992 time base

Expected Annual Damages	
w/o project	w/ project
$122,193.82	$21,571.80

Return Period (years)	Probability of Occurrence	w/o project N	w/ project N	w/o project Damages	w/ project Damages
100	0.01	0.0285	0.0321	$347,746	$69,328
10	0.1	0.2224	0.2323	$256,195	$42,020
5	0.2	0.1972	0.1873	$225,655	$38,790
2	0.5	0.5110	0.5068	$190,636	$34,094
1.8	0.55	0.0409	0.0415	$0	$0

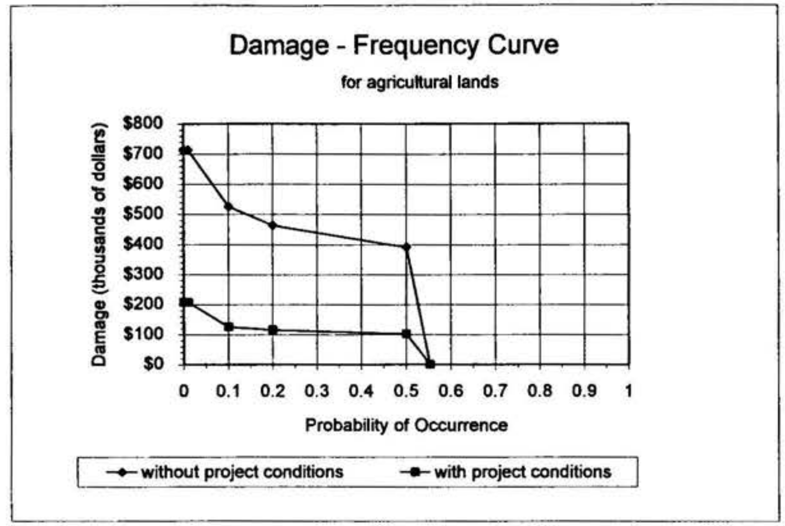


Figrue D.3 - 1992 time base damage-frequency curves for Indirect Damages.

Damage-Frequency Curve - Irrigated Agricultural Lands
1993 time base

Damageable Value Per Acre	
w/o project	w/ project
$139.34	$81.26

Return Period (years)	Probability of Occurrence	Without Project Acres Flooded	Without Project Damage in Dollar	With Project Acres Flooded	With Project Damage in Dollars
100	0.01	5,124	$713,970	2554	$207,535
10	0.1	3,775	$526,002	1548	$125,789
5	0.2	3,325	$463,300	1429	$116,119
2	0.5	2,809	$391,401	1256	$102,061
1.8	0.55	0	$0	0	$0



Damage-Frequency Curve -Other Agricultural
1993 time base

Expected Annual Damages	
w/o project	w/ project
$41,361.00	$17,083.89

Return Period (years)	Probability of Occurrence	w/o project N	w/ project N	w/o project Damages	w/ project Damages
100	0.01	0.0285	0.0321	$117,707	$54,905
10	0.1	0.2224	0.2323	$86,719	$33,278
5	0.2	0.1972	0.1873	$76,381	$30,720
2	0.5	0.5110	0.5068	$64,528	$27,001
1.8	0.55	0.0409	0.0415	$0	$0

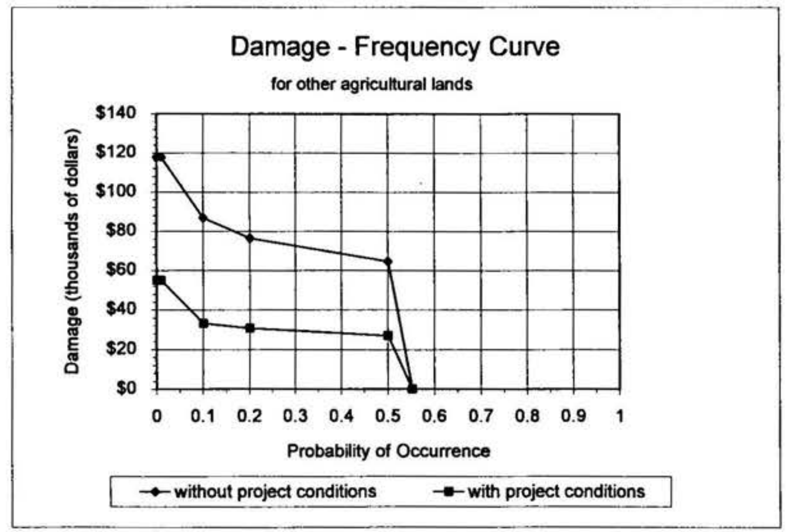
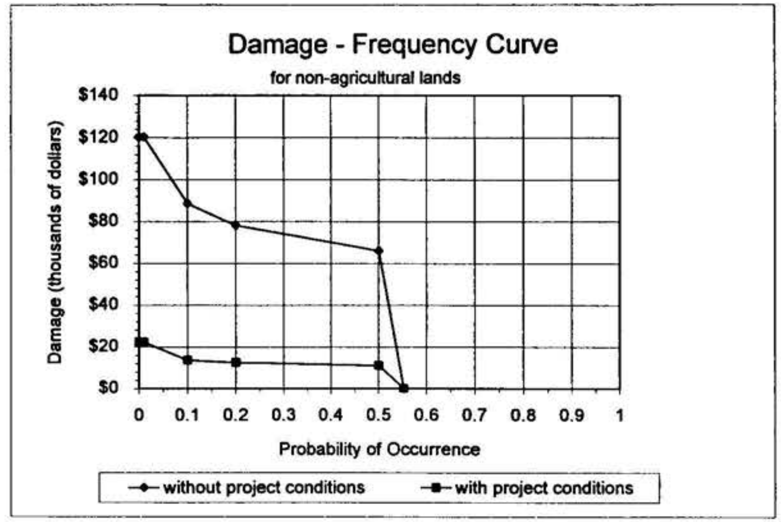


Figure D.4 - 1993 time base damage-frequency curves for Agricultural and Other-agricultural.

Damage-Frequency Curve - Non-Agricultural
1993 time base

Expected Annual Damages	
w/o project	w/ project
$42,296.11	$6,941.45

Return Period (years)	Probability of Occurrence	w/o project N	w/ project N	w/o project Damages	w/ project Damages
100	0.01	0.0285	0.0321	$120,369	$22,309
10	0.1	0.2224	0.2323	$88,679	$13,521
5	0.2	0.1972	0.1873	$78,108	$12,482
2	0.5	0.5110	0.5068	$65,987	$10,971
1.8	0.55	0.0409	0.0415	$0	$0



Damage-Frequency Curve - Sediment and Erosion
1993 time base

Expected Annual Damages	
w/o project	w/ project
$40,893.44	$15,177.69

Return Period (years)	Probability of Occurrence	w/o project N	w/ project N	w/o project Damages	w/ project Damages
100	0.01	0.0285	0.0321	$116,377	$48,778
10	0.1	0.2224	0.2323	$85,738	$29,565
5	0.2	0.1972	0.1873	$75,518	$27,292
2	0.5	0.5110	0.5068	$63,798	$23,988
1.8	0.55	0.0409	0.0415	$0	$0

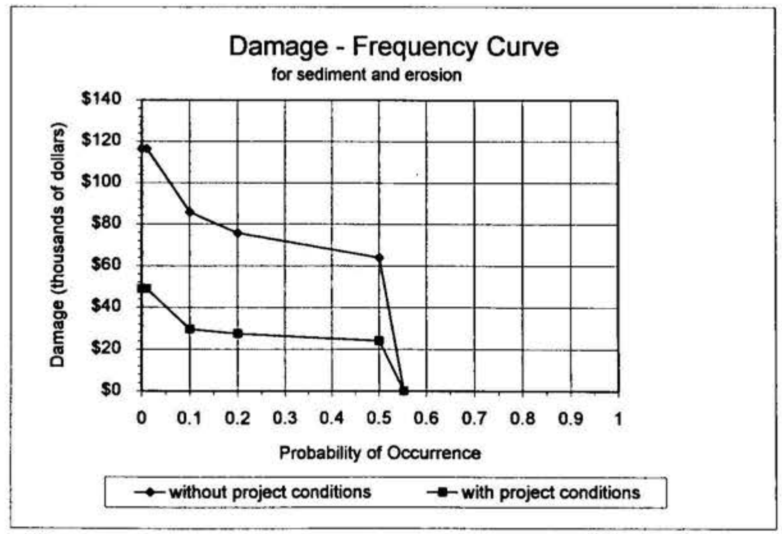
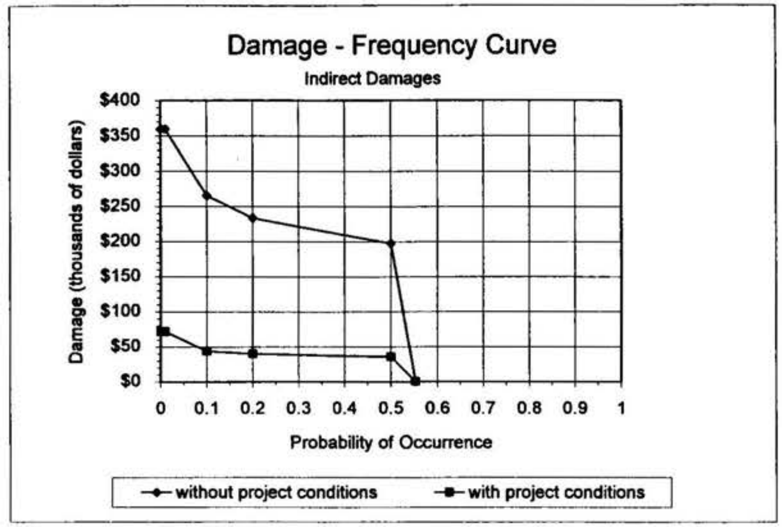


Figure D.5 - 1993 time base damage-frequency curves for Non-agricultural and Sediment and Erosion.

Damage Frequency Curve - Indirect Damages
1993 time base

Expected Annual Damages	
w/o project	w/ project
$126,312.89	$22,298.97

Return Period (years)	Probability of Occurrence	w/o project N	w/ project N	w/o project Damages	w/ project Damages
100	0.01	0.0285	0.0321	$359,468	$71,665
10	0.1	0.2224	0.2323	$264,831	$43,437
5	0.2	0.1972	0.1873	$233,262	$40,098
2	0.5	0.5110	0.5068	$197,062	$35,243
1.8	0.55	0.0409	0.0415	$0	$0

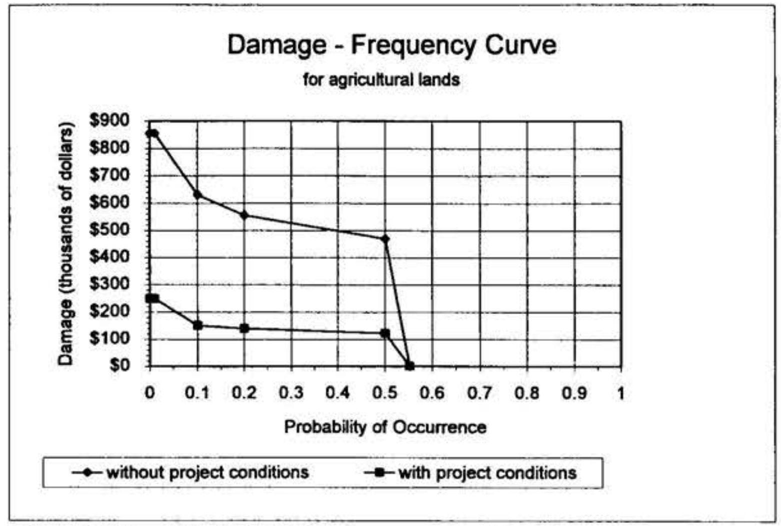


Figrue D.6 - 1993 time base damage-frequency curves for Indirect Damages.

Damage-Frequency Curve - Irrigated Agricultural Lands
1994 time base

Damageable Value Per Acre	
w/o project	w/ project
$166.89	$97.33

Return Period (years)	Probability of Occurrence	Without Project Acres Flooded	Without Project Damage in Dollar	With Project Acres Flooded	With Project Damage in Dollars
100	0.01	5,124	$855,166	2554	$248,578
10	0.1	3,775	$630,026	1548	$150,665
5	0.2	3,325	$554,923	1429	$139,083
2	0.5	2,809	$468,806	1256	$122,245
1.8	0.55	0	$0	0	$0



Damage-Frequency Curve -Other Agricultural
1994 time base

Expected Annual Damages	
w/o project	w/ project
$42,939.71	$17,735.97

Return Period (years)	Probability of Occurrence	w/o project N	w/ project N	w/o project Damages	w/ project Damages
100	0.01	0.0285	0.0321	$122,200	$57,000
10	0.1	0.2224	0.2323	$90,029	$34,548
5	0.2	0.1972	0.1873	$79,297	$31,893
2	0.5	0.5110	0.5068	$66,991	$28,031
1.8	0.55	0.0409	0.0415	$0	$0

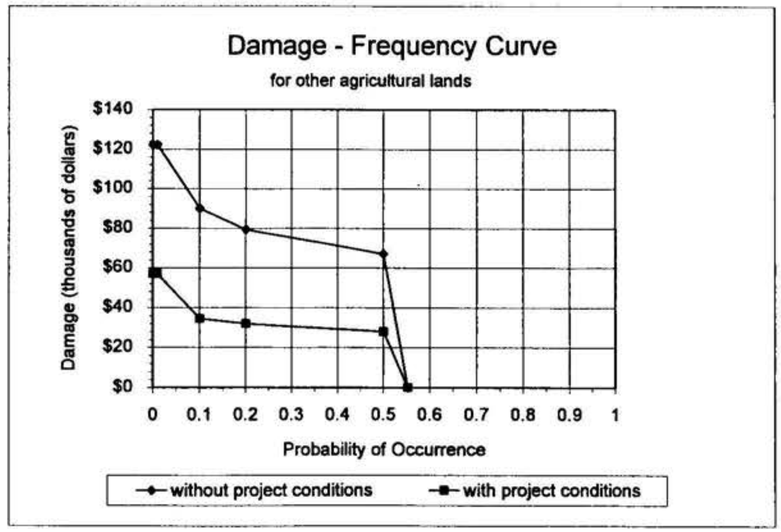
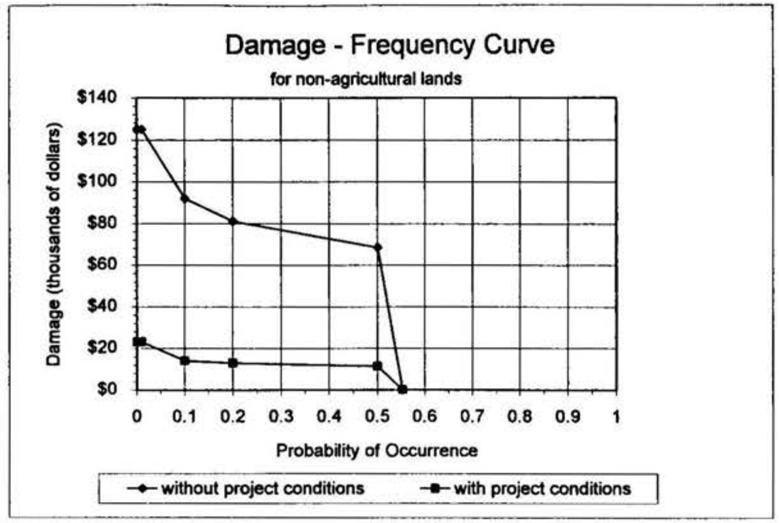


Figure D.7 - 1994 time base damage-frequency curves for Agricultural and Other-agricultural.

Damage-Frequency Curve - Non-Agricultural
1994 time base

Expected Annual Damages w/o project	Expected Annual Damages w/ project
$43,910.52	$7,206.40

Return Period (years)	Probability of Occurrence	w/o project N	w/ project N	w/o project Damages	w/ project Damages
100	0.01	0.0285	0.0321	$124,963	$23,160
10	0.1	0.2224	0.2323	$92,064	$14,038
5	0.2	0.1972	0.1873	$81,089	$12,958
2	0.5	0.5110	0.5068	$68,505	$11,390
1.8	0.55	0.0409	0.0415	$0	$0



Damage-Frequency Curve - Sediment and Erosion
1994 time base

Expected Annual Damages w/o project	Expected Annual Damages w/ project
$42,454.31	$15,757.01

Return Period (years)	Probability of Occurrence	w/o project N	w/ project N	w/o project Damages	w/ project Damages
100	0.01	0.0285	0.0321	$120,819	$50,640
10	0.1	0.2224	0.2323	$89,011	$30,693
5	0.2	0.1972	0.1873	$78,400	$28,334
2	0.5	0.5110	0.5068	$66,233	$24,904
1.8	0.55	0.0409	0.0415	$0	$0

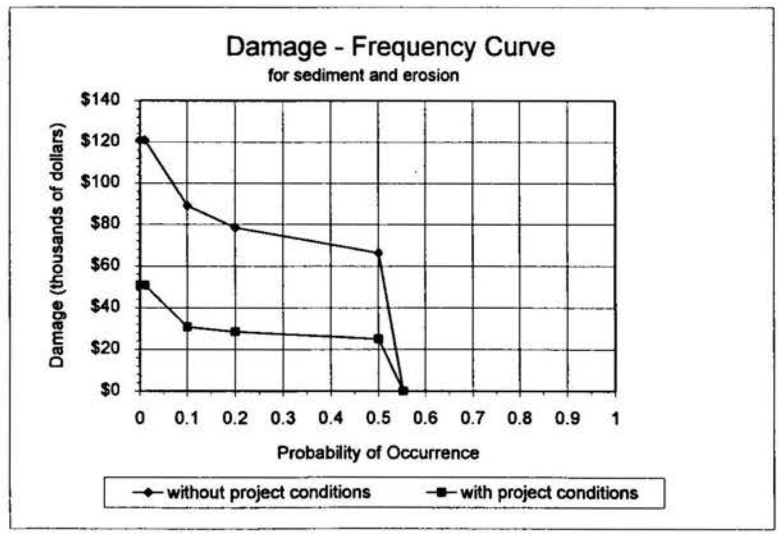
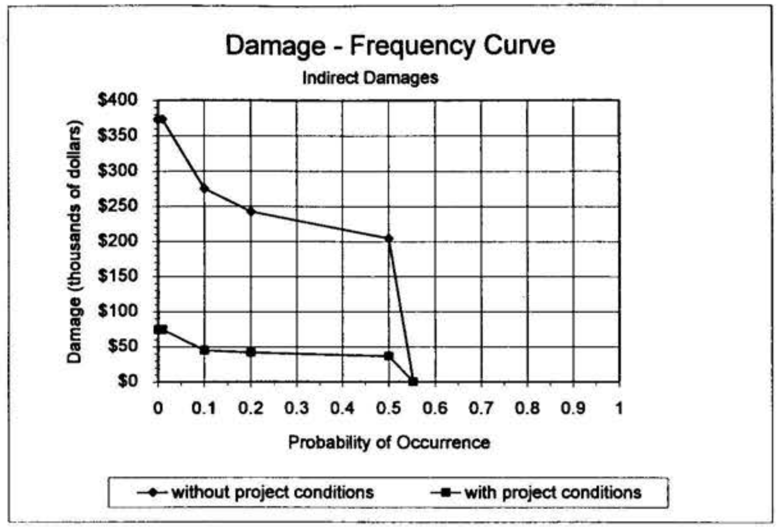


Figure D.8 - 1994 time base damage-frequency curves for Non-agricultural and Sediment and Erosion.

Damage Frequency Curve - Indirect Damages
1994 time base

Expected Annual Damages	
w/o project	w/ project
$131,134.15	$23,150.11

Return Period (years)	Probability of Occurrence	w/o project N	w/ project N	w/o project Damages	w/ project Damages
100	0.01	0.0285	0.0321	$373,189	$74,400
10	0.1	0.2224	0.2323	$274,939	$45,095
5	0.2	0.1972	0.1873	$242,165	$41,628
2	0.5	0.5110	0.5068	$204,584	$36,588
1.8	0.55	0.0409	0.0415	$0	$0

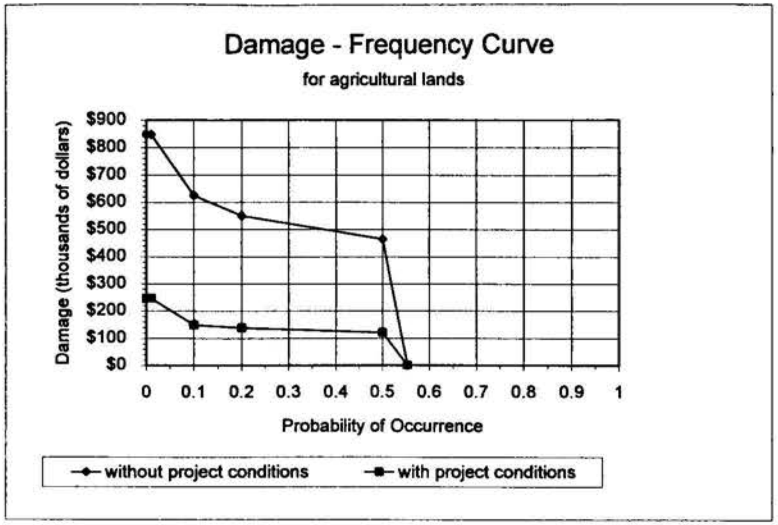


Figrue D.9 - 1994 time base damage-frequency curves for Indirect Damages.

Damage-Frequency Curve - Irrigated Agricultural Lands
1995 time base

Damageable Value Per Acre	
w/o project	w/ project
$165.39	$96.45

Return Period (years)	Probability of Occurrence	Without Project Acres Flooded	Without Project Damage in Dollar	With Project Acres Flooded	With Project Damage in Dollars
100	0.01	5,124	$847,481	2554	$246,344
10	0.1	3,775	$624,364	1548	$149,311
5	0.2	3,325	$549,936	1429	$137,833
2	0.5	2,809	$464,593	1256	$121,146
1.8	0.55	0	$0	0	$0



Damage-Frequency Curve -Other Agricultural
1995 time base

Expected Annual Damages	
w/o project	w/ project
$45,171.56	$18,657.82

Return Period (years)	Probability of Occurrence	w/o project N	w/ project N	w/o project Damages	w/ project Damages
100	0.01	0.0285	0.0321	$128,552	$59,963
10	0.1	0.2224	0.2323	$94,708	$36,344
5	0.2	0.1972	0.1873	$83,418	$33,550
2	0.5	0.5110	0.5068	$70,473	$29,488
1.8	0.55	0.0409	0.0415	$0	$0

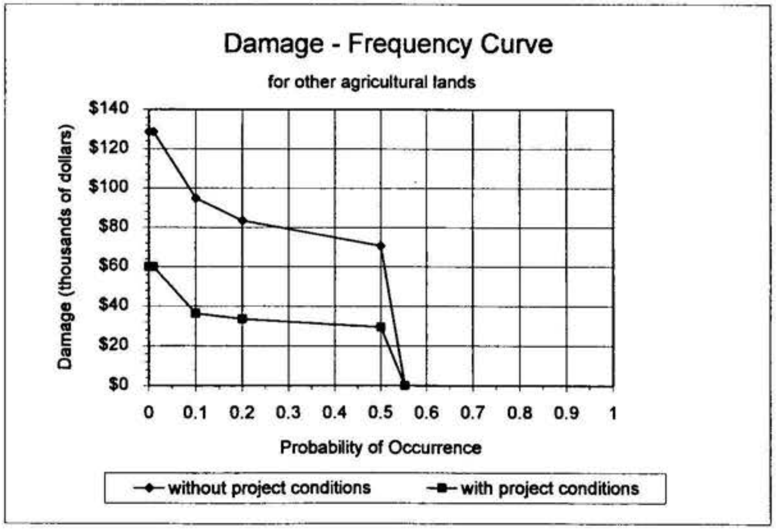
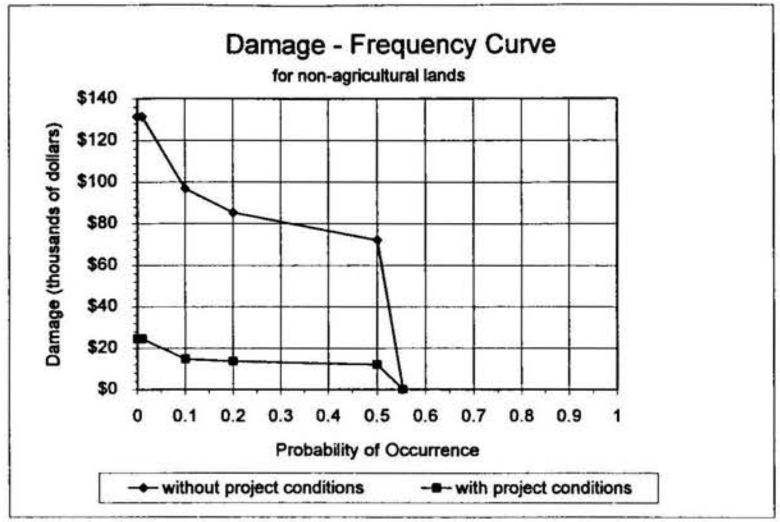


Figure D.10 - 1995 time base damage-frequency curves for Agricultural and Other-agricultural.

Damage-Frequency Curve - Non-Agricultural
1995 time base

Expected Annual Damages w/o project	Expected Annual Damages w/ project
$46,192.83	$7,580.97

Return Period (years)	Probability of Occurrence	w/o project N	w/ project N	w/o project Damages	w/ project Damages
100	0.01	0.0285	0.0321	$131,458	$24,364
10	0.1	0.2224	0.2323	$96,849	$14,767
5	0.2	0.1972	0.1873	$85,304	$13,632
2	0.5	0.5110	0.5068	$72,066	$11,982
1.8	0.55	0.0409	0.0415	$0	$0



Damage-Frequency Curve - Sediment and Erosion
1995 time base

Expected Annual Damages w/o project	Expected Annual Damages w/ project
$44,660.93	$16,576.00

Return Period (years)	Probability of Occurrence	w/o project N	w/ project N	w/o project Damages	w/ project Damages
100	0.01	0.0285	0.0321	$127,099	$53,272
10	0.1	0.2224	0.2323	$93,637	$32,289
5	0.2	0.1972	0.1873	$82,475	$29,807
2	0.5	0.5110	0.5068	$69,676	$26,198
1.8	0.55	0.0409	0.0415	$0	$0

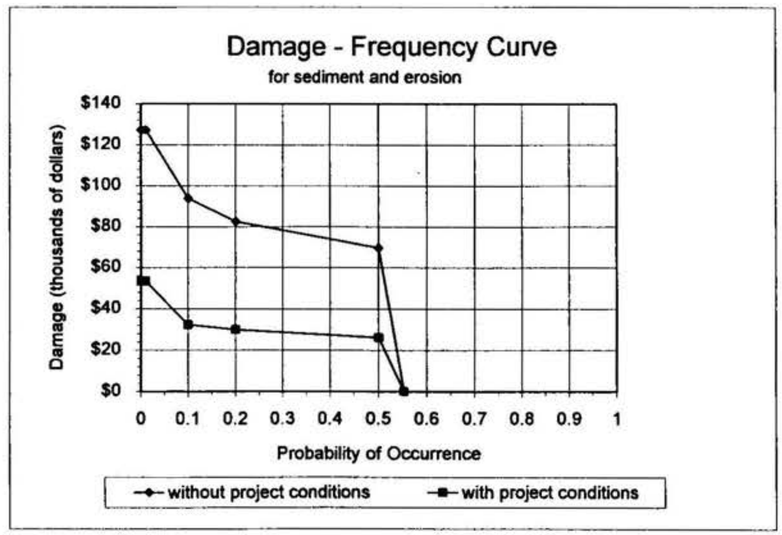
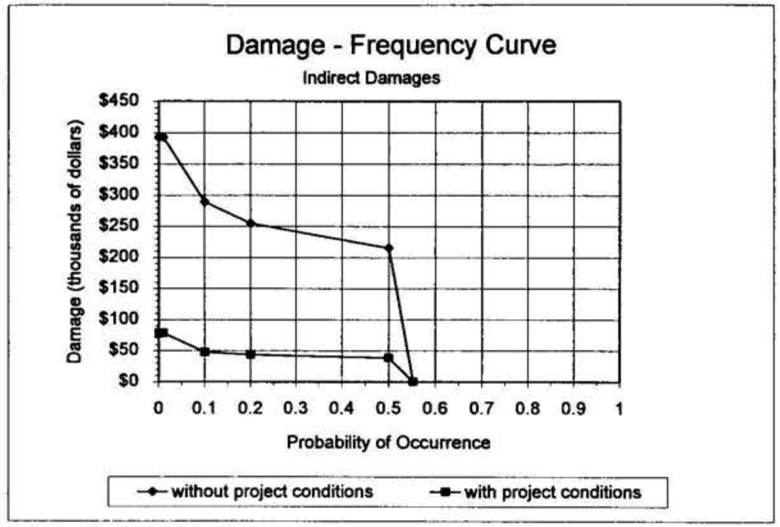


Figure D.11 - 1995 time base damage-frequency curves for Non-agricultural and Sediment and Erosion.

Damage Frequency Curve - Indirect Damages
1995 time base

Expected Annual Damages	
w/o project	w/ project
$137,950.02	$24,353.36

Return Period (years)	Probability of Occurrence	w/o project N	w/ project N	w/o project Damages	w/ project Damages
100	0.01	0.0285	0.0321	$392,586	$78,267
10	0.1	0.2224	0.2323	$289,230	$47,439
5	0.2	0.1972	0.1873	$254,752	$43,792
2	0.5	0.5110	0.5068	$215,217	$38,490
1.8	0.55	0.0409	0.0415	$0	$0

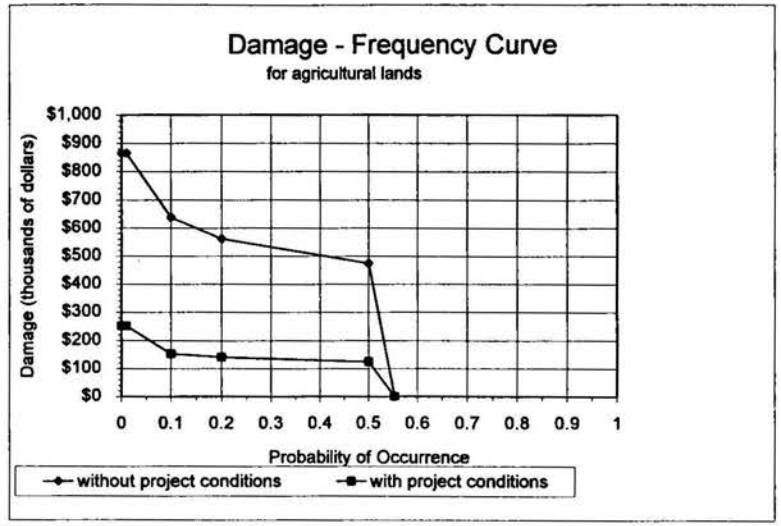


Figrue D.12 - 1995 time base damage-frequency curves for Indirect Damages.

Damage-Frequency Curve - Irrigated Agricultural Lands
1996 time base

Damageable Value Per Acre	
w/o project	w/ project
$168.77	$98.42

Return Period (years)	Probability of Occurrence	Without Project Acres Flooded	Without Project Damage in Dollar	With Project Acres Flooded	With Project Damage in Dollars
100	0.01	5,124	$864,767	2554	$251,368
10	0.1	3,775	$637,099	1548	$152,356
5	0.2	3,325	$561,154	1429	$140,644
2	0.5	2,809	$474,069	1256	$123,617
1.8	0.55	0	$0	0	$0



Damage-Frequency Curve -Other Agricultural
1996 time base

Expected Annual Damages	
w/o project	w/ project
$47,523.10	$19,629.11

Return Period (years)	Probability of Occurrence	w/o project N	w/ project N	w/o project Damages	w/ project Damages
100	0.01	0.0285	0.0321	$135,244	$63,085
10	0.1	0.2224	0.2323	$99,638	$38,236
5	0.2	0.1972	0.1873	$87,761	$35,297
2	0.5	0.5110	0.5068	$74,141	$31,024
1.8	0.55	0.0409	0.0415	$0	$0

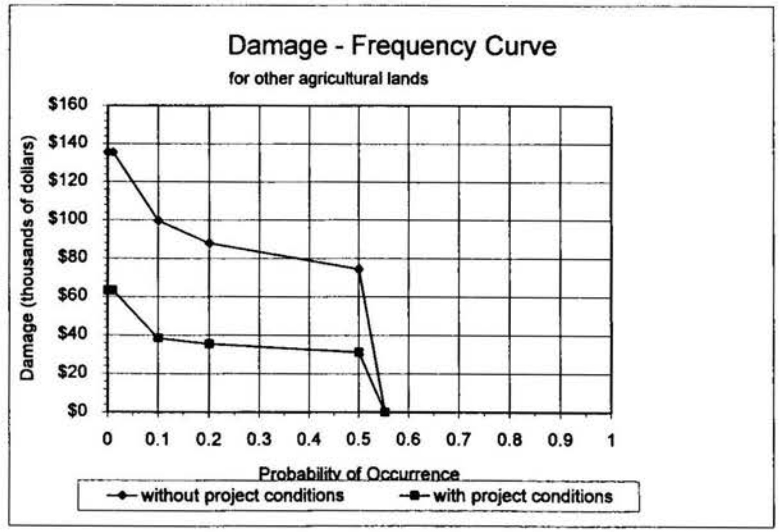
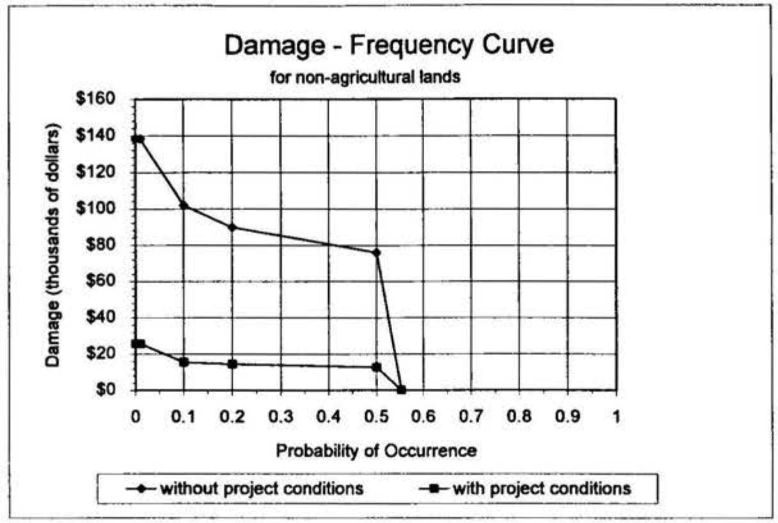


Figure D.13 - 1996 time base damage-frequency curves for Agricultural and Other-agricultural.

Damage-Frequency Curve - Non-Agricultural
1996 time base

Expected Annual Damages	
w/o project	w/ project
$48,597.54	$7,975.62

Return Period (years)	Probability of Occurrence	w/o project N	w/ project N	w/o project Damages	w/ project Damages
100	0.01	0.0285	0.0321	$138,302	$25,632
10	0.1	0.2224	0.2323	$101,891	$15,536
5	0.2	0.1972	0.1873	$89,745	$14,342
2	0.5	0.5110	0.5068	$75,818	$12,605
1.8	0.55	0.0409	0.0415	$0	$0



Damage-Frequency Curve - Sediment and Erosion
1996 time base

Expected Annual Damages	
w/o project	w/ project
$46,985.88	$17,438.91

Return Period (years)	Probability of Occurrence	w/o project N	w/ project N	w/o project Damages	w/ project Damages
100	0.01	0.0285	0.0321	$133,715	$56,046
10	0.1	0.2224	0.2323	$98,512	$33,970
5	0.2	0.1972	0.1873	$86,769	$31,358
2	0.5	0.5110	0.5068	$73,303	$27,562
1.8	0.55	0.0409	0.0415	$0	$0

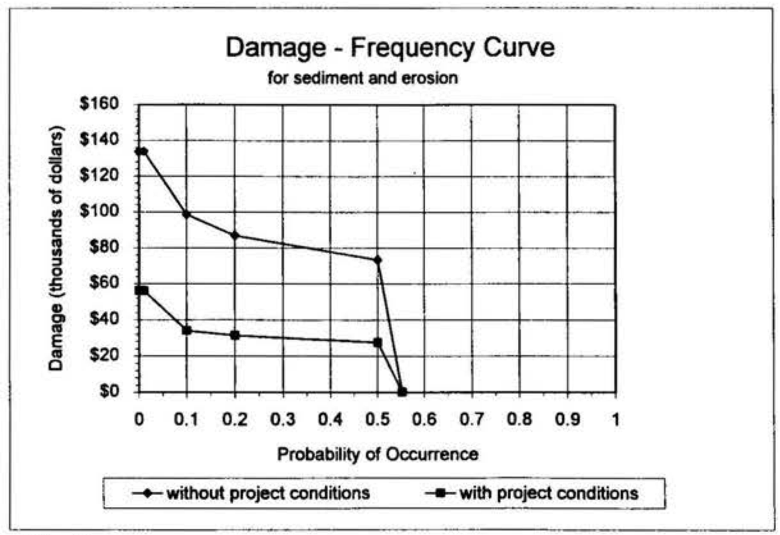
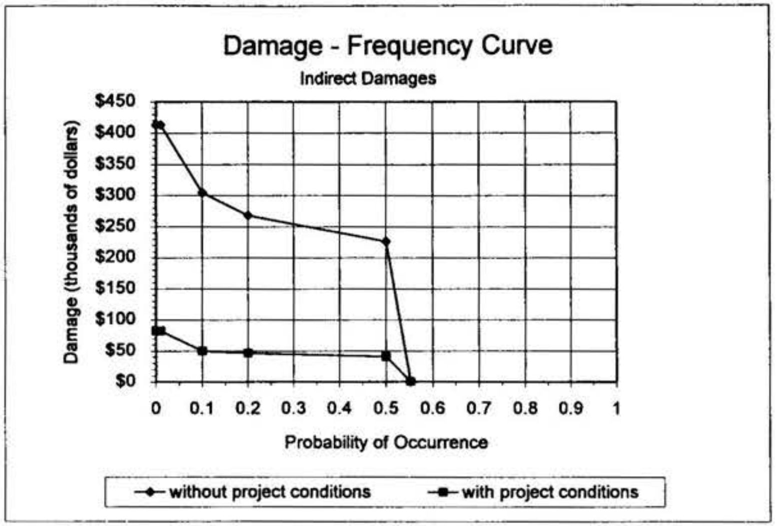


Figure D.14 - 1996 time base damage-frequency curves for Non-agricultural and Sediment and Erosion.

Damage Frequency Curve - Indirect Damages
1996 time base

Expected Annual Damages	
w/o project	w/ project
$145,131.42	$25,621.15

Return Period (years)	Probability of Occurrence	w/o project N	w/ project N	w/o project Damages	w/ project Damages
100	0.01	0.0285	0.0321	$413,023	$82,342
10	0.1	0.2224	0.2323	$304,286	$49,908
5	0.2	0.1972	0.1873	$268,014	$46,072
2	0.5	0.5110	0.5068	$226,421	$40,494
1.8	0.55	0.0409	0.0415	$0	$0

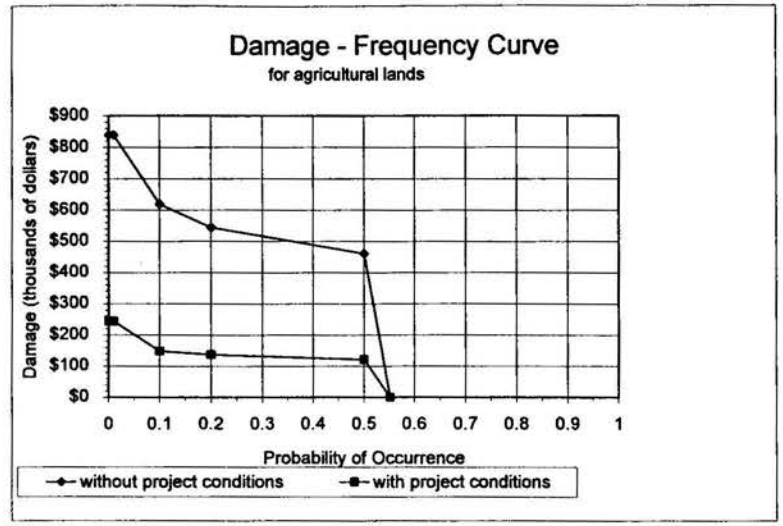


Figrue D.15 - 1996 time base damage-frequency curves for Indirect Damages.

Damage-Frequency Curve - Irrigated Agricultural Lands
1997 time base

Damageable Value Per Acre	
w/o project	w/ project
$163.70	$95.47

Return Period (years)	Probability of Occurrence	Without Project Acres Flooded	Without Project Damage in Dollar	With Project Acres Flooded	With Project Damage in Dollars
100	0.01	5,124	$838,805	2554	$243,822
10	0.1	3,775	$617,972	1548	$147,782
5	0.2	3,325	$544,307	1429	$136,422
2	0.5	2,809	$459,837	1256	$119,906
1.8	0.55	0	$0	0	$0



Damage-Frequency Curve -Other Agricultural
1997 time base

Expected Annual Damages	
w/o project	w/ project
$49,912.27	$20,615.94

Return Period (years)	Probability of Occurrence	w/o project N	w/ project N	w/o project Damages	w/ project Damages
100	0.01	0.0285	0.0321	$142,043	$66,256
10	0.1	0.2224	0.2323	$104,647	$40,158
5	0.2	0.1972	0.1873	$92,173	$37,071
2	0.5	0.5110	0.5068	$77,869	$32,583
1.8	0.55	0.0409	0.0415	$0	$0

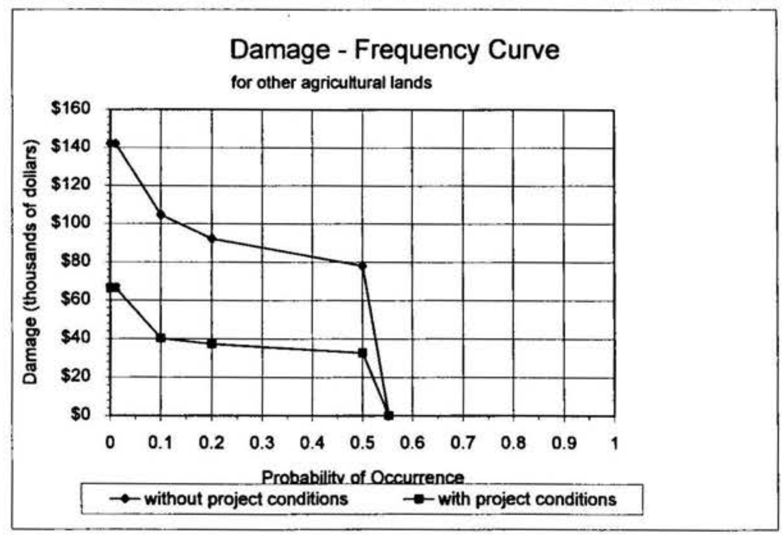
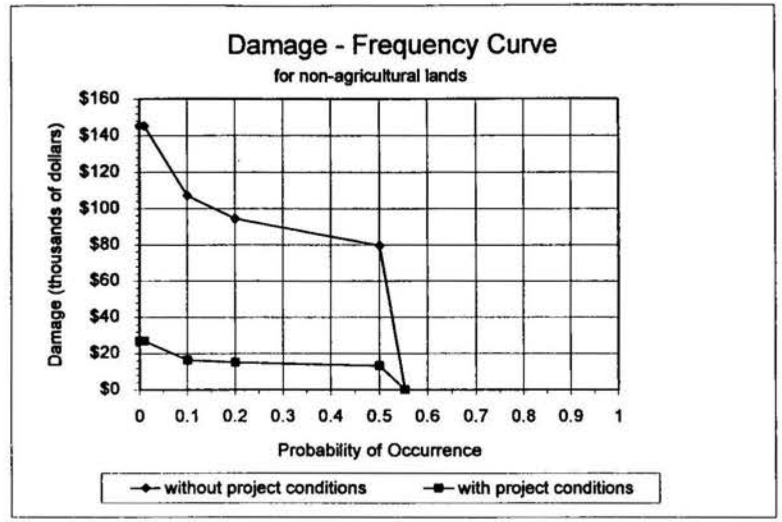


Figure D.16 - 1997 time base damage-frequency curves for Agricultural and Other-agricultural.

Damage-Frequency Curve - Non-Agricultural
1997 time base

Expected Annual Damages	
w/o project	w/ project
$51,040.73	$8,376.58

Return Period (years)	Probability of Occurrence	w/o project N	w/ project N	w/o project Damages	w/ project Damages
100	0.01	0.0285	0.0321	$145,255	$26,921
10	0.1	0.2224	0.2323	$107,013	$16,317
5	0.2	0.1972	0.1873	$94,257	$15,063
2	0.5	0.5110	0.5068	$79,629	$13,239
1.8	0.55	0.0409	0.0415	$0	$0



Damage-Frequency Curve - Sediment and Erosion
1997 time base

Expected Annual Damages	
w/o project	w/ project
$49,348.05	$18,315.63

Return Period (years)	Probability of Occurrence	w/o project N	w/ project N	w/o project Damages	w/ project Damages
100	0.01	0.0285	0.0321	$140,438	$58,863
10	0.1	0.2224	0.2323	$103,464	$35,678
5	0.2	0.1972	0.1873	$91,131	$32,935
2	0.5	0.5110	0.5068	$76,988	$28,948
1.8	0.55	0.0409	0.0415	$0	$0

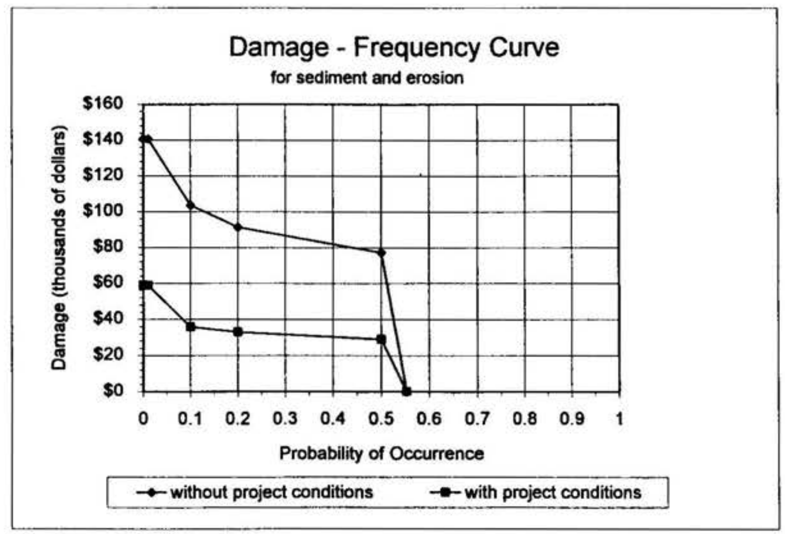
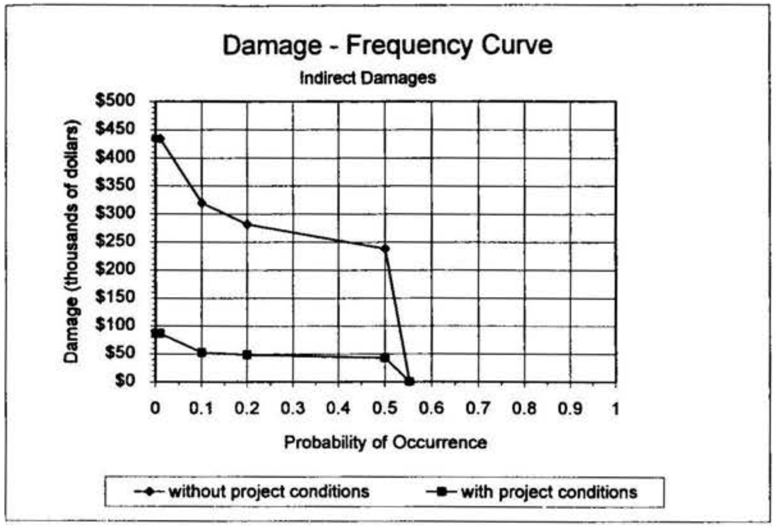


Figure D.17 - 1997 time base damage-frequency curves for Non-agricultural and Sediment and Erosion.

Damage Frequency Curve - Indirect Damages
1997 time base

Expected Annual Damages	
w/o project	w/ project
$152,427.74	$26,909.23

Return Period (years)	Probability of Occurrence	w/o project N	w/ project N	w/o project Damages	w/ project Damages
100	0.01	0.0285	0.0321	$433,788	$86,482
10	0.1	0.2224	0.2323	$319,584	$52,417
5	0.2	0.1972	0.1873	$281,488	$48,388
2	0.5	0.5110	0.5068	$237,804	$42,530
1.8	0.55	0.0409	0.0415	$0	$0



Figrue D.18 - 1997 time base damage-frequency curves for Indirect Damages.

APPENDIX E

FEDERAL DISCOUNT INTEREST RATES

Table E.1 - Average Annual Federal Discount Interest Rate 1975 - 1997.

Year	Average Interest Rate (percent)
1975	6.25
1976	5.50
1977	5.46
1978	7.46
1979	10.28
1980	11.77
1981	13.42
1982	11.02
1983	8.50
1984	8.80
1985	7.69
1986	6.33
1987	5.66
1988	6.20
1989	6.92
1990	6.98
1991	5.45
1992	3.25
1993	3.00
1994	3.60
1995	5.21
1996	5.02
1997	5.00

APPENDIX F

SITE INSPECTION SHEETS

Floodwater Retarding Structure Inspection Sheet

Structure Number: SS-1 Date: 6/30/98

Inspection Party Present: Jason Ward, Tom Gill, James Ruff, Larry Frame

UPSTREAM SLOPE — Observed Conditions

Vegetative growth: good, short grass cover

Surface Erosion: none

Cracking: none

Animal Burrows: none

Debris: none

Unusual Conditions: none

DOWNSTREAM SLOPE

Vegetative growth: good

Surface Erosion: none

Cracking: none

Signs of Seepage: none

Animal Burrows: none

Debris: tumbleweeds

Unusual Conditions: none

ABUTMENTS

Surface Erosion: none

Signs of Seepage: none

Unusual Conditions: none

EMERGENCY SPILLWAY

General Condition: good

PRINCIPLE SPILLWAY — Observed Conditions

Number of Stages / Open Stages: 4 / 2 (#1 & #4)

Debris: none

High Water Mark: no visible mark

Drawdown Opening: stage 1

Cattle Fence(s): open access at principle spillway

Other: good condition

OUTLET WORKS

Debris: none

Plunge Pool: sparse riprap - acceptable condition

Downstream Channel: acceptable

General Condition: acceptable, some erosion around outlet works on right side (looking d.s)

NOTES / SKETCHES

principle spillway stages are numbered from bottom to top.

OBSERVED CONDITIONS:	GOOD	ACCEPTABLE	POOR
	near new appearance, no threat to safety of dam.	Surfaces irregular or otherwise not in new condition, no threat to safety of dam.	Conditions observed appear to threaten safety of dam.

Floodwater Retarding Structure Inspection Sheet

Structure Number: SS-2 Date: 6/30/98

Inspection Party Present: Jason Ward, Tom Gill, James Ruff, Larry Frame

UPSTREAM SLOPE — Observed Conditions

Vegetative growth: good, short grass cover

Surface Erosion: none

Cracking: none

Animal Burrows: none

Debris: none

Unusual Conditions: none

DOWNSTREAM SLOPE

Vegetative growth: good

Surface Erosion: none

Cracking: none

Signs of Seepage: none

Animal Burrows: few on crest

Debris: large amount of tumbleweeds

Unusual Conditions: none

ABUTMENTS

Surface Erosion: none

Signs of Seepage: none

Unusual Conditions: none

EMERGENCY SPILLWAY

General Condition: good grass cover

PRINCIPLE SPILLWAY — Observed Conditions

Number of Stages / Open Stages: 3 / all

Debris: none

High Water Mark: no visible mark

Drawdown Opening: stage 1

Cattle Fence(s): open access at principle spillway

Other: good condition

150+ cattle grazing around principle spillway

OUTLET WORKS

Debris: few tumbleweeds

Plunge Pool: sparse riprap - acceptable condition

Downstream Channel: good

General Condition: good concrete structure

NOTES / SKETCHES

principle spillway stages are numbered from bottom to top.

OBSERVED CONDITIONS:	GOOD	ACCEPTABLE	POOR
	near new appearance, no threat to safety of dam.	Surfaces irregular or otherwise not in new condition, no threat to safety of dam.	Conditions observed appear to threaten safety of dam.

Floodwater Retarding Structure Inspection Sheet

Structure Number: SS-3 Date: 6/30/98

Inspection Party Present: Jason Ward, Tom Gill, James Ruff, Larry Frame

UPSTREAM SLOPE — Observed Conditions

Vegetative growth: good, short grass cover

Surface Erosion: none

Cracking: none

Animal Burrows: none

Debris: some - possibly water line

Unusual Conditions: none

DOWNSTREAM SLOPE

Vegetative growth: good

Surface Erosion: none

Cracking: none

Signs of Seepage: none

Animal Burrows: few on crest

Debris: tumbleweeds

Unusual Conditions: obvious sedimentation occurring in retarding pool

ABUTMENTS

Surface Erosion: none

Signs of Seepage: none

Unusual Conditions: none

EMERGENCY SPILLWAY

General Condition: good grass cover

PRINCIPLE SPILLWAY — Observed Conditions

Number of Stages / Open Stages: 4 / all

Debris: large clumps around trash rack

High Water Mark: no visible mark

Drawdown Opening: stage 1

Cattle Fence(s): 2+ft under sediment

Other: good with clean up of tower

OUTLET WORKS

Debris: none - some large vegetative growth

Plunge Pool: acceptable

Downstream Channel: acceptable

General Condition: acceptable

appear to be fairly deep (5-6ft) scour hole

NOTES / SKETCHES

principle spillway stages are numbered from bottom to top.

dam was 3/4 full on 6/11/98 after storm on 6/10/98

OBSERVED CONDITIONS:	GOOD	ACCEPTABLE	POOR
	near new appearance, no threat to safety of dam.	Surfaces irregular or otherwise not in new condition, no threat to safety of dam.	Conditions observed appear to threaten safety of dam.

Floodwater Retarding Structure Inspection Sheet

Structure Number: SS-4.5 Date: 6/30/98

Inspection Party Present: Jason Ward, Tom Gill, James Ruff, Larry Frame

UPSTREAM SLOPE — Observed Conditions

Vegetative growth: good, tall grass cover

Surface Erosion: none

Cracking: none

Animal Burrows: none

Debris: none - very clean

Unusual Conditions: none

DOWNSTREAM SLOPE

Vegetative growth: good - tall grass, weeds

Surface Erosion: none

Cracking: none

Signs of Seepage: none

Animal Burrows: few on crest

Debris: few tumbleweeds

Unusual Conditions: acceptable w/ clean up

ABUTMENTS

Surface Erosion: none

Signs of Seepage: none

Unusual Conditions: none

EMERGENCY SPILLWAY

General Condition: good grass cover

PRINCIPLE SPILLWAY — Observed Conditions

Number of Stages / Open Stages: 2 / #1 & #2

Debris: none

High Water Mark: no visible mark

Drawdown Opening: stage 1

Cattle Fence(s): good

Other: no cattle access, tall grasses

OUTLET WORKS

Debris: visible sedimentation, riprap is covered

Plunge Pool: ill defined, sediment filled

Downstream Channel: acceptable

General Condition: acceptable

left riprap slope completely filled in with sediment

NOTES / SKETCHES

principle spillway stages are numbered from bottom to top.

OBSERVED CONDITIONS:	GOOD	ACCEPTABLE	POOR
	near new appearance, no threat to safety of dam.	Surfaces irregular or otherwise not in new condition, no threat to safety of dam.	Conditions observed appear to threaten safety of dam.

Floodwater Retarding Structure Inspection Sheet

Structure Number: SS-5 Date: 6/30/98

Inspection Party Present: Jason Ward, Tom Gill, James Ruff, Larry Frame

UPSTREAM SLOPE — Observed Conditions

Vegetative growth: good, short grass cover

Surface Erosion: none

Cracking: none

Animal Burrows: none

Debris: none

Unusual Conditions: none

DOWNSTREAM SLOPE

Vegetative growth: large vegetation on left ½ of dam

Surface Erosion: none

Cracking: none

Signs of Seepage: none

Animal Burrows: none

Debris: few tumbleweeds

Unusual Conditions: none

ABUTMENTS

Surface Erosion: none

Signs of Seepage: none

Unusual Conditions: none

EMERGENCY SPILLWAY

General Condition: good grass cover

PRINCIPLE SPILLWAY — Observed Conditions

Number of Stages / Open Stages: 4 / (#1 & #4)

Debris: none

High Water Mark: no visible mark

Drawdown Opening: stage 1

Cattle Fence(s): open access at principle spillway

Other: good condition

OUTLET WORKS

Debris: none

Plunge Pool: large scour hole, no riprap

Downstream Channel: good

General Condition: acceptable, scour hole needs riprap replacement

NOTES / SKETCHES

principle spillway stages are numbered from bottom to top.

OBSERVED CONDITIONS:	GOOD	ACCEPTABLE	POOR
	near new appearance, no threat to safety of dam.	Surfaces irregular or otherwise not in new condition, no threat to safety of dam.	Conditions observed appear to threaten safety of dam.

Floodwater Retarding Structure Inspection Sheet

Structure Number: SS-6 Date: 6/30/98

Inspection Party Present: Jason Ward, Tom Gill, James Ruff, Larry Frame

UPSTREAM SLOPE — Observed Conditions

Vegetative growth: good, short grass cover

Surface Erosion: none

Cracking: none

Animal Burrows: none

Debris: none

Unusual Conditions: none

DOWNSTREAM SLOPE

Vegetative growth: good , few weeds

Surface Erosion: none

Cracking: none

Signs of Seepage: none

Animal Burrows:

Debris: few tumbleweeds

Unusual Conditions: none

ABUTMENTS

Surface Erosion: none

Signs of Seepage: none

Unusual Conditions: none

EMERGENCY SPILLWAY

General Condition: good grass cover

PRINCIPLE SPILLWAY — Observed Conditions

Number of Stages / Open Stages: 4 / all

Debris: none

High Water Mark: possibly, ref photo

Drawdown Opening: stage 1

Cattle Fence(s): good

Other: good condition

OUTLET WORKS

Debris: none

Plunge Pool: good condition, good riprap protection

Downstream Channel: good

General Condition: good

NOTES / SKETCHES

principle spillway stages are numbered from bottom to top.

noticeable signs of water flow in recent past.

OBSERVED CONDITIONS:	GOOD	ACCEPTABLE	POOR
	near new appearance, no threat to safety of dam.	Surfaces irregular or otherwise not in new condition, no threat to safety of dam.	Conditions observed appear to threaten safety of dam.

Floodwater Retarding Structure Inspection Sheet

Structure Number: SS-7 Date: 6/30/98

Inspection Party Present: Jason Ward, Tom Gill, James Ruff, Larry Frame

UPSTREAM SLOPE — Observed Conditions

Vegetative growth: good, short grass cover

Surface Erosion: none

Cracking: none

Animal Burrows: none

Debris: none

Unusual Conditions: none

DOWNSTREAM SLOPE

Vegetative growth: good, few large flower plants

Surface Erosion: none

Cracking: none

Signs of Seepage: none

Animal Burrows: none

Debris: none

Unusual Conditions: none

ABUTMENTS

Surface Erosion: none

Signs of Seepage: none

Unusual Conditions: none

EMERGENCY SPILLWAY

General Condition: good grass cover

PRINCIPLE SPILLWAY — Observed Conditions

Number of Stages / Open Stages: 3 / all

Debris: small amount

High Water Mark: no visible mark

Drawdown Opening: stage 1

Cattle Fence(s): fair condition

Other: good condition

OUTLET WORKS

Debris: none

Plunge Pool: no riprap, cattle guard rail - good cond

Downstream Channel: good

General Condition: acceptable - non riprap though

NOTES / SKETCHES

principle spillway stages are numbered from bottom to top.

OBSERVED CONDITIONS:	GOOD	ACCEPTABLE	POOR
	near new appearance, no threat to safety of dam.	Surfaces irregular or otherwise not in new condition, no threat to safety of dam.	Conditions observed appear to threaten safety of dam.

Floodwater Retarding Structure Inspection Sheet

Structure Number: SS-8 Date: 6/30/98

Inspection Party Present: Jason Ward, Tom Gill, James Ruff, Larry Frame

UPSTREAM SLOPE — Observed Conditions

Vegetative growth: good, tall grass cover

Surface Erosion: none

Cracking: none

Animal Burrows: none

Debris: none

Unusual Conditions: none

DOWNSTREAM SLOPE

Vegetative growth: tall grass

Surface Erosion: none

Cracking: none

Signs of Seepage: none

Animal Burrows:

Debris: few tumbleweeds

Unusual Conditions: none

ABUTMENTS

Surface Erosion: none

Signs of Seepage: none

Unusual Conditions: none

EMERGENCY SPILLWAY

General Condition: good grass cover

PRINCIPLE SPILLWAY — Observed Conditions

Number of Stages / Open Stages: 3 / all

Debris: none

High Water Mark: no visible mark

Drawdown Opening: stage 1

Cattle Fence(s): good, no cattle access

Other: tall grasses around drawdown

OUTLET WORKS

Debris: none

Plunge Pool: small ripraped area

Downstream Channel: good

General Condition: good

NOTES / SKETCHES

principle spillway stages are numbered from bottom to top.

OBSERVED CONDITIONS:	GOOD	ACCEPTABLE	POOR
	near new appearance, no threat to safety of dam.	Surfaces irregular or otherwise not in new condition, no threat to safety of dam.	Conditions observed appear to threaten safety of dam.

Floodwater Retarding Structure Inspection Sheet

Structure Number: SS-8.5 Date: 6/30/98

Inspection Party Present: Jason Ward, Tom Gill, James Ruff, Larry Frame

UPSTREAM SLOPE Observed Conditions

Vegetative growth good, short grass, few tree at base

Surface Erosion none

Cracking none

Animal Burrows none

Debris none

Unusual Conditions none

DOWNSTREAM SLOPE

Vegetative growth tall grasses / weeds

Surface Erosion none

Cracking none

Signs of Seepage none

Animal Burrows none

Debris none

Unusual Conditions good

ABUTMENTS

Surface Erosion none

Signs of Seepage none

Unusual Conditions none

EMERGENCY SPILLWAY

General Condition good grass cover

PRINCIPLE SPILLWAY Observed Conditions

Number of Stages / Open Stages 1 / 1

Debris none

High Water Mark no visible mark

Drawdown Opening stage I

Cattle Fence(s) good, no cattle access

Other good condition

OUTLET WORKS

Debris none

Plunge Pool good riprap cover

Downstream Channel good

General Condition good

NOTES / SKETCHES

principle spillway stages are numbered from bottom to top.

OBSERVED CONDITIONS:	GOOD	ACCEPTABLE	POOR
	near new appearance, no threat to safety of dam.	Surfaces irregular or otherwise not in new condition, no threat to safety of dam.	Conditions observed appear to threaten safety of dam.