5.8 FLOOD CONTROL, INTERIOR DRAINAGE, AND GROUNDWATER IMPACTS

The Mainstem Lake System dams, in conjunction with other flood control measures, provide flood control benefits to lands adjacent to the downstream river reaches. The dams store upstream inflow and release flows downstream at a controlled rate. The lower, controlled releases limit impacts to farmlands, buildings, and other floodplain development along the river reaches. The lower river stages facilitate surface water drainage from adjacent lands protected by flood control levees. The lower river stages also allow groundwater levels under adjacent croplands to stay below levels that may not have an adverse effect on the crops.

Three separate analyses were developed to quantify potential impacts on flood control, interior drainage, and groundwater. Hypothetically, a major flood event could damage crops that could also be damaged in the same year by inadequate interior drainage or high groundwater levels. No attempt was made to compute a consolidated damage or benefit to the affected lands. Two major factors limited the possibility for this consolidation. First, the interior drainage and groundwater analyses were done for representative sites – seven interior drainage sites and four groundwater sites – instead of all land along the river. The complexity of the modeling processes limited these two analyses to these representative sites. Second, each analysis covered a different time period – 100 years for flood control, 45 years for interior drainage, and 10 years for groundwater. Again, the complexity of the latter two modeling processes (as well as the availability of data for the interior drainage model) limited the period that could be modeled. Flood control effects were measured in terms of the difference in value (in millions of dollars) of flood control benefits provided by each alternative compared to the Run-of-River (ROR) scenario. The ROR scnario represents natural base inflow with no control placed on the inflow by the dams. Alternatives that include projected lake levels that are higher than the ROR alternative, which had the lake levels held constant at the base of flood control, are reflected by additional damages, or negative benefit values, in the summary tables and figures. The methods applied to get the results presented in this section are described in the Economic Studies – Flood Control, Interior Drainage, Groundwater Technical Report (Corps, 1998d).

5.8.1 Flood Control

Flood control benefits were computed for four mainstem lakes: Fort Peck Lake, Lake Sakakawea, Lake Oahe, and Lake Francis Case. Flood control benefits were also computed for the river reaches downstream from five of the six Mainstem Reservoir System dams, with the Big Bend Dam being the exception. These reaches are Fort Peck Dam downstream, Garrison Dam downstream, Oahe Dam downstream, Fort Randall Dam downstream, and Gavins Point Dam downstream. The Lower River downstream from Gavins Point Dam was divided into seven subreaches. These subreaches are the Sioux City, Omaha, Nebraska City, St. Joseph, Kansas City, Boonville, and Hermann subreaches. Total system flood control benefits and the differences among the alternatives are discussed in this section.

Figure 5.8-1 illustrates the total average annual flood control benefits for the submitted alternatives. These alternatives are clustered into three groups. The CWCP and the MLDDA alternative offer the highest level of flood control benefits. The BIOP, MODC, and MRBA alternatives offer the next highest level, and the ARNRC and the FWS30 alternative offer the lowest level of flood control benefits.

Table 5.8-1 also presents the total average annual flood control benefits for the alternatives. The table also breaks down these benefits into reaches. Total flood control benefits provided by the CWCP are $410.30 million over the 100-year period of analysis. The CWCP has a flat release from Gavins Point Dam in the spring and summer equaling 34.5 kcfs in non-drought periods and 28.5 kcfs during major droughts. The largest portion of the CWCP flood control benefits is provided to the Sioux City subreach, with $112.51 million, or 27.42 percent of the total benefits provided. The reach downstream from Garrison Dam receives $72.41 million, or 17.7 percent of the total protection, and the Omaha and Nebraska City subreaches receives 12.0 percent and 10.2 percent of the total benefit respectively. All other reaches and subreaches receive less than 10 percent of the total benefit. The Sioux City and Garrison Dam downstream reaches will be discussed in some detail at the end of the section.

Table 5.8-1. Average annual flood control benefits ($millions).

Reach Name	CWCP	MLDDA	ARNRC	MRBA	MODC	BIOP	FWS30
Fort Peck Lake	-0.07	-0.05	-0.06	-0.09	-0.07	-0.07	-0.07
Fort Peck Dam downstream	2.96	2.92	2.95	2.93	2.94	2.89	2.88
Lake Sakakawea	-0.07	-0.04	-0.13	-0.10	-0.11	-0.11	-0.11
Garrison Dam downstream	72.41	72.50	72.16	72.19	72.21	72.14	72.19
Lake Oahe	-0.28	-0.18	-0.54	-0.30	-0.38	-0.52	-0.48
Oahe Dam downstream	14.75	14.76	14.62	14.75	14.73	14.67	14.65
Lake Francis Case	-0.17	-0.11	-0.31	-0.18	-0.18	-0.17	-0.12
Fort Randall Dam downstream	0.70	0.70	0.68	0.70	0.70	0.70	0.69
Gavins Point Dam downstream	15.94	15.91	15.71	15.94	15.93	15.88	15.89
Sioux City	112.51	112.46	111.80	111.96	112.17	112.19	112.08
Omaha	49.30	49.33	49.16	49.18	49.19	49.23	49.33
Nebraska City	41.66	41.72	41.52	41.13	41.10	40.96	40.90
St. Joseph	36.71	36.70	36.08	36.47	36.49	36.34	36.08
Kansas City	37.73	37.68	37.21	37.16	36.48	37.16	37.06
Boonville	9.29	9.26	9.28	9.19	9.13	9.10	8.99
Hermann	16.93	16.93	16.57	16.91	16.96	16.79	16.74
Total	**410.30**	**410.49**	**406.70**	**407.83**	**407.29**	**407.17**	**406.70**

The MLDDA alternative sets aside an additional 2 MAF of system storage for flood control beyond that provided under the CWCP. This alternative provides total average annual flood control benefits of $410.49 million. The additional 2 MAF of storage increase the benefit level over the CWCP by $0.19 million (0.1 percent), and provide the highest average annual flood control benefits of all the alternatives. Of all of the alternatives analyzed, the MLDDA is the only one that increases annual flood control benefits over the CWCP benefit level.

The ARNRC alternative, with $406.70 million total average annual flood supply benefits, has greater conservation measures than the CWCP, and it includes a 15-kcfs spring rise from mid-May to mid-June followed by an 18-kcfs summer release until September 1 from Gavins Point Dam. This alternative decreases the average annual flood control benefits compared to the CWCP by $3.60 million, or 0.9 percent due to the spring rise and the lower level of summer releases. Of this total, $2.74 million, or 76.1 percent, of the increased damages are from Gavins Point Dam to the mouth. The spring rise increases the flow levels in the river during the time when high flows are most common, resulting in decreases in the flood control benefit. This simulation of this alternative by the DRM did not allow evacuation during the summer low-flow period except in the greater runoff years in the upper basin. This forced the model to move more water in the spring for the ARNRC alternative, which resulted in even greater damages in the spring months in certain years. The ARNRC provides the same flood control benefits as the FWS30 alternative, which is the lowest average annual flood control benefits for the alternatives analyzed in this section.

The MRBA alternative, with $407.83 million total average annual flood control benefits, provides higher drought conservation measures than the CWCP. This alternative includes a 7.1-month navigation season and, typically, a navigation service level that is 3 kcfs lower (relative to full service) in drought years. The increased drought conservation measures maintain the lakes at higher levels through the extended droughts. Unbalancing of the storage among the upper three lakes as part of this alternative results in higher flows in some years in the reaches downstream from Fort Peck and Garrison Dams. Flood control benefits are slightly decreased by $2.47 million, or 0.6 percent, from the level provided by the CWCP. Of this total difference, $2.13 million, or 86.2 percent of the difference occurs on the Lower River. There is no spring rise included in the Gavins Point release. A portion of the damages occurs in 1995, which is a year in which excess releases were made from the Mainstem Reservoir System beyond those that would occur under day-to-day management of the system. The others are spread throughout the 100-year period of analysis, 1898 to 1997, with no clear rationale for the decrease in benefits.

The MODC alternative is like the MRBA alternative except the release under the MODC alternative is extended out to mid-September to allow for continuing low flows for the pallid sturgeon. This alternative also has a spring rise from Fort Peck Dam in about 1 out of 3 years on average. The drought conservation measures and protection for the pallid sturgeon in this alternative decrease the average annual flood control benefits by $3.01 million to $407.29 million, a decrease of 0.7 percent from the CWCP. Of this total difference, $2.62 million, or 87.0 percent, occurs on the Lower River, similar to results for the MRBA alternative.

The alternative prescribed by the Biological Opinion, the BIOP alternative, includes a 17.5-kcfs spring rise followed by a 25/21 summer low flow, and incorporates the same conservation measures as the MRBA alternative. The combination of the spring rise, the 25/21 summer low flow, and the drought conservation measures in this alternative provides $407.17 million in average flood control benefits. The BIOP alternative benefits are lower by $3.13 million, or 0.8 percent, than the CWCP in flood control benefits. Of this difference, $2.42 million, or 77.3 percent, occurs on the Lower River.

One of the alternatives suggested by the USFWS, the FWS30 alternative, is identical to the BIOP alternative except that the spring rise is 30 kcfs higher than the CWCP. This alternative provides $406.70 million in flood control benefits. As with the ARNRC alternative, the FWS30 alternative provides the lowest average annual flood control benefits, a decrease of $3.60 million, or 0.9 percent, from the benefit level of the CWCP. Of this total difference, $3.00 million, or 83.3 percent, occurs on the Lower River. The decrease in flood protection provided by this alternative can be attributed to the drought conservation measures, the unbalancing of the upper three lakes, the higher spring rise, and the lower level of summer release.

The reach-specific data are addressed by alternative and only address the reaches and subreaches that receive the greatest percentages of the flood control benefits. Most of the average annual flood control benefits occur in the Lower River reach in the subreaches of Sioux City, Omaha, Nebraska City, St Joseph, and Kansas City (Table 5.8.1-1). The CWCP provides the highest level of benefit for the Sioux City, St. Joseph, and Kansas City subreaches. The CWCP provides the second highest level of benefit to the reach downstream from Garrison Dam and the Nebraska City subreach, and the third highest level of benefit to the Omaha subreach. The analysis focuses on the percentage change from the CWCP starting with the greatest percentage first.

The MLDDA alternative provides greater flood control benefits than the CWCP for the Nebraska City subreach, the reach below Garrison Dam, and the Omaha subreach. The percentage increase above the level of the CWCP for all these sections is 0.1 percent.

The ARNRC alternative provides a lower flood control benefit level than the CWCP for all reaches and subreaches analyzed in detail. The percentage decrease below the level of the CWCP for the sections are as follows: 1.7 percent for St. Joseph, 1.4 percent for Kansas City, 0.6 percent for Sioux City, 0.4 percent for the reach downstream of Garrison Dam, 0.3 percent for Nebraska City, and 0.3 percent for Omaha.

The MRBA alternative provides a lower benefit level than the CWCP for all reaches and subreaches analyzed in detail. The percentage decrease for each of the reaches and subreaches are as follows: 1.5 percent for Kansas City, 1.3 percent for Nebraska City, 0.7 percent for St. Joseph, 0.5 percent for Sioux City, 0.3 percent for the reach downstream of Garrison Dam, and 0.2 percent for Omaha.

The MODC alternative provides a lower benefit level than the CWCP for all reaches and subreaches analyzed in detail. The percentage decrease for each of the reaches and subreaches are as follows: 3.3 percent for Kansas City, 1.3 percent for Nebraska City, 0.6 percent for St. Joseph, 0.3 percent for Sioux City, 0.3 percent for the reach downstream of Garrison Dam, and 0.2 percent for Omaha.

The BIOP alternative provides a lower benefit level than the CWCP for all reaches and subreaches analyzed in detail. The percentage decrease for each of the reaches and subreaches are as follows:

1.7 percent for Nebraska City, 1.5 percent for Kansas City, 1.0 percent for St. Joseph, 0.4 percent for the reach downstream of Garrison Dam, 0.3 percent for Sioux City, and 0.1 percent for Omaha.

The FWS30 alternative provides a lower benefit level than the CWCP for all reaches and subreaches analyzed in detail except for the Omaha subreach. The percentage decrease for the reaches and subreaches with lower benefit levels are as follows: 1.8 percent for Nebraska City, 1.8 percent for Kansas City, 1.7 percent for St. Joseph, 0.4 percent for Sioux City, and 0.3 percent for the reach downstream of Garrison Dam. The Omaha subreach receives increased protection by 0.1 percent over the level of the CWCP.

Figures 5.8-2 through 5.8-4 graphically illustrate the very slight differences between all alternatives during the 100-year study period. There are no obvious trends for any of the alternatives. An in-depth analysis found that major differences in flood control benefits in certain years were due to a multitude of differences in the simulation runs; however, not once in the years examined was the major difference due to the Gavins Point spring rise.

Flood Control for Tribal Reservations

In terms of Reservation impacts, each Reservation identified within one of the five reaches analyzed is considered within the analysis of that particular reach. The reach downstream from Fort Peck Dam includes benefits to Fort Peck Reservation. The reach downstream from Fort Randall Dam includes the benefits to Yankton Reservation, Ponca Tribal Lands, and Santee Reservation. The Sioux City reach includes the benefits to both the Winnebago and Omaha Reservations while the St. Joseph reach includes benefits to Sac and Fox and Iowa Reservations.

Table 5.8-2, Average annual flood control benefits for Reservations, provides the data for comparing the alternatives for flood control benefits to the Reservations. The data for Fort Peck Reservation show that the CWCP and the ARNRC, MRBA, and MODC alternatives provide the same average annual flood control benefit of $0.85 million. The MLDDA alternative provides slightly lower benefits of $0.84 million. The BIOP and FWS30 alternatives also provide slightly lower flood control benefits of $0.83 million.

The benefits provided to Fort Berthold Reservation are highest under the MLDDA alternative with a 33 percent increase over the CWCP, which provides the next highest benefit level. The ARNRC alternative provides a 100.0 percent decrease in flood control benefits from the level of the CWCP.

Standing Rock Reservation receives the highest benefit level from the MLDDA alternative at $0.03 million in damages over the ROR alternative. This benefit level is a 40.0 percent increase over the level of the CWCP. The lowest flood control benefits for this Reservation are provided by the ARNRC alternative with an 80.0 percent decrease from the level of the CWCP.

The highest benefits for Cheyenne River Reservation is provided by the MLDDA alternative with $0.03 million in damages over the ROR, a 40.0 percent increase over the benefits of the CWCP. The CWCP provides $0.05 million in damages over the ROR. The ARNRC alternative provides the lowest benefits with a 100.0 percent decrease below the CWCP.

The benefits provided to Lower Brule Reservation are the same for all submitted alternatives. The level of benefit for Crow Creek Reservation is also the same for all submitted alternatives except for the MLDDA alternative, which provides a slight increase in flood control benefits over the other alternatives.

The data for the Fort Randall reach, which includes Yankton Reservation, Ponca Tribal Lands, and Santee Reservation, indicate no change in flood control benefits for any alternative during any period of analysis.

The Sioux City subreach includes Winnebago and Omaha Reservations. This subreach receives about 95 percent of the total flood control benefits under all alternatives. The CWCP and the MLDDA alternative provide $8.52 million in average annual flood control benefits to Winnebago Reservation, $0.05 million more than the lowest benefit level under the ARNRC alternative. The ARNRC alternative also provides the least amount of average annual flood control benefits to the Omaha Reservation at $7.91 million, which is lower than those provided by the CWCP by $0.05 million. The CWCP provides the largest annual flood control benefits to Omaha Reservation at $7.96 million. The largest percentage change for the Sioux City subreach is a decrease of 0.6 percent between the CWCP and the ARNRC alternative.

Table 5.8-2. Average annual flood control benefits for Reservations ($millions).

Reservation	CWCP	MLDDA	ARNRC	MRBA	MODC	BIOP	FWS30
Fort Peck	0.85	0.84	0.85	0.85	0.85	0.83	0.83
Fort Berthold	-0.03	-0.02	-0.06	-0.04	-0.05	-0.05	-0.05
Standing Rock	-0.05	-0.03	-0.09	-0.05	-0.06	-0.08	-0.08
Cheyenne River	-0.05	-0.03	-0.10	-0.06	-0.07	-0.09	-0.09
Lower Brule	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01
Crow Creek	-0.01	0.00	-0.01	-0.01	-0.01	-0.01	-0.01
Yankton and Ponca Tribal Lands	0.12	0.12	0.12	0.12	0.12	0.12	0.12
Santee	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Winnebago	8.52	8.52	8.47	8.48	8.50	8.50	8.49
Omaha	7.96	7.95	7.91	7.92	7.93	7.93	7.92
Iowa, Sac and Fox	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	**17.30**	**17.34**	**17.08**	**17.20**	**17.20**	**17.14**	**17.12**

There is no difference in the benefits among the submitted alternatives for the St Joseph reach, which includes Sac and Fox Reservation and Iowa Reservation.

5.8.2 Interior Drainage

Analysis of interior drainage impacts was completed for six representative sites downstream of Gavins Point Dam along the Missouri River from Nebraska City to Hermann. The sites are levee unit L575 around Hamburg, Iowa; levee unit L536 near Corning, Missouri; levee unit L488 north of St. Joseph, Missouri; levee unit R351 east of Independence, Missouri; levee unit L246 near Boonville, Missouri; and the Tri-County levee unit, across the river from Hermann, Missouri. The sites represent combinations of the non-flow factors that contribute to interior drainage damage such as topography, drainage structure size and placement, rainfall, etc. that may be found at leveed areas along the river

With the exception of L575, all of the basins that exited directly to the Missouri River or the lower reaches of a tributary adjacent to each levee unit were modeled. For L575, the portion of the levee unit that drains into Main Ditch 6 was not modeled. Simulation runs of the alternatives were made for a 45-year period from October 1, 1949 through September 30, 1994 (Water Years 1950 through 1994). The simulation runs, completed using an adapted version of a model developed for the Corps' Hydrologic Engineering Center called HEC-IFH, computed the size of the ponding areas within the six levee units on a daily basis for this period.

These files were input to an economic model that was an adapted version of a model that was also developed for the Corps' Hydrologic Engineering Center called HEC-PBA. This model computed the damages to the potential crops raised in the areas where the water ponded. Each ponding site had an assumed area that stored water often enough that the farmer did not plant a crop in this portion of the site. This area was input to the HEC-PBA model as a "zero-damage" acreage that was subtracted from the total ponding area for each of the modeled basins within the levee unit. The resulting damages to the crops were not converted to benefits for this report because the primary interest is on the relative differences among the alternatives. A negative difference between two alternatives is a relative benefit. Figure 5.8-5 presents graphically the total average annual damage for each alternative. Table 5.8-3 presents the average annual data for each area modeled.

The CWCP does not have a spring rise or summer low-flow period. The flat release from mid-May through late August is 34.5 kcfs in non-drought periods and goes to 28.5 kcfs in major droughts. Over the 45-year simulation period, the total interior drainage damages for the CWCP average $1.34 million per year. This is the alternative with the lowest damages. Due to the differences in sites, there can be significant variation in the interior damages for the same alternative. For example, for the 45-year period, the damages for the CWCP range from a low of $0.06 million at site R351 to a high of $0.52 million at the L246 site. Both of these sites are downstream from Kansas City, and have major inflows entering the Missouri River from upstream tributaries. The primary difference between the two sites is the amount of "zero-damage" acreage. The R351 has a number of very large ditches that drain the site. These ditches provide considerable storage space for the runoff from the interior of the levee should the outlets to the Missouri River be blocked by high river stages.

The range of interior drainage damage is from $1.51 million for the FWS30 alternative to $1.34 million for the CWCP, a difference of $0.17 million per year. As Figure 5.8-5 shows, the alternatives can be grouped according to the amount of total interior drainage damage for the six sites analyzed. Four of the alternatives are grouped close to the CWCP, ranging from 40 million, a difference of only $0.06 million. Three of the alternatives, MLDDA, MODC and MRBA, are similar to the CWCP in that they do not have increased spring or reduced summer releases from Gavins Point Dam. The ARNRC alternative, with a spring rise but lower summer releases, is also grouped with these lower damage alternatives. The second grouping includes the BIOP and FWS30 alternatives that have a spring rise and low summer flow from Gavins Point Dam. They show the highest damages at $1.46 and $1.51 million per year, respectively.

Table 5.8-3 shows that the effect of moderating releases from Gavins Point Dam declines significantly at the sites further down river from the dam. As one moves further downstream from Gavins Point Dam, there are more outside influences on interior drainage damages, such as tributary inflow. This reduces the effect of controlling releases on sites further from the dam. Site L575 is closest to the dam and accounts for the majority of changes in total damages for each alternative.

The MLDDA alternative is like the CWCP with balanced intrasystem regulation and no additional spring and summer release, but sets aside an additional 2 MAF of storage for flood control. It has $0.01 million higher damages per year than the CWCP, only a 0.7 percent difference. Compared to the CWCP, the MLDDA alternative has the smallest difference in damages in total and at each of the sites.

The ARNRC alternative has an unbalanced intrasystem regulation and a split navigation season that mimic the natural flow of the Lower River, unlike the CWCP. From Gavins Point Dam there is a spring rise of 15 kcfs above full navigation service in many years and a lower summer release of 18 kcfs. The combination of an additional spring and a lower summer release creates average interior drainage damages of $1.40 million per year, $0.06 million more damages per year than the CWCP. This is a 4.4 percent increase overall. Essentially, all the difference in damages occurs at site L575, where the damages are $0.06 million more than the CWCP, for a 14.0 percent increase.

Although the MRBA alternative has unbalanced intrasystem regulation and an increase in conservation slightly less than the ARNRC alternative, a major difference between these two alternatives is that under the MRBA alternative, a steady flow is maintained through the late spring and summer, as with the CWCP. A spring rise is not included in the MRBA alternative. The damages average $1.38 million per year, which is an increase of $0.04 million per year or 3.0 percent higher than the CWCP. The majority of the increase occurs at site L575 with a $0.03 million (7.0 percent) per year increase over the CWCP.

The MODC alternative is identical to the MRBA alternative except there is a Fort Peck spring rise and the flat release from Gavins Point was extended out to mid-September to allow for continuing low flows for the pallid sturgeon. The MODC alternative shows average annual interior drainage damages of $1.37 million, $0.03 million more per year than the CWCP, or a 2.2 percent increase. There is virtually no change in damages at five of the six sites, but site L575 shows a $0.02 million (4.7 percent) increase.

Table 5.8-3. Average annual interior drainage damages for 1950 to 1994 ($millions).

Alternative	Total	L575	L536	L488	R351	L246	Tri-County
CWCP	**1.34**	0.43	0.12	0.15	0.06	0.52	0.07
MLDDA	**1.35**	0.44	0.12	0.15	0.06	0.51	0.07
ARNRC	**1.40**	0.49	0.12	0.15	0.06	0.51	0.07
MRBA	**1.38**	0.46	0.12	0.15	0.06	0.52	0.07
MODC	**1.37**	0.45	0.12	0.15	0.06	0.52	0.07
BIOP	**1.46**	0.52	0.13	0.16	0.06	0.52	0.07
FWS30	**1.51**	0.55	0.14	0.16	0.06	0.53	0.07

The BIOP and FWS30 alternatives also have most of the components of the MRBA and MODC alternatives; however, there is variation with the spring/summer release criteria compared to the CWCP. The BIOP alternative, prescribed in the Biological Opinion, includes a 17.5-kcfs increased spring release from Gavins Point Dam, followed by a 25-kcfs low flow from June 21 to July 15, and then a 21-kcfs flow from July 16 to August 15. The Gavins Point Dam release then goes back up to 25 kcfs until September 1 to restore service to navigation targets. This alternative is among the alternatives with the highest damages, at $1.46 million per year, a $0.12 million increase in damages over the CWCP, which is a 9.0 percent increase. Most of the increase in total damages is due to the increase at L575. It shows $0.09 million per year higher damages than the CWCP, a 20.9 percent increase.

The FSW30 alternative, submitted by USFWS, is identical to the BIOP alternative except that it has a higher spring rise of 30 kcfs. It has the largest interior drainage damages of the alternatives. The average annual damages for FWS30 are $1.51 million, $0.17 million more than CWCP for a 12.7 percent increase. As with the other alternatives, most of the increase in damages is attributable to L575. The damages at L575 are $0.12 million per year higher than for the CWCP, an increase of 27.9 percent.

Figures 5.8-6 through 5.8-8 show that there can be considerable variance through the years. For example, the CWCP shows average damages of $1.34 million, but yearly damages range from $0.03 million in 1956 to $0.11 million in 1993, a flood year. In all but 7 years though, the damages are less than $2.00 million. Only 2 years, 1984 and 1993, have damages above $3.00 million. The other alternatives follow a similar pattern as the CWCP, with the same low damage years and the same high damage years. In 1993, a major flood year, all submitted alternatives are greater than $11.0 million in damages and are within $0.05 million of the CWCP.

The MLDDA, MRBA, and MODC alternatives have the least annual variability from the CWCP and only show an increase of greater than $0.20 million over the CWCP in 1965, 1983, and 1986. The ARNRC, BIOP, and FWS30 alternatives, with the spring rise and summer low flows, show considerable more variability than the CWCP. They have many more years with increases of more than $0.20 million higher than the CWCP. The ARNRC alternative is more than $0.20 million higher than the CWCP in 10 of the 45 years of analysis, while the BIOP alternative and the FWS30 alternatives are more than $0.20 million higher than the CWCP in 13 and 18 years, respectively. The ARNRC alternative also has 3 years where the damages are at least $0.20 million less than the CWCP while the BIOP and FWS30 alternatives do not have years showing that level of damage reduction. Thus, while the ARNRC alternative shows variability like the BIOP and FWS30 alternatives, its average damages are lower and more like alternatives without the spring rise and summer low flows, as shown in Figure 5.8-4.

Interior Drainage for Tribal Reservations

The sites included for interior drainage analysis did not include any Tribal Reservation land; therefore, damage estimates for interior drainage damages on Reservation land were not developed.

The Reservations located within this reach are Sac and Fox Reservation and Iowa Reservation. The nearest site analyzed to the Reservations is the L488 site, which is downstream and across the Missouri River from the Reservations. In terms of Reservation lands, it must be noted that Sac and Fox Reservation and Iowa Reservation floodplain land is protected by non-Federal levees that may or may not have non-flow factors similar to L488. To the extent that they are similar, they will have similar damages. For Iowa Reservation and Sac and Fox Reservation, about 1,000 acres are located in the Missouri River floodplain. The value of the crops that could be damaged is $0.30 million. Four residential buildings are located in the floodplain and subject to flooding. Their value is estimated to be $0.40 million.

If the Reservation lands respond similarly to that of the L488 lands, the ARNRC alternative creates the least damage. The most damage is indicated under the FWS30 alternative. At site L488, only $0.01 million average annual damages separates the ARNRC damages from the FWS30 damages, a relatively small variance. If the Reservations are more similar to the total of all the sites, CWCP would sustain the least interior drainage damage and FWS30 would sustain the most.

5.8.3 Groundwater Effects

Analyses of groundwater effects were computed for four representative sites along the Missouri River from Onawa, Iowa to Hermann, Missouri. These four sites are designated as RM691, an unleveed site near Onawa; levee unit L575 near Hamburg, Iowa (across the river from Nebraska City); levee unit L488/L497 north of St. Joseph, Missouri; and the Tri-County levee unit across the river from Hermann, Missouri.

Simulation runs were made of the submitted alternatives and the CWCP for the 10-year period of October 1, 1969 through September 30, 1979 (Water Years 1970 through 1979). The results of the groundwater model simulation runs were in terms of percent of the modeled area that had groundwater levels at 1-foot increments from zero feet deep up to 9 feet deep. These files were input to another adapted version of the HEC-PBA model, which is the same model used for the interior drainage analysis. This economics model computed the annual crop damages associated with the shallow groundwater levels on the crops raised at each representative site. These damages were not converted to benefits for this report because the primary interest is on the relative differences among the alternatives. A negative difference between two alternatives is a relative benefit. Table 5.8-4 and Figure 5.8.3-1 present the average annual groundwater damages for the submitted alternatives and the CWCP. The table also presents the damages by area modeled.

Over the 10-year simulation period, the total damages for the modeled sites for the CWCP average $4.52 million per year. At individual sites it ranges from a low of $0.30 million per year at the Tri-County site near Hermann to a high of $2.18 million per year at the L575 site near Hamburg, Iowa. Two factors contribute to differences in the damages. First, there is a difference in the relative size of the sites (RM 691 and L575 are much larger than Tri-County and L488/497). Second, there is a difference in the lay of the farmable land with respect to the river. Although the RM691 site is larger than the L575 site, it has only 34 percent of the damages of the L575 site, which has more land with elevations closer to the river water surface.

Figure 5.8-9 shows the average annual damages by alternative. Groundwater damages for the alternatives range from $4.31 million for the MODC alternative to $5.20 million for the ARNRC alternative, compared to the CWCP at $4.52 million. This range is 4.6 percent lower annual groundwater damages for the MODC alternative to 15.0 percent increased damages for the ARNRC alternative when compared to the CWCP. The alternatives with the changes in the annual release patterns from Gavins Point Dam show the largest increases in damages. Of these, the ARNRC and FWS30 alternatives show essentially the same increase ($5.20 and $5.18 million), with the BIOP alternative ($4.96 million) being somewhat lower. The other three alternatives show much smaller changes from the CWCP. The MLDDA alternative, with more steady year-round flows, shows a small increase in damages to $4.58 million. The MRBA and MODC alternatives, also with more steady year-round flows, actually show a reduction in damages to $4.50 and $4.31 million, respectively.

In some cases, the reduction or increase in damages may look small. It should be noted that even a small difference of $0.02 million per year translates to $0.20 million for the 10-year period. Also, the damages may be limited to a small area and affect only a few individuals. In that case, the effect could be relatively high to a small number of individuals.

The MLDDA alternative sets aside 2 MAF for flood control. This results in total average groundwater damage for the four sites of $4.58 million. That is $0.06 million or only 1.3 percent more than the CWCP. At three of the four sites, the change from the CWCP is less than 2 percent, but at site L488/497, MLDDA is among the alternatives with the highest annual damages, at 4 percent, or $0.053 million, more per year than the CWCP.

Table 5.8-4. Average annual groundwater damages, 1970 to 1979 ($millions).

Alternative	Total	RM691	L575	L488/497	Tri-County
CWCP	**4.52**	0.74	2.18	1.30	0.30
MLDDA	**4.58**	0.74	2.19	1.35	0.29
ARNRC	**5.20**	0.85	2.64	1.36	0.35
MRBA	**4.50**	0.74	2.17	1.29	0.30
MODC	**4.31**	0.72	2.10	1.20	0.29
BIOP	**4.96**	0.86	2.48	1.30	0.32
FWS30	**5.18**	0.89	2.62	1.34	0.33

The ARNRC alternative, with an average annual groundwater damage of $5.20 million, has the highest groundwater damages of the alternatives. The ARNRC alternative has an unbalanced intrasystem regulation and a split navigation season that mimics the natural flow of the Lower River. From Gavins Point Dam there is a spring release increase of 15 kcfs and a lower summer release of 18 kcfs. The combination of an additional spring and a lower summer release creates groundwater damages that are $680,000 or 15.0 percent higher than computed for the CWCP. This alternative has the highest increase over the CWCP. It also has the highest increase at three of the four sites, ranging from a 4.6 percent increase at L488/497 to a 21.1 percent increase at L575.

Although the MRBA alternative has unbalanced intrasystem regulation and an increase in drought conservation similar to the ARNRC alternative, a major difference between these two alternatives is that in the MRBA alternative, a flat release is maintained from Gavins Point Dam during the summer, as with the CWCP. A spring rise is not included in the MRBA alternative. Thus, the MRBA alternative shows essentially no change from the CWCP with damages of $4.50 million, $21,000 less than the CWCP or a 0.5 percent decrease in damages. There is also essentially no effect at three of the four sites. The fourth site, L488/497, shows a small (1.1 percent) decrease in damages.

The MODC alternative is identical to the MRBA alternative except the flat release from Gavins Point Dam is extended to mid-September to allow for continuing low flows for the pallid sturgeon. This low-flow extension decreases damages from the MRBA alternative by an average of $0.19 million per year. At $4.31 million annual groundwater damage to crops, it shows the largest decrease in damages from the CWCP. The average annual groundwater damages are $0.21 million, 4.6 percent below those of the CWCP.

The BIOP and FWS30 alternatives also have most of the basic components of the MRBA and MODC alternatives; however, there is variation in the additional spring/summer release criteria compared to the CWCP. The BIOP alternative, prescribed in the USFWS Biological Opinion, includes a 17.5-kcfs increased spring release from Gavins Point Dam, followed by a 25-kcfs low flow from June 21 to July 15, followed by a 21-kcfs flow from July 16 to August 15. The Gavins Point Dam release then goes back up to 25 kcfs until September 1 when it meets navigation targets. This alternative is among the alternatives with the highest damages. It shows average groundwater damages of $4.91 million per year, $0.44 million more than the CWCP or a 9.8 percent increase. Although the BIOP alternative shows no increase in damages at site L488/497, it shows significant increases at the other sites: between a 7.6 percent increase at Tri-County to 16.2 percent at RM691.

The FWS30 alternative, submitted by the USFWS, is identical to the BIOP alternative except there is a higher spring rise of 30 kcfs. The damages are very close to the highest groundwater damages to crops per year at $5.18 million, an increase from the CWCP of $0.66 million per year, or 14.6 percent. By including the higher spring rise, average annual crop damages increase by $0.22 million over the BIOP alternative. At each of the individual sites, the FWS30 alternative is among those with the highest increases.

Figures 5.8-10 to 5.8-12 show that there can be considerable variance in damages per year. Although the CWCP has average damages of $4.52 million, the range is from $2.37 million in 1976 to $6.92 million in 1978. The highest groundwater damages occur in 1978 because it was a very wet year in the upper Missouri River basin (highest runoff year in the period of analysis). All of the alternatives follow a similar pattern, but there are differences. The MRBA and MODC alternatives follow the CWCP most closely except in 1978 and 1979. In the wet year, 1978, the MRBA alternative shows damages that are much higher than the CWCP ($1.32 million higher), but the extended flat release of the MODC alternative keeps damages below the CWCP ($0.25 million lower). In the following year, 1979, both MRBA and MODC are much lower than the CWCP ($1.15 and $1.36 million lower).

Damages for the MLDDA alternative are very close to the CWCP with an increase of $0.06 million per year, but it shows more variance. Although the increased set aside for flood control was focused on reducing flooding, it results in increased groundwater damages of $1.31 million in 1978, a very wet year, but then shows decreased damages of $0.87 million in 1979.

The alternatives with the changed releases from Gavins Point Dam show the largest increases in damages and are fairly consistently higher than the

CWCP. The ARNRC, BIOP and FWS30 alternatives have lower damages than the CWCP in only 2 of the 10 years. Of the three, the FWS30 alternative shows the greatest differences in individual years, ranging from $1.71 million higher in 1976 to $0.53 lower than the CWCP in 1979.

Groundwater Effects for Tribal Reservations

The sites included for groundwater analysis did not include any Reservation land; therefore, damage estimates for excessive groundwater on Reservations were not developed.

Sac and Fox Reservation and Iowa Reservation are in the vicinity of the L488/L497 site that is downstream and across the Missouri River from the Reservation. If groundwater damage on the Reservation land responds similarly to that of the L488/497 site, a decrease in crop damage from the CWCP would be expected with the MRBA and MODC alternatives. An increase in crop damage over the CWCP would be expected for the MLDDA, ARNRC, and FWS30 alternatives. An estimated $150,000 per year separates the groundwater damages of the ARNRC, MLDDA, and FWS30 alternatives from the damages of the MODC alternative at L488/497. If groundwater levels cause a damage response on the Reservations more like that of the total damages, higher damages would result from all alternatives except the MRBA and MODC alternatives.

Winnebago and Omaha Reservations are located primarily across the river and upstream from RM 691. To the extent that these Reservation floodplain lands have similar characteristics to the RM 691 site, a reduction in damages from the CWCP can be expected from the MODC alternative. If instead they respond more like total damages, a decrease in crop damages from the CWCP can be expected from the MRBA and MODC alternatives. Increases in damages would occur for the ARNRC, BIOP, and FWS30 alternatives under either the similarity to the RM691 or the total damages conditions.

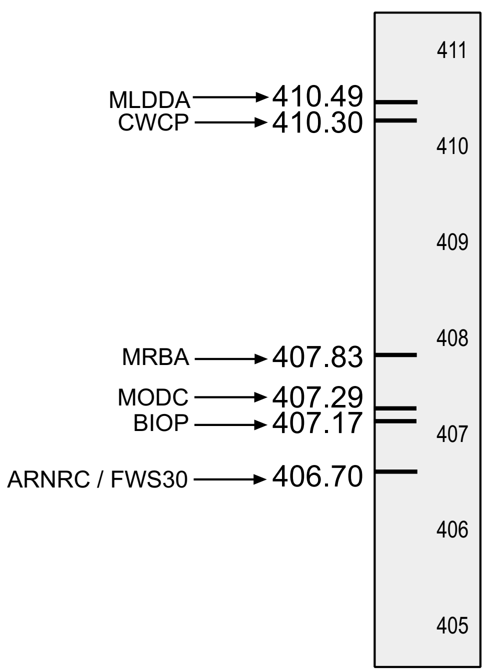

Figure 5.8-1. Average annual flood control benefits for submitted alternatives ($millions).

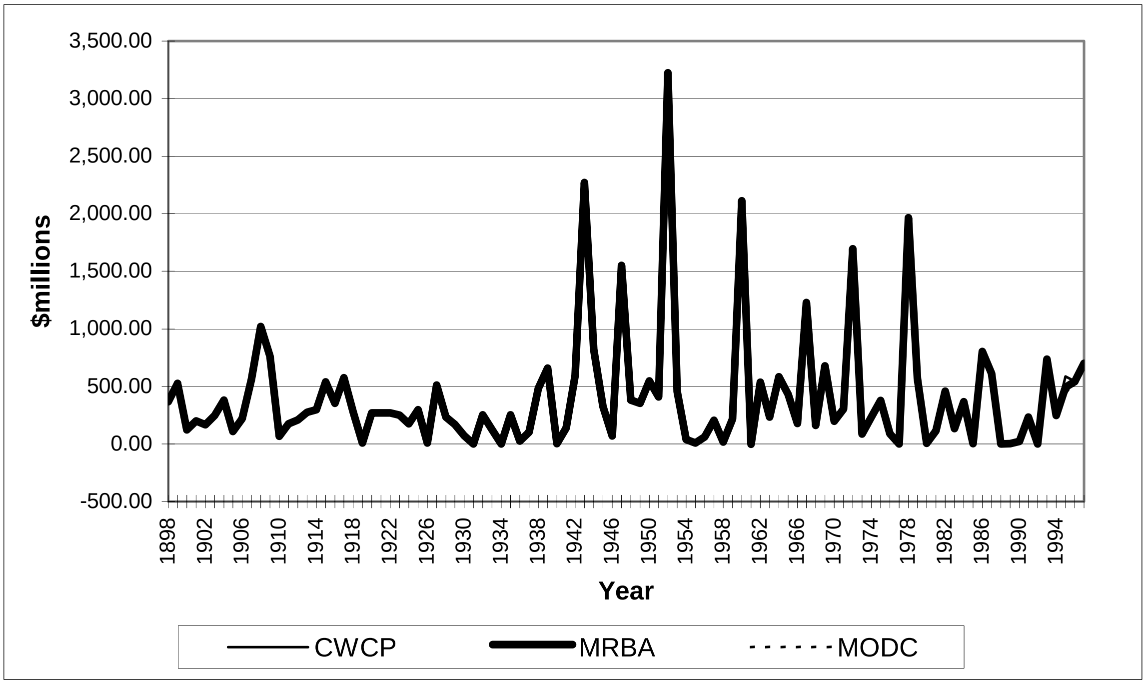

Figure 5.8-2. Average annual flood control benefits for alternatives CWCP, MRBA, and MODC ($millions).

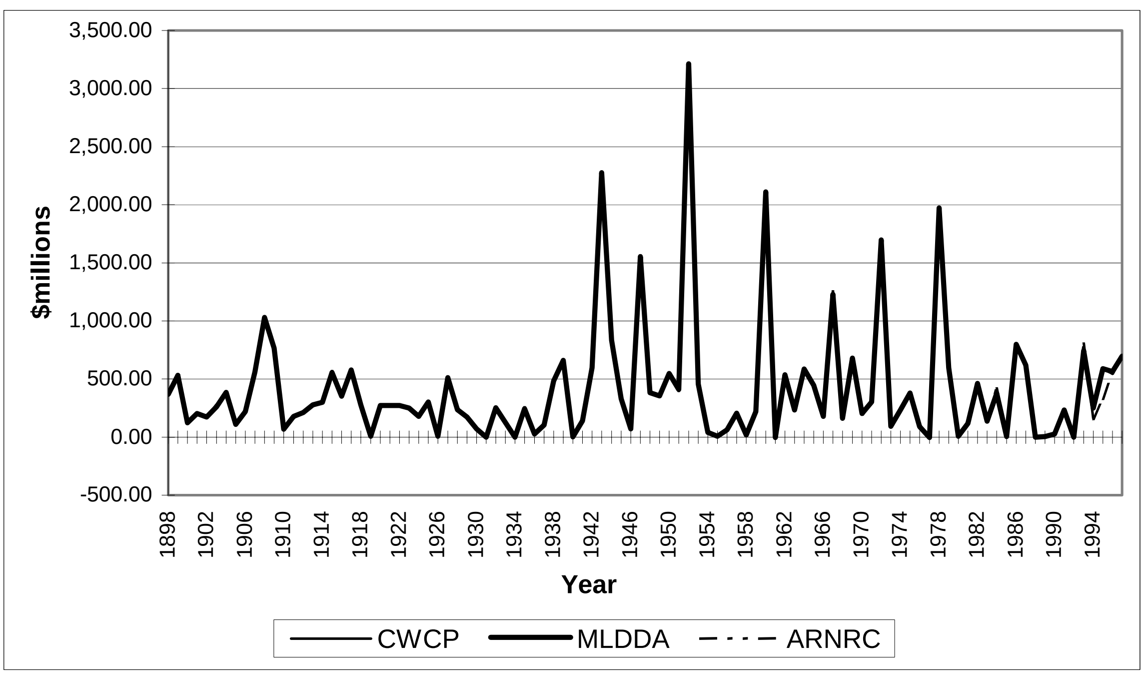

Figure 5.8-3. Average annual flood control benefits for alternatives CWCP, MLDDA, and ARNRC ($millions).

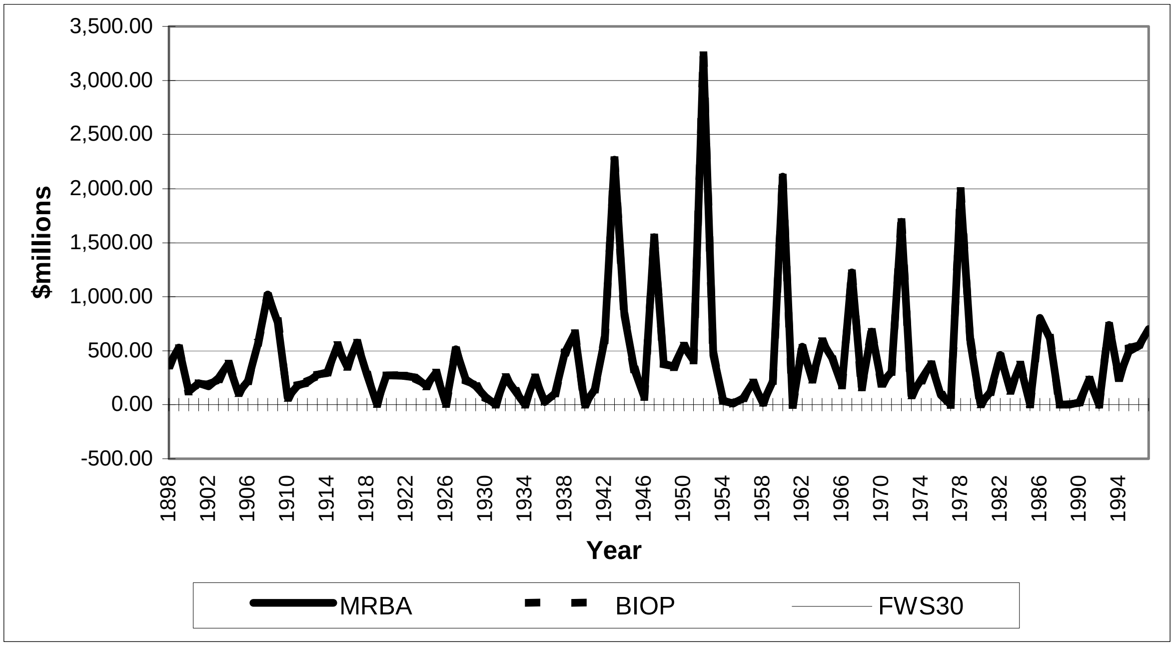

Figure 5.8-4. Average annual flood control benefits for alternatives MRBA, BIOP, and FWS30 ($millions).

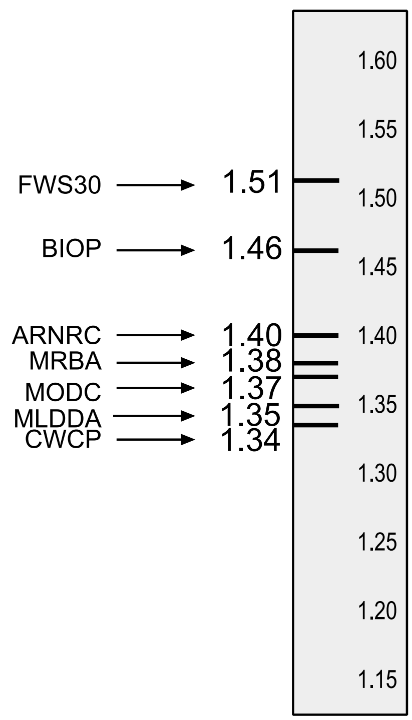

Figure 5.8-5. Average annual interior damages for submitted alternatives ($millions).

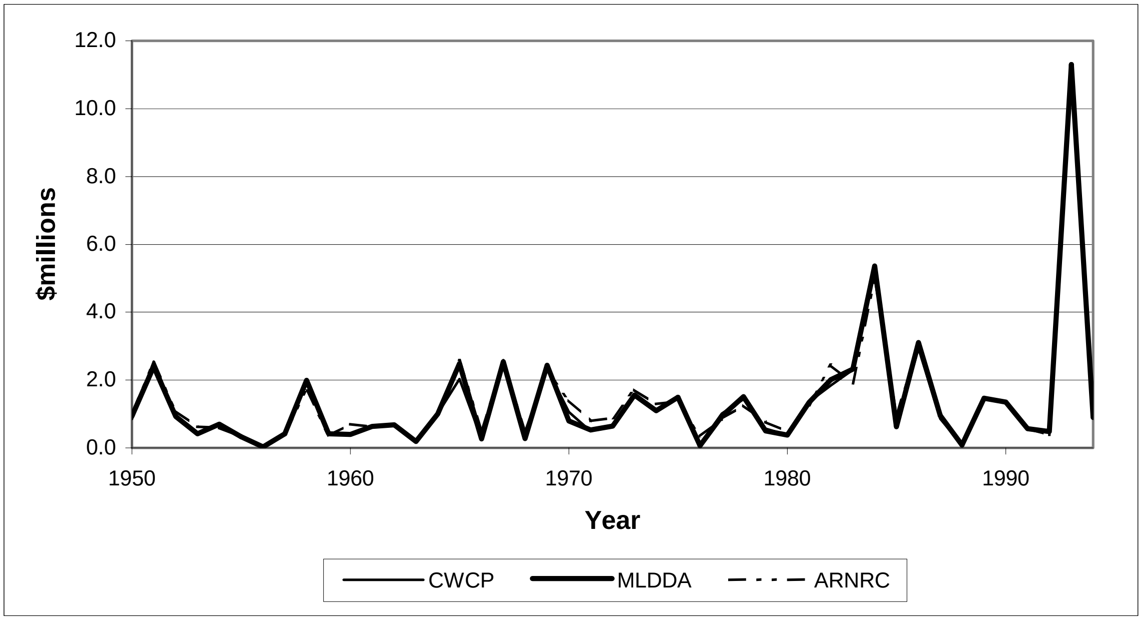

Figure 5.8-6. Average annual interior drainage damages for alternatives CWCP, MLDDA, and ARNRC.

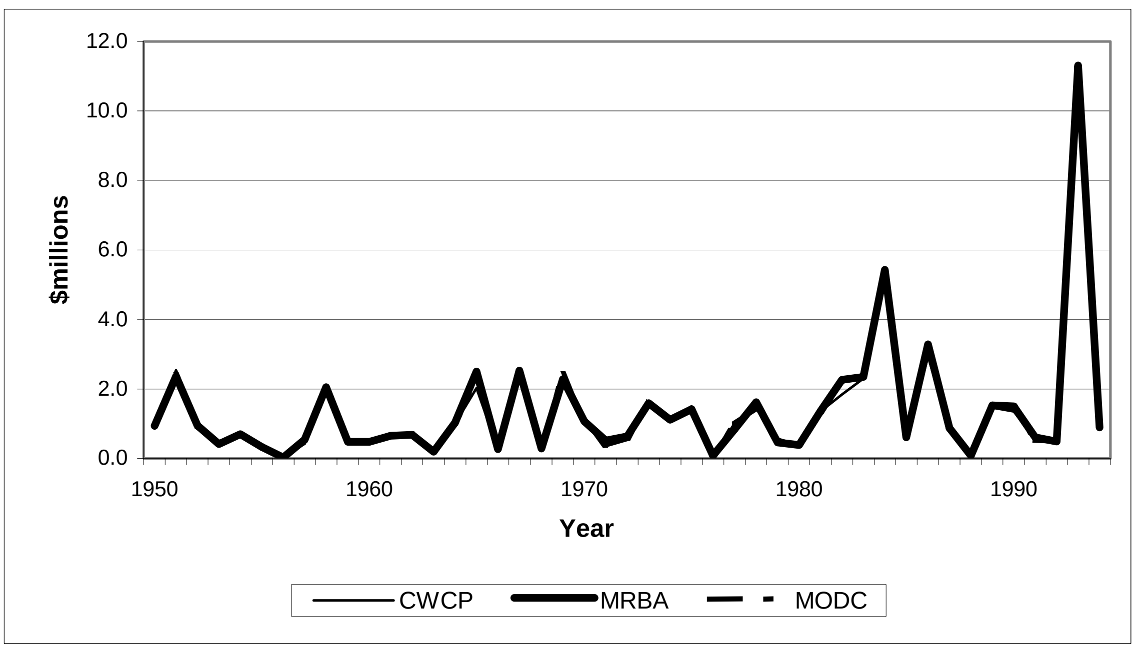

Figure 5.8-7. Average annual interior drainage damages for alternatives CWCP, MRBA, and MODC.

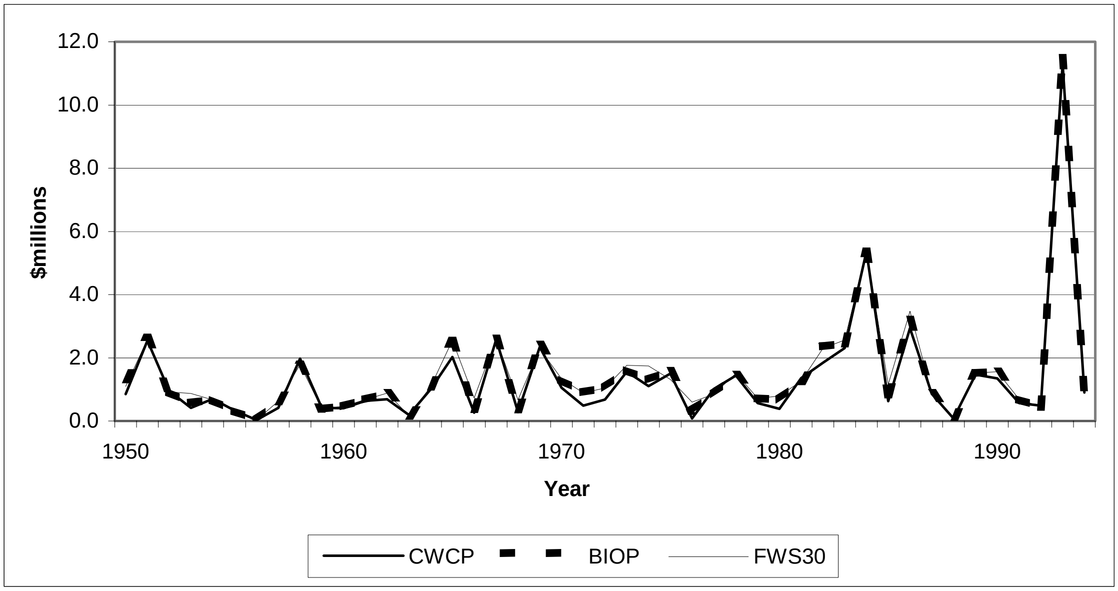

Figure 5.8-8. Average annual interior drainage damages for alternatives CWCP, BIOP, and FWS30.

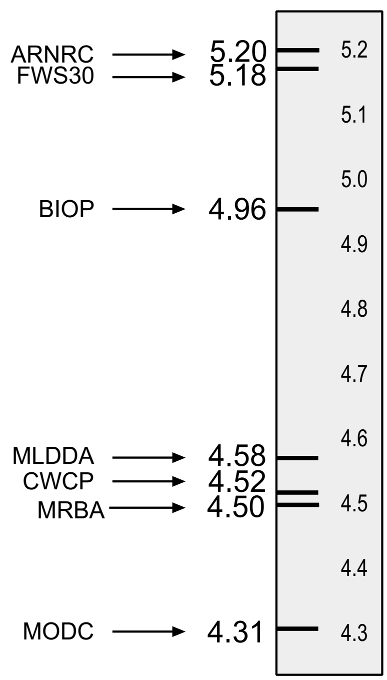

Figure 5.8-9. Average average annual groundwater damages for submitted alternatives ($millions).

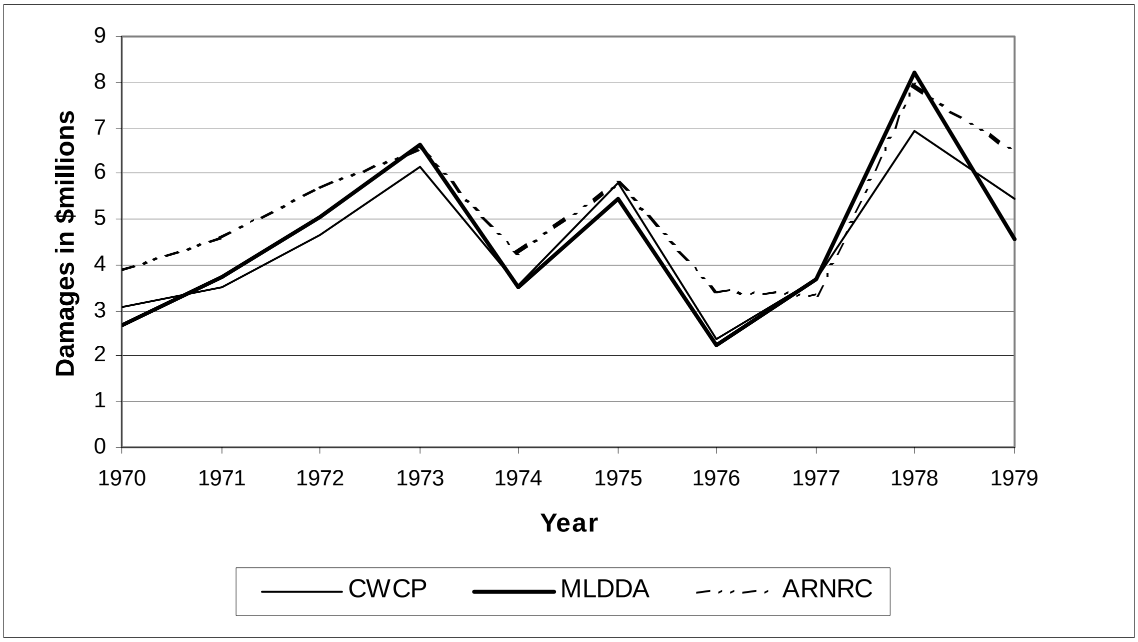

Figure 5.8-10. Average annual groundwater damages for alternatives CWCP, MLDDA, and ARNRC.

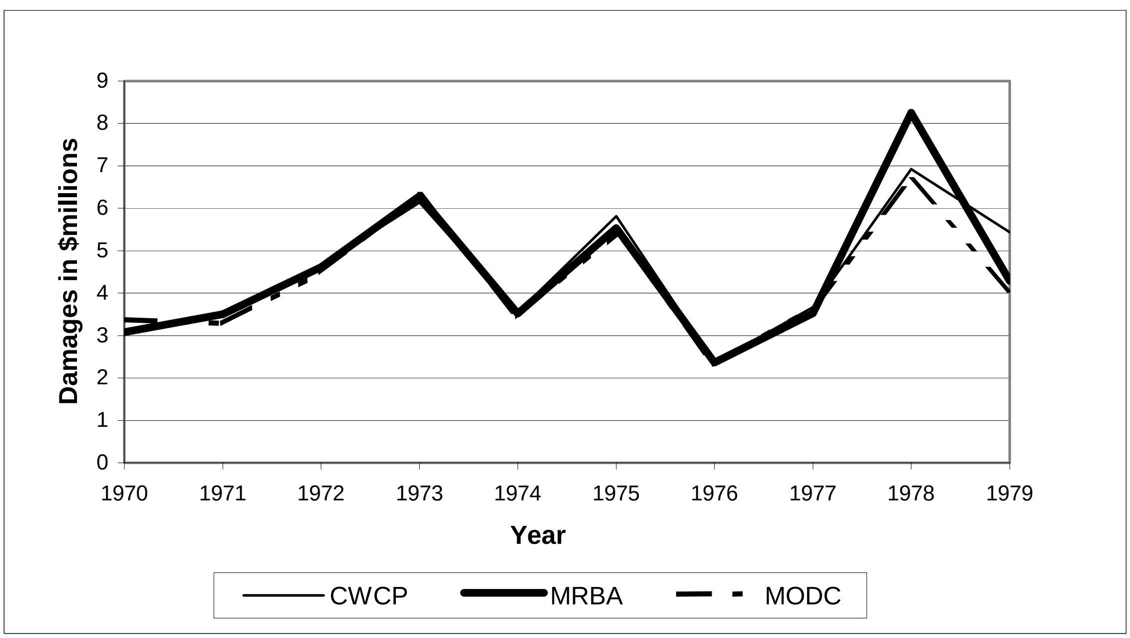

Figure 5.8-11. Average annual groundwater damages for alternatives CWCP, MRBA, and MODC.

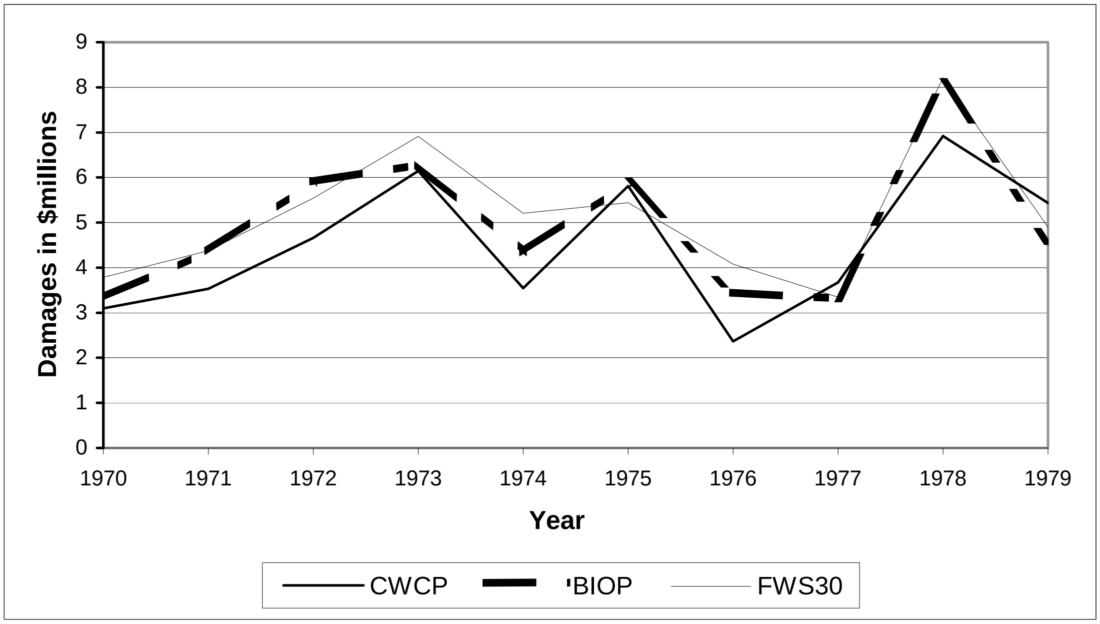

Figure 5.8-12. Average annual groundwater damages for alternatives CWCP, BIOP and FWS30.