DRAFT FOR REVIEW

Appendix A

Risk-Based Economic Analysis

29 February 2004

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1. INTRODUCTION

1.1 Report Purpose

The purpose of the economic analysis is to quantify the economic impacts of Clearwater Dam's current operating condition, evaluate rehabilitation plans that address the problems and opportunities at the dam, and determine the economic feasibility of implementing the rehabilitation plans. The objective of the analysis is to identify the most efficient plan for correcting the serious seepage problems at Clearwater Dam.

1.2 Economic Considerations

The objective of the analysis is to identify the plan that maximizes National Economic Development (NED) benefits. Potential NED benefits include:

1) Increased reliability results in reduced future maintenance expenditures
2) With the life of the project extended, there is no structure replacement cost in future funding streams; the replacement cost is considered deferred beyond the period of analysis;
3) Extending the life of the project results in additional average annual flood control and recreation benefits over the extended time frame; and
4) With the potential for failure reduced or eliminated, there are flood control and recreation benefits that would have been lost during the period of time necessary to accomplish the major repairs.

2. PROJECT LOCATION AND DESCRIPTION

2.1 Location

Clearwater Lake is located on the Black River in Wayne and Reynolds Counties in southeast Missouri. The dam is about 43 miles north of the Missouri-Arkansas State line and is 257 river miles upstream from the mouth of the Black River. It is approximately 5 miles southwest of Piedmont, Missouri, the nearest town, and is 125 miles southwest of St. Louis, Missouri. The project is situated in a rural area in the eastern part of the Ozark Plateau.

2.2 Description

Construction of the Clearwater project began in May 1940, but was suspended in November 1942 by order of the War Production Board. The project at that time was about 55 percent complete. Construction resumed in May 1946 and completed in October 1948.

The dam is a rolled-fill earth embankment extending across the Black River Valley between the two abutments, has a crest length of approximately 4,225 feet and a maximum height of about 154 feet above the streambed. The dam contains approximately 5,500,000 cubic yards of fill material. The outlet works for releasing impounded waters from the lake consist of a tunnel through the right abutment, an intake structure, a control tower, and a stilling basin and discharge channel. The tunnel, which is circular in section except for the upper and lower transition sections, has an inside diameter of 23 feet and is 1,177 feet long. The stilling basin has a maximum width of 75 feet and is 190 feet long. A total of 37,600 cubic yards of concrete was used in the construction of the outlet works. The spillway is located in a natural saddle and 1,200 feet from right abutment end of the dam. The spillway provides for the passage of flood flows around the right end of the dam and outlet works.

The dam's embankment is an earthen structure with an impervious earth core. The top of the dam reaches elevation 608.0 NGVD and rises 154 feet above the streambed. A 3-foot high concrete parapet wall was added in 1989 to extend the height of the dam to elevation 611.0 thereby providing the required freeboard. At the top of the dam, the crest length stretches 4,225 feet. Normal side slopes on the dam are 1 vertical on 2 horizontal with an impervious fill blanket added to the upstream face at a 1 vertical on 4 horizontal slope. The blanket, added in 1989, extends to elevation 575.0 feet NGVD. A portion of Missouri State Highway HH runs across the top of the dam. It is the only highway leading to Clearwater Dam from the west and east.

2.3 Downstream Development

Description of the downstream reaches used in the economic analysis are contained in the following paragraphs:

Reach 1: Clearwater Dam to 9 miles downstream. Communities within this reach include Piedmont (4.5 miles d/s), Leeper (7.0 miles d/s) and Mill Spring (9.0 miles d/s). Floodwaters in this reach would rise gradually under "without dam failure" flood conditions. The community of Piedmont would be affected by backwater flooding along McKenzie Creek, which enters Black River 4.5 miles downstream from Clearwater Dam. Residents would evacuate with little loss of life, but property damage would be unavoidable. Arrival times of dangerously high flows for "with dam failure" floods are determined by the amount of time it takes flood waters for each event to reach the first structure or evacuation route at a particular location with time measured from the time of peak rainfall. Warning would be given when spillway discharge begins allowing time for evacuation. For "with dam failure" floods, residents would have less than four hours to evacuate. The population at risk by flooding after a dam failure would increase significantly. Groups of residences within this reach would be at risk from dam failure that would otherwise not be flooded. Much of Piedmont, Leeper, and Mill Spring would be impacted. Reach 1 is shown in Plate A1.

Reach 2: 9 to 22 miles downstream. The communities of Markham Springs (17.4 miles d/s) and Williamsville (21.4 miles d/s) are located in the reach. Williamsville would be impacted by backwater flooding along Williams Creek, which enters Black River 22.4 miles downstream from the dam. There are small groupings of houses and isolated residences throughout the reach. For "without dam failure" floods, residents throughout Reach 2 could evacuate safely because of the slow rate of inundation and warning time from the beginning of spillway discharges. For "with dam failure" floods, residents would have less than 10 hours to evacuate. Reach 2 is shown in Plate A2.

Reach 3: 22 to 48 miles downstream. Communities within this reach include Keener Cave (25.4 miles d/s), Hendrickson (28.7 miles d/s), Hilliard (37.0 miles d/s) and Poplar Bluff (45.9 miles d/s). The majority of the population-at-risk in Reach 3 reside in the City of Poplar Bluff. A large section of agricultural land east Poplar Bluff would be inundated for both "with dam failure" and "without dam failure" floods. For "without dam failure" events, the arrival time of flooding in all areas of Reach 3 would be slow enough to allow for the safe evacuation of the population. For "with dam failure" floods, residents would have less than a 12 hours to evacuate more upstream areas of the reach. Residents in more downstream areas of the reach would have less than 18 hours to evacuate. Reach 3 is shown in Plate A3.

2.4 Project Benefits

2.4.1 Flood Reduction

Clearwater Dam provides both urban and agricultural flood reduction benefits. Table 1 shows the historical flood damages prevented by Clearwater Dam by fiscal year. For the period fiscal year 1948 to 1962, the flood damages prevented are shown as a cumulative figure due to the lack of better data. The fiscal year damages are escalated to reflect current fiscal year prices; the project has prevented $232,909,600 in damages since the lake was impounded. The average annual damages prevented are $4,159,100.

2.4.2 Recreation

Popular recreation activities include swimming, boating, water skiing, camping, picnicking, sightseeing, hunting, and fishing. Estimates for recreation losses were based on the loss of facility use due to inundation or loss of the dam. Annual visitation data available from the VERS system for FY 1992 to 2002, shown in Table 2, shows steady visitation to Clearwater Dam for the last 10 years. This data is used to calculate an average value of annual visitor hours, which will be projected through the 50-year period of analysis. Average annual visitor hours are converted to average annual visitor days by assuming 12 hours in a visitor day (the standard in the VERS program). A generalized recreation unit day value of $7.92 (EGM 03-04, 78 points by Mike Dowell, Natural Resources, CESWL) is assigned. Generalized recreation unit day value for zero points equals $3.00. With an increment of $4.92, loss of annual recreation benefits is estimated at $2,126,000. In sensitivity analysis, removing the years 1993 and 1994 from the average does not significantly change the annual recreation benefits.

Total annual Clearwater Dam benefits are as follows:

Flood Damage Reduction	$4,159,100
Recreation	2,126,000
Total	$6,285,100

Table 1: Historical Flood Damages Prevented

Year	Flood Damages Prevented	Prices Received by Farmers	Factor of Increase	FDP at Current Prices
Cumulative thru 1962	$4,983,000	255	2.596	$13,073,000
1963	582,000	243	2.724	1,602,000
1964	43,000	237	2.793	121,000
1965	4,000	245	2.702	11,000
1966	2,211,000	264	2.508	5,603,000
1967	16,000	250	2.648	43,000
1968	327,000	255	2.596	858,000
1969	239,000	268	2.470	597,000
1970	349,000	274	2.416	852,000
1971	0	281	2.356	0
1972	904,000	313	2.115	1,932,000
1973	2,715,000	447	1.481	4,063,000
1974	1,529,000	481	1.376	2,127,000
1975	1,429,000	466	1.421	2,052,000
1976	352,000	475	1.394	496,000
1977	1,355,000	462	1.433	1,962,000
1978	467,000	529	1.251	591,000
1979	6,093,000	600	1.103	6,794,000
1980	0	624	1.061	0
1981	1,530,000	634	1.044	1,614,000
1982	5,240,000	598	1.107	5,862,000
1983	15,831,000	625	1.059	16,946,000
1984	2,268,000	641	1.033	2,367,000
1985	16,046,000	579	1.143	18,540,000
1986	10,259,000	554	1.195	12,389,000
1987	0	563	1.176	0
1988	1,241,000	627	1.056	1,324,000
1989	1,780,000	659	1.005	1,807,000
1990	1,883,560	660	1.003	1,909,000
1991	2,870,100	632	1.047	3,038,000
1992	2,775,020	626	1.058	2,966,000
1993	2,688,440	642	1.031	2,802,000
1994	32,590,430	634	1.044	34,390,000
1995	2,937,000	647	1.023	3,037,000
1996	13,173,810	712	0.930	12,378,000
1997	11,018,900	679	0.975	10,857,000
1998	22,451,200	643	1.030	23,359,000
1999	11,106,200	607	1.091	12,241,000
2000	724,500	611	1.083	793,000
2001	214,900	649	1.020	222,000
2002	19,917,800	627	1.056	21,252,000
2003	39,600	669	1.000	39,600
Total	$202,184,460			$232,909,600

Table 2: Calculating Average Recreation Hours

Year	Visitor Hours
1992	4,186,000
1993	6,690,000
1994	6,567,700
1995	4,946,000
1996	5,055,500
1997	4,991,300
1998	5,016,000
1999	5,014,000
2000	4,805,300
2001	4,879,100
2002	4,887,100
Average	**5,185,300**

3. PROBLEMS AND OPPORTUNITIES

As the dam is currently configured, there is a highly permeable section inside the structure where seepage flows have historically concentrated. This section was originally allowed as part of construction of the dam as a cost saving measure since the associated seepage was not thought at that time to pose a significant problem. However, as early as two years after the dam was completed, seepage flows exceeding what was expected were detected.

Of particular concern were the overburden contact and the section or “window” area, which is the space between the right end of the upstream, left abutment impervious blanket, and the left end of the embankment core. Since about 1978, the downstream left abutment area has experienced observable seepage at pool elevations above about 530. Various reports and studies concluded the seepage condition gradually worsened up to 1986 and have continued to worsen to the present, including development of sinkholes in January 2003.

Since the initial impoundment of water in 1948, for lake levels exceeding about elevation 510, surface seepage has been documented as occurring along the contact of and downstream of the left abutment ridge which forms the left end of the dam embankment From a comprehensive analysis of seepage, the seepage path was concluded to probably occur through the upper layers of the limestone rock along the entire left abutment ridge.

The scope of the seepage problem is flow beneath and through the dam that exits along the downstream left abutment along flow lines mainly through the section in question. The site is underlain with alluvial and residual deposits overlying bedrock that is known to be highly fractured and prone to substantial weathering. During every major flood event there continues to be noticeable quantities of excessive seepage observed downstream of the left abutment. There is internal seepage and piping that occurs during higher lake levels, and there are verified concerns that every high water event is causing additional incremental and cumulative damages. During large flood events or other conditions leading to high lake levels, the existing seepage protection, an impervious clay blanket partially covering the embankment about 2/3 of the way to the top, is overtopped and water is allowed to flow unimpeded throughout the internal shell of the dam, thoroughly saturating the core and causing steady state seepage.

In the projected failure scenario, the interior of the embankment will become saturated during a time period of approximately 48 hours after the estimated flood or other high water event has commenced. Steady state internal seepage would begin to occur throughout and around the dam's left abutment immediately following thorough saturation of the internal dam structure. After approximately 36 hours, the seepage becomes evident from traditional downstream discharges from the downstream toe and from the base of the left abutment ridge.

After the commencement of a high water event and steady state seepage has been evident downstream for a period of time, discoloration of the discharge will begin to occur. During the next estimated 11 hours, extensive muddy water will be observed at the discharge areas confirming that internal piping and erosion is taking place. This could lead to the appearance of large visible sinkholes. During the next hour (48 hours after saturation occurs), it is projected that the embankment would begin to settle and rapidly breach. This is thought to primarily occur at the left abutment. An ultimate breach opening (caused by the highest lake level) would measure approximately 100 feet wide at the base, 130 feet high and 360 feet long at the crest, with 1 vertical to 1 horizontal side slopes. This is in contrast to a dam height of 154 feet above the riverbed.

4. WITHOUT-PROJECT CONDITION

The without project condition represents the current operating condition of Clearwater Dam and takes into consideration the probability of future emergency action and the probability of dam failure given distress. Under the without project condition, the seepage problem at Clearwater is expected to continue over time, leading to an eventual failure of the dam and the rapid release of the pool downstream. It is unknown specifically the conditions that would eventually lead to such a failure or how long it will take for these conditions to develop. However, there is a high degree of confidence that a failure will eventually occur.

The without project condition forecasts a failure over a varying range of time with a range of flood damages downstream depending upon the pool elevation when the failure occurs. The economic evaluation of Clearwater Dam compares economic losses under the without-project condition to the economic losses with the rehabilitation plans in place.

The economic impacts of dam failure are measured in four categories. First, economic losses include distress costs. These costs could include, but are not limited to, the costs of lowering the pool elevation, mobilizing equipment and personnel for investigations, mobilizing equipment and personnel for repairs, and producing public address announcements. These costs exceed the bounds of regular O&M costs at the project. One assumption applied in this analysis is that expenditures for normal O&M at the project are assumed to be the same for both with and without project conditions. The evaluation of each rehab plan includes the quantification of the reduction in distress costs from the without project condition.

The second category of economic loss is agricultural and non-agricultural damages. One of the greatest concerns arising from the structural integrity problems of the dam is the certain catastrophic flood damage caused by a dam failure. The methodology for estimating flood damages is addressed in section 6.

The third category of economic loss is the cost of dam replacement. A basic assumption of the without project condition is that operating the dam is a primary objective. According to ER 1105-2-100, Section X – Major Rehabilitation Studies, "Should the project benefit stream be interrupted due to unsatisfactory feature performance, it is assumed that emergency funds will be available to fix the feature." In the economic analysis of the without project condition, a dam failure is followed by dam replacement. This assumption also applies in evaluating each rehabilitation plan considered in this analysis. For the period of time in which the dam is being rebuilt, foregone recreation benefits are counted as the fourth category of economic loss.

5. MEASURES CONSIDERED

An interdisciplinary study team identified a variety of measures that could be used to address the seepage problem. Each measure was developed considering the best alignment that would optimize or minimize various issues and risks related to cost, success of controlling gradient or eliminating seepage, and experiencing future damage or deterioration to the seepage barrier/cutoff or dam. The following sections describe the plans considered in the economic analysis.

5.1 Non-Structural Measures

Although the study team initially identified six non-structural measures, none of the measures passed through a preliminary screening. For further detail, see Section 8.6.4 of the main report.

5.2 Structural Measures

Measure S1 – Extend the Impervious Fill Blanket. At the present, an impervious soil blanket covers much of the upstream embankment slope of the dam to elevation 575 ft. This measure extends the blanket to the top of the dam (bottom of the parapet wall) in order to withstand internal infiltration and saturation problems. Such an extension would eliminate the seepage through the embankment that currently occurs with a 20% Probable Maximum Flood (PMF) or larger event.

Measure S2A – Slurry Cutoff Wall to Rock Located 500 ft Upstream of Existing Dam Toe Without Extension of Impervious Blanket. Construct a bentonite cement cutoff wall penetrating to rock. This would be placed upstream of the dam toe and through the existing seepage berm. It would begin at the right abutment and extend out approximately 500 feet onto the seepage berm and terminate into high ground near the left abutment. The total length would be about 4,300 feet. The cutoff would extend to a depth of about 70 feet to top of rock. The seepage blanket would not be extended.

Measure S2B – Slurry Cutoff Wall to Rock Located 500 ft Upstream of Existing Dam Toe With Extension of Impervious Blanket. Same as Measure S2A, with extension of the impervious fill blanket.

Measure S2C – Slurry Cutoff Wall to Rock Located at Existing Upstream Embankment Toe of Dam With Extension of Impervious Blanket – Same as Measure S2B except the location of the cutoff wall is moved to the upstream toe of the existing dam.

Measure S3 – Slurry Cutoff Wall to Rock Located 500 ft Upstream of Existing Dam Toe Including Deep Panels into Rock With Extension of Impervious Blanket. Same as Measure S2A except the seepage blanket would be extended and deep intermittent concrete cutoff wall panels would be extended 60 feet into rock where defects or voids are detected. The cutoff wall would have a depth of between 70 feet to rock and 130 feet for the deep cutoff panels.

Measure S4A – Concrete Cutoff Wall to Rock Located at Existing Upstream Embankment Toe of Dam With Extension of Impervious Blanket. Same as Measure S2C except concrete would be used in lieu of bentonite slurry.

Measure S4B – Concrete Cutoff Wall into Rock Located at Existing Upstream Embankment Toe of Dam With Extension of Impervious Blanket. Same as Measure S3 except that the cutoff wall (either secant pile or "Hydrofraise" method) would be extended into rock continuously (60 feet into rock) with concrete. The total length would be about 4,300 feet. Steel reinforcement may be required to a minimal depth into bedrock to account for cracking and seismic conditions.

Measure S4C – Concrete Cutoff Wall into Rock Located Through the Dam and Through the Centerline of the Clay Core Trench With Extension of Impervious Blanket. Same as Measure S4B except placement would be through dam and through the centerline of the clay core trench. Penetration of the wall would begin along seepage berm at Elev. 575 of the dam's upstream face and extend 60 feet into rock for a total depth of 200 feet. Length and width would be the same. A berm would have to be constructed for access and to allow for a 30 feet wide working platform. Extension of seepage blanket will be required to prevent seepage inflow directly into the window area. The total length would be about 4,300 feet.

Measure S4D – Concrete Cutoff Wall into Rock Located Through the Centerline of the Dam Alignment. Same as Measure S4C except the cutoff wall location would move to the centerline of the dam alignment. The total depth of the wall would be 230 feet with the same length and thickness. The total length would be about 4,300 feet. Extension of the seepage berm would not be required.

Measure S4E – Concrete Cutoff Wall into Rock Located Through the Dam and Through the Centerline of the Clay Core Trench from Sinkhole to End of Left Abutment With Extension of Impervious Blanket. Same as Measure S4C except the total length would be shortened to approximately 2,800 feet.

5.3 Cost Estimates

Little Rock District Cost Engineering prepared MCACES cost estimates for all the structural measures. These estimates can be found in Table 3.

Table 3: Cost Estimates of Clearwater Major Rehab Measures (in $1,000s)

	S1	S2A	S2B	S2C	S3	S4A	S4B	S4C	S4D	S4E
Subtotal Construction	5,958	2,244	8,198	8,738	14,340	22,282	59,553	59,058	56,480	51,682
PED/EDC	357	135	820	699	1,728	1,114	1,191	1,181	1,130	1,034
S&A	596	337	984	1,049	1,728	2,674	4,466	4,429	4,236	3,876
Subtotal	8,467	3,854	12,258	12,856	21,892	31,955	73,057	71,948	68,812	57,963
Interest During Construction	276	44	547	636	1,190	2,211	6,905	6,616	6,151	4,592
Total Costs	8,743	3,898	12,805	13,492	23,082	34,166	79,962	78,563	74,963	62,556

6. EVALUATION METHODOLOGY

The economic evaluation was performed using a model to simulate the operation of the dam under existing conditions and under alternative future conditions based on proposed rehabilitation Measures. The economic model utilizes the probabilities of emergency action and probabilities of failure given distress to estimate the resulting economic losses.

6.1 Estimating Damage

Floodplain damage data of the project area from prior flood studies was not available; secondary methods of inventory were used to estimate damages. Automated HEC-RAS inundation mapping was used to delineate the floodplain for the 20% and 100% PMF events under failure and non-failure scenarios. Using a GIS program (ESRI ArcGIS 8.3), the inundated area for each breach condition was overlaid on geo-referenced USGS 7.5 minute topographic quad maps of the study area. (Plates A4-A6) The inundated area was also overlaid on Census block and NRCS land-use-land-cover data in an ArcGIS format.

6.1.1 Structures

Residential damage was estimated using 2000 Census population and housing data for the inundated Census blocks. The 2000 Census housing data includes “Tenure” count of occupied housing units in each Census block. If a Census block did not completely lie in the inundated area, the population was adjusted to exclude residents living outside the floodplain. Using geo-referenced USGS topographic quad maps, a geo-referenced dot was placed on any visible structure within the inundated area (Plate A7). Census blocks, which were partially inundated, were identified (Plate A8). The tenure count was limited to the minimum of inundated geo-reference dots or Census tenure count. For example, Wayne County Census Tract 9904 Block 1063 has tenure count 40 and population 117 (Plate A9). Within the inundated area, only 24 structures were represented on the geo-referenced USGS topographic quad maps. With a small cross, one of the structures is symbolized as a church. The tenure for this census block was adjusted to 23. To adjust the block’s population, a ratio of inundated structures to total structures was applied to the population. After adjustment, Tract 9904 Block 1063 has tenure count 23 and population 67 (Plate A10).

Geo-referenced dots were also placed on non-residential, non-commercial, non-public structures (“Other” structures) within the inundated area. These structures were represented by hollow squares on the USGS topographic quad maps. A visual inventory of the inundated areas provided a list of commercial and public structures. The structures were assigned a Census block number based upon inventory descriptions, USGS 7.5 minute topographic quad maps, and aerial photos.

Samples of assessed housing values obtained from the Wayne and Butler County Assessor’s offices were ineffective in estimating replacement less depreciation values. Housing values were estimated using “Lower Value Quartile (Dollars) for Specified Owner-Occupied Housing Units” from 2000 Census data. Sensitivity of housing values was tested by using “Median Value for Specified Owner-Occupied Housing Units.” Using median housing values, damages for the 20% and 100% PMF events increased from 22% to 26%. Estimates of values of commercial and public structures were made for this evaluation by an economist experienced in data collection for Federal flood damage studies. Each “Other” structure (such as a garage, barn, shed, recreation pavilion, etc.) was estimated at $5,000.

Table 4: Damaged Property by Reach for 20%PMF

Structures		Residential	Commercial	Public	Other
Reach 1	Failure	373	22	4	50
	Without Failure	208	7	0	14
Reach 2	Failure	122	29	6	20
	Without Failure	19	9	0	2
Reach 3	Failure	2,998	75	38	206
	Without Failure	2,930	75	37	189
Subtotal	Failure	3,493	126	48	276
	Without Failure	3,157	91	37	205
Increment		336	35	11	71

Table 5: Damaged Property by Reach for 100%PMF

Structures		Residential	Commercial	Public	Other
Reach 1	Failure	538	44	19	67
	Without Failure	331	16	3	22
Reach 2	Failure	199	30	9	31
	Without Failure	102	19	6	16
Reach 3	Failure	3045	75	38	219
	Without Failure	3013	75	38	215
Subtotal	Failure	3,782	149	66	317
	Without Failure	3,446	110	47	253
Increment		336	39	19	64

6.1.2 Contents

Residential contents were assumed to be 40 percent of structure value. Commercial and public contents were assumed to be 60 percent of structure value. These ratios represent a composite average of values used by the Little Rock District in other flood damage evaluations. With adequate flood warning and no other complications, residents and businesses would have time to move some of their high investment, highly damageable property to flood-free locations. Using the estimates of warning times and understanding of flood severity, (as described in section 9.1.5) it was assumed that people in Reach 2 and Reach 3 would salvage 25% of total contents.

6.1.3 Agriculture

The inundated area was also overlaid on Census block and NRCS land-use-land-cover data in an ArcGIS format. Using an Xtools extension tool, inundated acreage was calculated for row crops and pastureland. Historic acreage and yield data for Butler County and Wayne County were obtained from National Agricultural Statistics Service for the last 10 years. The inundated acreage was then allocated among crops by historic cropping patterns. Crop acreage was multiplied by an average historic yield and normalized prices to calculate total crop damages. No adjustments were made to account for growing season, loss of topsoil, or damage to capital equipment. Damage by crop is provided in Table 6.

6.1.4 Roads and Utilities

The inundated area was overlaid on road data in an ArcGIS format. Using an ArcGIS tool, miles of inundated road were calculated. Road damage was based on damages experienced in Galveston and Harris Counties (Galveston District) in July 1979. Values of $6,000 per mile of 2-lane highway and $1,000 per mile of county road were indexed to current price levels with CWCCIS “Roads, Railroads, & Bridges” index (EM 1110-2-1304, Revised 30 Sep 03, FY78 to FY03). Summaries of road damage are provided in Table 7 and Table 8.

Table 6: Agricultural Damages

	20% PMF With Failure	20% PMF Without Failure	100% PMF With Failure	100% PMF Without Failure
Total Acreage	33116	32321	33573	33464
Non-Hay Acreage	29843	29703	30155	30152
Corn Acreage	2,119	2,109	2,141	2,141
Yield	125.8	125.8	125.8	125.8
Total Production	266,552	265,301	269,338	269,312
Price	2.16	2.16	2.16	2.16
Corn Damage	$575,752	$573,051	$581,771	$581,713
Rice Acreage	9,013	8,970	9,107	9,106
Yield	5484	5484	5484	5484
Total Production	494,250	491,932	499,417	499,368
Price	7.8	7.8	7.8	7.8
Rice Damage	$3,855,152	$3,837,066	$3,895,456	$3,895,069
Soybean Acreage	15,727	15,653	15,892	15,890
Yield	32	32	32	32
Total Production	503,272	500,911	508,534	508,483
Price	5.65	5.65	5.65	5.65
Soybean Damage	$2,843,489	$2,830,149	$2,873,217	$2,872,931
Wheat Acreage	2,984	2,970	3,016	3,015
Yield	44.21	44.21	44.21	44.21
Total Production	131,936	131,317	133,315	133,302
Price	2.72	2.72	2.72	2.72
Wheat Damage	$358,866	$357,182	$362,617	$362,581
Hay	3273	2618	3418	3312
Yield	1.88	1.88	1.88	1.88
Total Production	6,153	4,922	6,426	6,227
Price	75.5	75.5	75.5	75.5
Hay Damage	$464,570	$371,599	$485,151	$470,105
Total Damage	$7,633,258	$7,597,449	$7,713,061	$7,712,294

Table 7: Road Damage for 20% PMF ($1,000's)

	Miles	Damage per Mile	Total Damage
With Failure			
Improved Highway	30.68	13,546	$416
County Roads	129.46	2,258	$292
Total Damage With Failure	160.14		$708
Without Failure			
Improved Highway	24.82	13,546	$336
County Roads	106.31	2,258	$240
Total Damage With Failure	131.13		$576
Increment	29.01		$132

Table 8: Road Damage for 100% PMF ($1,000's)

	Miles	Damage per Mile	Total Damage
With Failure			
Improved Highway	33.80	13,546	$458
County Roads	135.14	2,258	$305
Total Damage With Failure	168.94		$763
Without Failure			
Improved Highway	31.14	13,546	$422
County Roads	129.79	2,258	$293
Total Damage With Failure	160.93		$715
Increment	8.01		$48

Utility damage per-structure estimate was based on damages experienced in Galveston. Utility damage information was obtained after the July 1979 storm from city and county governments and the various utility companies servicing the area. Utility damage values were estimated at $77 per residential, commercial, and public structure. Amounts were indexed to current levels with CWCCIS "Relocations" index (EM 1110-2-1304, Revised 30 Sep 03, FY78 to FY03).

6.1.5 Distress Costs

Clearwater Dam has a history of seepage through the left abutment ridge dating from initial impoundment in 1948. Recent developments expanded the concern for the dam's safety to include the "entire dam" length. Past seepage-related costs included installation of 73 piezometers, a grout curtain, and two underdrainage systems. The current sinkhole investigation and potential grout curtain were estimated to cost $1.5 million. Under distress, seepage-related expenditures were estimated to range from $500,000 for a slope failure to $2.5 million for multiple sinkhole repairs.

6.1.6 Dam Replacement

According to ER 1105-2-100, Section X – Major Rehabilitation Studies, "Should the project benefit stream be interrupted due to unsatisfactory feature performance, it is assumed that emergency funds will be available to fix the feature." The regulation also states, "The timing, frequency, and consequences of system disruption are all unknown and must be estimated." Two pieces of information were used to estimate dam replacement cost. Clearwater Dam was originally constructed for $11.4 million (1983$). Construction costs were indexed to current replacement cost with CWCCIS "Dams" index (EM 1110-2-1304, Revised 30 Sep 03, FY83 to FY03). In addition, a replacement dam would include a concrete seepage cutoff wall. The cost of Measure S-4D was used to estimate construction cost of a concrete seepage cutoff wall. Total replacement construction time was estimated at four years.

6.2 Property Losses With and Without Dam Failure

One of the greatest concerns arising from the structural integrity problems of the dam is the certain catastrophic flood damage caused by a dam failure. A seepage induced dam breach can be expected to result in an increase in flood heights throughout the downstream reaches. The failure versus without failure increase in flood heights varies significantly depending on the antecedent flood event and downstream distance from the dam. Technical details of the hydrologic and hydraulic analyses associated with the seepage failure analysis are contained in Appendix C – Hydrologic and Hydraulic Analyses.

6.2.1 Complete Damage

For this analysis, economic losses were based on total value of structures, contents. Actual damages would be dependent upon a depth-damage relationship. In a dam breach situation, the intensity of flows and the rate of rise in floodwater would likely result in complete loss of any structure within the path of floodwater. The top of the conservation pool is 500. The top of the flood pool is 567. For failure condition, damages begin at elevations greater than 495. The peak pool elevation for the 20% PMF event is 581.4. For without-failure condition, damages begin at elevations greater than 523. The peak pool elevation for the 100% event is 611.2.

6.2.2 20% Probable Maximum Flood (PMF) Event

Failure versus without failure increase in flood heights varies significantly depending on the antecedent flood event and downstream distance from the dam. Failure versus without failure increases in flood heights for the 20% PMF ranged from about 26 feet in the vicinity of the dam to about 5 feet in the vicinity of Poplar Bluff. Property damages for the 20% PMF event are shown in Table 9. Agricultural, road, and utility damages are shown in Table 10. Total damages for the 20% PMF are shown in Table 11.

Table 9: Property Damages by Reach for 20%PMF

Damage ($1,000s)		Residential	Commercial	Public	Other
Reach 1	Failure	$10,854	$4,636	$247	$100
	Without Failure	$6,714	$4,198	$0	$28
Reach 2	Failure	$4,667	$1,555	$392	$40
	Without Failure	$428	$115	$0	$4
Reach 3	Failure	$125,794	$6,482	$19,445	$412
	Without Failure	$125,794	$6,482	$19,349	$378
Subtotal	Failure	$141,315	$12,673	$20,084	$552
	Without Failure	$132,936	$10,795	$19,349	$410
Incremental Damage		$8,379	$1,878	$735	$142

Table 10: Other Damages for 20%PMF

Units	Agricultural (Acres)	Road (Miles)	Utility (Structures)
Failure	33,116	160.14	3,667
Without Failure	32,321	131.13	3,285
Incremental Damage	795	29.01	382

Damage ($1,000s)	Agricultural	Road	Utility
Failure	$7,633	$708	$637
Without Failure	$7,597	$576	$571
Incremental Damage	$36	$132	$66

Table 11: Total Flood Damages by Reach ($1,000's)

Reach 1	Failure	$15,837
	Without Failure	$10,940
Reach 2	Failure	$6,654
	Without Failure	$547
Reach 3	Failure	$152,133
	Without Failure	$152,003
Subtotal	Failure	$183,602
	Without Failure	$172,234
Incremental Damage		$11,368

6.2.3 100% Probable Maximum Flood (PMF) Event

Failure versus without failure increase in flood heights varies significantly depending on the antecedent flood event and downstream distance from the dam. Failure versus without failure increases in flood heights for the 100% PMF ranged from about 15 feet in the vicinity of the dam to less than one foot in the vicinity of Poplar Bluff. Property damages for the 100% PMF events are shown in Table 12. Agricultural, road, and utility damages are shown in Table 13. Total damages for the 20% PMF are shown in Table 14.

Table 12: Property Damages by Reach for 100%PMF (cont.)

Damage ($1,000s)		Residential	Commercial	Public	Other
Reach 1	Failure	$16,661	$5,994	$1,758	$134
	Without Failure	$9,654	$3,076	$188	$90
Reach 2	Failure	$8,126	$1,567	$916	$62
	Without Failure	$2,677	$738	$392	$32
Reach 3	Failure	$129,123	$6,482	$19,499	$438
	Without Failure	$129,123	$6,482	$19,445	$430
Subtotal	Failure	$153,910	$14,043	$22,173	$634
	Without Failure	$139,316	$10,296	$20,025	$552
Incremental Damage		$14,594	$3,747	$2,148	$82

Table 13: Other Damages for 100%PMF

Units	Agricultural (Acres)	Road (Miles)	Utility (Structures)
Failure	33,573	169	3,997
Without Failure	33,464	161	3,603
Incremental Damage	109	8	394

Damage ($1,000s)	Agricultural	Road	Utility
Failure	$7,713	$763	$695
Without Failure	$7,712	$715	$626
Incremental Damage	$1	$48	$69

Table 14: Total Flood Damages by Reach ($1,000's)

Reach 1	Failure	$24,548
	Without Failure	$13,008
Reach 2	Failure	$10,671
	Without Failure	$3,839
Reach 3	Failure	$155,541
	Without Failure	$155,479
Subtotal	Failure	$199,931
	Without Failure	$181,380
Incremental Damage		$18,551

6.3 Traffic Delay

Under construction of Measure S-4D, Missouri Highway HH would close for 1,000 days. This highway is the only road approaching the dam. In 2002, average traffic estimates just east and west of the dam ranged from 950 to 3150 vehicles per day. This traffic would detour to other highways in the area. IWR Report 91-R-12 was used to estimate the value of time delay.

6.3.1 Calculation of Median Family Income

Clearwater Dam lies just inside the western boundary of Wayne County. Missouri Highway HH continues west into Reynolds County. Median Family Income for both counties was obtained from 2000 Census data. The average median family income equals $30,115. Given 8 working hours per day and 260 working days per year, the average median hourly family income equals $14.48.

6.3.2 Determination of Average Number of Vehicles by Day and Purpose

. In 2002, average traffic estimates just east and west of the dam ranged from 950 to 3150 vehicles per day. This traffic would detour to other highways in the area. Traffic was estimated with a triangular distribution (1000,2000,3000). Percentage of work traffic (W) was estimated with a triangular distribution (60, 65, 70). Percentage of social/recreation (R) traffic was estimated with a triangular distribution (10, 12.5, 15). Percentage of other traffic (O) was estimated as 100 – W – R.

6.3.3 Calculation of Time Delay

Three scenarios were considered as representative detour routes. The shortest route from Ellington, MO to Piedmont, MO goes across Highway HH. The detour delay, using Rand McNally Trip Maker software and Rand McNally Internet source, equaled 8 miles and 13 minutes. The delay from a residence along Route A to the Wal-Mart store in Piedmont, MO equaled 12.5 miles and 20 minutes. The delay for a USACE Clearwater Project Office employee equaled 14.2 miles and 23 minutes. The minutes of delay (M) were estimated with a triangular distribution (15, 20, 25).

6.3.4 Calculation of the Dollar Value of Delay by Trip Purpose

IWR Report 91-R-12 lists “Value of time saved adjusted to hourly basis % of hourly family income of driver.” For high time delays over 15 minutes, work trips were valued at 53.8% of the median hourly family income. Social/Recreation trips were valued at 60%; other trips were valued at 64.5%. For each hour of delay, work traffic was valued at $7.79. Social/Recreation traffic was valued at $8.69; other traffic was valued at $9.34.

6.3.5 Calculation of Value of Time Delay

The following formula was used to calculate the total value of time delay.

$$\text{Days of Delay} \times \#\text{Vehicles per day} \times [\,\$7.79W + \$8.69R + \$9.34O\,] \times [\,M \div 60\,]$$

6.4 Risk-Based Model

6.4.1 Probabilistic Analysis

A probabilistic, risked based approach, using event trees, life cycle analyses, and Monte Carlo simulation to model the expected reliability of the dam and costs of consequences was employed in this evaluation. Monte Carlo simulation combined the probabilities of occurrence of pool stages, emergency action, and dam failure presented in the event trees with the consequences of various occurrences over a 50-year period of analysis. The expected costs resulting from these analyses of the current condition and operation of the dam was compared to the expected costs with rehabilitation of the dam.

One of the primary reasons for developing event trees is to aid in computing the probabilities of the combined outcomes of events represented by the branches of the tree. An example of the probability computations performed for expected costs of consequences of the base condition with a pool elevation 554 is as follows:

Probability of Pool Elevation	x	Probability of Emergency Action	x	Probability of Failure	
0.0505	x	1.0	x	0.6 =	.0303

6.4.2 Event Trees

Eleven conditions were evaluated for this report: the base condition and the 10 alternatives listed in section 5.2. The initiating event of the Clearwater event trees is the probability, or likelihood, of the pool reaching certain elevations under current and repaired conditions. These are based on historical data of annual peak pool elevations of the reservoir for the period of record, 1940 to 1992. The pool elevations are recorded on a daily basis. Plate C-1 in the Hydrologic and Hydraulic Appendix plots the percent of time that elevations are equaled or exceeded. The data was converted to a cumulative distribution function, which was converted to incremental probabilities by subtracting to obtain the difference in probabilities of selected pool elevations. These incremental probabilities of the pool being within a certain elevation range were then used in the event trees.

A panel of technical experts estimated probabilities of emergency action at the dam at various pool stages and then probabilities of failure of the dam, given the stage. Each expert was asked to provide estimated probability factors considering that emergency action may be required at the project for five separate lake levels. The process was continued for each of the remediation measures for the possible remaining life of the dam. Additionally, the experts were asked to provide estimated probabilities for failure of the dam given the existence of distress and emergency action. After receiving these estimates, it was evident that the estimates were a combination of risk and uncertainty. In an effort to distinguish the level of risk, a follow-up discussion was held with each expert. The follow-up discussion encouraged the experts to express their probability estimates with descriptive phrases from "A Practical Guide on Conducting Expert-Opinion Elicitation of Probabilities and Consequences for Corps Facilities," (IWR Report 01-R-01). The responses were recorded, and for each category, the median value was determined. This median value represents the probabilities of emergency action and failure given distress that are used in the event trees, life cycle analyses, and Monte Carlo simulations.

The panel of experts outlined the tasks and definitions of the survey. It was assumed that the currently planned sinkhole grouting program would have been successfully completed prior to construction of any of the proposed measures. The experts were asked to exclusively utilize his engineering and geological judgment of the existing and proposed site conditions based on knowledge and history of the project. The experts were cautioned against the influence of outside economic or political considerations. Emergency action probability was defined as the probability that some kind of distress, which would require emergency action, could occur. Situations of distress are those that would necessitate emergency action because of concern for the stability of the dam, as described in earlier sections. Corps of Engineer actions in response to distress include frequent piezometer readings, mobilizing a survey crew, Dam Safety personnel on site, daily reports to state and local Emergency Management officials, public relations, 24-hour surveillance of the dam, and stockpiling materials for dam stabilization. Every situation of distress would not expected to result in failure of the dam. The probabilities for emergency action and failure given distress are given in Tables 15 to 25. Event trees for the eleven conditions are located on Plates 13 to 23.

Table 15: Existing Site Condition

	EMERGENCY ACTION				
NAME	LAKE ELEV. <500	LAKE ELEV. 500-525	LAKE ELEV. 525-550	LAKE ELEV. 550-575	LAKE ELEV. >575
POULOS	1	1	1	1	1
ARNOLD	1	1	1	1	1
JORDAN	1	1	1	1	1
HARRIS	1	1	1	1	1
HARTUNG	1	1	1	1	1
VAN CLEAVE	1	1	1	1	1
WEBB	1	1	1	1	1
MEDIAN	**1**	**1**	**1**	**1**	**1**

	FAILURE				
NAME	LAKE ELEV. <500	LAKE ELEV. 500-525	LAKE ELEV. 525-550	LAKE ELEV. 550-575	LAKE ELEV. >575
POULOS	0.16	0.33	0.7	0.8	0.9
ARNOLD	0.25	0.49	0.6	0.6	0.6
JORDAN	0.1	0.16	0.33	0.49	0.5
HARRIS	0.05	0.16	0.49	0.5	0.7
HARTUNG	0.1	0.1	0.16	0.25	0.49
VAN CLEAVE	0.33	0.49	0.49	0.7	0.8
WEBB	0.1	0.1	0.49	0.7	0.9
MEDIAN	**0.10**	**0.16**	**0.49**	**0.60**	**0.70**

Table 16: S1 - Extend the Impervious Fill Blanket

	EMERGENCY ACTION				
NAME	LAKE ELEV. <500	LAKE ELEV. 500-525	LAKE ELEV. 525-550	LAKE ELEV. 550-575	LAKE ELEV. >575
POULOS	0.9	0.9	0.9	0.9	0.9
ARNOLD	0.9	0.9	0.9	0.9	0.9
JORDAN	0.9	0.9	0.9	0.9	0.9
HARRIS	0.05	0.05	0.33	0.5	0.8
HARTUNG	0.1	0.1	0.16	0.25	0.49
VAN CLEAVE	0.6	0.7	0.7	0.8	0.8
WEBB	0.1	0.16	0.6	0.8	0.9
MEDIAN	**0.60**	**0.70**	**0.70**	**0.80**	**0.90**

	FAILURE				
NAME	LAKE ELEV. <500	LAKE ELEV. 500-525	LAKE ELEV. 525-550	LAKE ELEV. 550-575	LAKE ELEV. >575
POULOS	0.16	0.33	0.7	0.8	0.9
ARNOLD	0.25	0.49	0.6	0.6	0.6
JORDAN	0.1	0.16	0.33	0.49	0.5
HARRIS	0.05	0.1	0.25	0.49	0.5
HARTUNG	0.1	0.1	0.16	0.25	0.49
VAN CLEAVE	0.33	0.49	0.49	0.6	0.8
WEBB	0.1	0.1	0.49	0.7	0.9
MEDIAN	**0.10**	**0.16**	**0.49**	**0.60**	**0.60**

Table 17: S2-A - Slurry Cutoff Wall To Rock Located 500 ft Upstream of Existing Dam Toe Without Extension of Impervious Blanket

	EMERGENCY ACTION				
NAME	LAKE ELEV. <500	LAKE ELEV. 500-525	LAKE ELEV. 525-550	LAKE ELEV. 550-575	LAKE ELEV. >575
POULOS	0.25	0.49	0.5	0.8	0.9
ARNOLD	0.33	0.33	0.33	0.33	0.7
JORDAN	0.49	0.49	0.5	0.6	0.9
HARRIS	0.05	0.1	0.49	0.7	0.9
HARTUNG	0.9	0.9	0.9	0.9	0.9
VAN CLEAVE	0.33	0.33	0.49	0.6	0.9
WEBB	0.1	0.16	0.25	0.7	0.9
MEDIAN	**0.33**	**0.33**	**0.49**	**0.70**	**0.90**

	FAILURE				
NAME	LAKE ELEV. <500	LAKE ELEV. 500-525	LAKE ELEV. 525-550	LAKE ELEV. 550-575	LAKE ELEV. >575
POULOS	0.25	0.49	0.8	0.9	0.9
ARNOLD	0.8	0.8	0.9	0.9	0.9
JORDAN	0.1	0.16	0.33	0.49	0.5
HARRIS	0.05	0.05	0.25	0.49	0.7
HARTUNG	0.1	0.1	0.16	0.25	0.49
VAN CLEAVE	0.33	0.49	0.49	0.6	0.8
WEBB	0.1	0.1	0.49	0.7	0.9
MEDIAN	**0.10**	**0.16**	**0.49**	**0.60**	**0.80**

Table 18: S2-B - Slurry Cutoff Wall To Rock Located 500 ft Upstream of Existing Dam Toe With Extension of Impervious Blanket

	EMERGENCY ACTION				
NAME	LAKE ELEV. <500	LAKE ELEV. 500-525	LAKE ELEV. 525-550	LAKE ELEV. 550-575	LAKE ELEV. >575
POULOS	0.25	0.49	0.5	0.8	0.8
ARNOLD	0.33	0.33	0.33	0.33	0.33
JORDAN	0.16	0.16	0.33	0.5	0.6
HARRIS	0.05	0.1	0.49	0.7	0.9
HARTUNG	0.1	0.1	0.16	0.25	0.49
VAN CLEAVE	0.33	0.33	0.49	0.6	0.8
WEBB	0.1	0.16	0.25	0.5	0.7
MEDIAN	**0.16**	**0.16**	**0.33**	**0.50**	**0.70**

	FAILURE				
NAME	LAKE ELEV. <500	LAKE ELEV. 500-525	LAKE ELEV. 525-550	LAKE ELEV. 550-575	LAKE ELEV. >575
POULOS	0.25	0.49	0.8	0.8	0.9
ARNOLD	0.33	0.49	0.5	0.6	0.7
JORDAN	0.1	0.16	0.33	0.49	0.5
HARRIS	0.05	0.05	0.16	0.49	0.5
HARTUNG	0.1	0.1	0.16	0.25	0.49
VAN CLEAVE	0.33	0.49	0.49	0.6	0.8
WEBB	0.1	0.1	0.49	0.7	0.9
MEDIAN	**0.10**	**0.16**	**0.49**	**0.60**	**0.70**

Table 19: S2-C - Slurry Cutoff Wall To Rock Located at Existing Upstream Embankment Toe of Dam With Extension of Impervious Blanket

EMERGENCY ACTION					
NAME	LAKE ELEV. <500	LAKE ELEV. 500-525	LAKE ELEV. 525-550	LAKE ELEV. 550-575	LAKE ELEV. >575
POULOS	0.33	0.49	0.5	0.8	0.8
ARNOLD	0.33	0.33	0.33	0.33	0.33
JORDAN	0.1	0.16	0.33	0.5	0.6
HARRIS	0.05	0.1	0.49	0.7	0.9
HARTUNG	0.1	0.1	0.16	0.25	0.49
VAN CLEAVE	0.33	0.33	0.49	0.6	0.8
WEBB	0.1	0.1	0.16	0.5	0.7
MEDIAN	0.10	0.16	0.33	0.50	0.70

FAILURE					
NAME	LAKE ELEV. <500	LAKE ELEV. 500-525	LAKE ELEV. 525-550	LAKE ELEV. 550-575	LAKE ELEV. >575
POULOS	0.25	0.49	0.8	0.8	0.9
ARNOLD	0.33	0.5	0.5	0.6	0.7
JORDAN	0.1	0.16	0.33	0.49	0.5
HARRIS	0.05	0.05	0.16	0.49	0.5
HARTUNG	0.1	0.1	0.16	0.25	0.49
VAN CLEAVE	0.33	0.49	0.49	0.6	0.8
WEBB	0.1	0.1	0.49	0.7	0.9
MEDIAN	0.10	0.16	0.49	0.60	0.70

Table 20: S3 - Slurry Cutoff Wall To Rock Located 500 ft Upstream of Existing Dam Toe Including Deep Panels into Rock With Extension of Impervious Blanket

EMERGENCY ACTION					
NAME	LAKE ELEV. <500	LAKE ELEV. 500-525	LAKE ELEV. 525-550	LAKE ELEV. 550-575	LAKE ELEV. >575
POULOS	0.5	0.5	0.6	0.7	0.7
ARNOLD	0.16	0.16	0.16	0.25	0.25
JORDAN	0.05	0.1	0.16	0.5	0.6
HARRIS	0.05	0.1	0.49	0.7	0.9
HARTUNG	0.1	0.1	0.16	0.25	0.49
VAN CLEAVE	0.33	0.3	0.49	0.5	0.7
WEBB	0.1	0.1	0.16	0.7	0.9
MEDIAN	0.10	0.10	0.16	0.50	0.70

FAILURE					
NAME	LAKE ELEV. <500	LAKE ELEV. 500-525	LAKE ELEV. 525-550	LAKE ELEV. 550-575	LAKE ELEV. >575
POULOS	0.49	0.49	0.7	0.8	0.8
ARNOLD	0.33	0.33	0.5	0.6	0.7
JORDAN	0.1	0.16	0.33	0.49	0.5
HARRIS	0.05	0.05	0.16	0.49	0.7
HARTUNG	0.1	0.1	0.16	0.25	0.49
VAN CLEAVE	0.33	0.49	0.49	0.6	0.8
WEBB	0.1	0.1	0.49	0.7	0.9
MEDIAN	0.10	0.16	0.49	0.60	0.70

Table 21: S4-A - Concrete Cutoff Wall To Rock Located at Existing Upstream Embankment Toe of Dam With Extension of Impervious Blanket

EMERGENCY ACTION					
NAME	LAKE ELEV. <500	LAKE ELEV. 500-525	LAKE ELEV. 525-550	LAKE ELEV. 550-575	LAKE ELEV. >575
POULOS	0.33	0.49	0.5	0.8	0.8
ARNOLD	0.33	0.33	0.33	0.33	0.33
JORDAN	0.1	0.16	0.33	0.5	0.6
HARRIS	0.05	0.1	0.49	0.7	0.9
HARTUNG	0.1	0.1	0.16	0.25	0.49
VAN CLEAVE	0.49	0.5	0.6	0.7	0.8
WEBB	0.1	0.1	0.16	0.5	0.7
MEDIAN	0.10	0.16	0.33	0.50	0.70

FAILURE					
NAME	LAKE ELEV. <500	LAKE ELEV. 500-525	LAKE ELEV. 525-550	LAKE ELEV. 550-575	LAKE ELEV. >575
POULOS	0.25	0.49	0.8	0.8	0.9
ARNOLD	0.33	0.5	0.5	0.6	0.7
JORDAN	0.1	0.16	0.33	0.49	0.5
HARRIS	0.05	0.05	0.16	0.49	0.5
HARTUNG	0.1	0.1	0.16	0.25	0.49
VAN CLEAVE	0.33	0.49	0.49	0.6	0.8
WEBB	0.1	0.1	0.49	0.7	0.9
MEDIAN	0.10	0.16	0.49	0.60	0.70

Table 22: S4-B - Concrete Cutoff Wall Into Rock Located at Existing Upstream Embankment Toe of Dam With Extension of Impervious Blanket

EMERGENCY ACTION					
NAME	LAKE ELEV. <500	LAKE ELEV. 500-525	LAKE ELEV. 525-550	LAKE ELEV. 550-575	LAKE ELEV. >575
POULOS	0.05	0.25	0.5	0.8	0.8
ARNOLD	0.1	0.16	0.16	0.16	0.16
JORDAN	0.05	0.1	0.16	0.5	0.6
HARRIS	0.05	0.05	0.16	0.49	0.5
HARTUNG	0.1	0.1	0.1	0.25	0.49
VAN CLEAVE	0.33	0.33	0.33	0.49	0.7
WEBB	0.1	0.1	0.16	0.5	0.8
MEDIAN	0.10	0.10	0.16	0.49	0.60

FAILURE					
NAME	LAKE ELEV. <500	LAKE ELEV. 500-525	LAKE ELEV. 525-550	LAKE ELEV. 550-575	LAKE ELEV. >575
POULOS	0.16	0.33	0.5	0.8	0.9
ARNOLD	0.33	0.49	0.5	0.6	0.7
JORDAN	0.1	0.16	0.33	0.49	0.5
HARRIS	0.05	0.05	0.16	0.25	0.49
HARTUNG	0.1	0.1	0.1	0.25	0.49
VAN CLEAVE	0.33	0.49	0.49	0.6	0.8
WEBB	0.1	0.1	0.49	0.7	0.9
MEDIAN	0.10	0.16	0.49	0.60	0.70

Table 23: S4-C - Concrete Cutoff Wall Into Rock Located Through the Dam and Through the Centerline of the Clay Core Trench With Extension of Impervious Blanket

EMERGENCY ACTION					
NAME	LAKE ELEV. <500	LAKE ELEV. 500-525	LAKE ELEV. 525-550	LAKE ELEV. 550-575	LAKE ELEV. >575
POULOS	0.05	0.05	0.1	0.1	0.1
ARNOLD	0.16	0.16	0.16	0.16	0.16
JORDAN	0.1	0.1	0.1	0.25	0.49
HARRIS	0.05	0.05	0.05	0.33	0.5
HARTUNG	0.05	0.05	0.1	0.16	0.25
VAN CLEAVE	0.16	0.16	0.16	0.33	0.49
WEBB	0.1	0.1	0.16	0.7	0.9
MEDIAN	0.10	0.10	0.10	0.25	0.49

FAILURE					
NAME	LAKE ELEV. <500	LAKE ELEV. 500-525	LAKE ELEV. 525-550	LAKE ELEV. 550-575	LAKE ELEV. >575
POULOS	0.05	0.05	0.05	0.05	0.1
ARNOLD	0.1	0.1	0.1	0.1	0.9
JORDAN	0.1	0.16	0.33	0.49	0.5
HARRIS	0.05	0.05	0.05	0.1	0.33
HARTUNG	0.05	0.05	0.1	0.16	0.25
VAN CLEAVE	0.33	0.49	0.49	0.6	0.8
WEBB	0.1	0.1	0.1	0.5	0.9
MEDIAN	0.10	0.10	0.10	0.16	0.50

Table 24: S4-D - Concrete Cutoff Wall Into Rock Located Through the Centerline of the Dam Alignment

EMERGENCY ACTION					
NAME	LAKE ELEV. <500	LAKE ELEV. 500-525	LAKE ELEV. 525-550	LAKE ELEV. 550-575	LAKE ELEV. >575
POULOS	0.05	0.05	0.1	0.1	0.1
ARNOLD	0.16	0.16	0.16	0.16	0.16
JORDAN	0.05	0.05	0.05	0.16	0.25
HARRIS	0.05	0.05	0.05	0.16	0.6
HARTUNG	0.05	0.1	0.1	0.16	0.25
VAN CLEAVE	0.16	0.16	0.16	0.16	0.16
WEBB	0.1	0.1	0.1	0.33	0.6
MEDIAN	0.05	0.05	0.10	0.16	0.25

FAILURE					
NAME	LAKE ELEV. <500	LAKE ELEV. 500-525	LAKE ELEV. 525-550	LAKE ELEV. 550-575	LAKE ELEV. >575
POULOS	0.05	0.05	0.05	0.05	0.1
ARNOLD	0.05	0.05	0.05	0.05	0.05
JORDAN	0.1	0.16	0.33	0.49	0.5
HARRIS	0.05	0.05	0.05	0.1	0.16
HARTUNG	0.05	0.05	0.1	0.16	0.25
VAN CLEAVE	0.33	0.33	0.33	0.49	0.5
WEBB	0.1	0.1	0.1	0.16	0.25
MEDIAN	0.05	0.05	0.10	0.16	0.25

Table 25: S4-E - Concrete Cutoff Wall Into Rock Located Through the Dam and Through the Centerline of the Clay Core Trench from the Sinkhole to the End of the Left Abutment with the Extension of the Impervious Blanket

EMERGENCY ACTION					
NAME	LAKE ELEV. <500	LAKE ELEV. 500-525	LAKE ELEV. 525-550	LAKE ELEV. 550-575	LAKE ELEV. >575
POULOS	0.9	0.9	0.9	0.9	0.9
ARNOLD	0.16	0.16	0.16	0.16	0.16
JORDAN	0.16	0.25	0.49	0.5	0.8
HARRIS	0.05	0.05	0.16	0.49	0.6
HARTUNG	0.1	0.1	0.16	0.25	0.49
VAN CLEAVE	0.5	0.6	0.7	0.8	0.8
WEBB	0.1	0.1	0.16	0.6	0.9
MEDIAN	**0.16**	**0.16**	**0.16**	**0.50**	**0.80**

FAILURE					
NAME	LAKE ELEV. <500	LAKE ELEV. 500-525	LAKE ELEV. 525-550	LAKE ELEV. 550-575	LAKE ELEV. >575
POULOS	0.16	0.33	0.7	0.8	0.9
ARNOLD	0.25	0.49	0.6	0.6	0.6
JORDAN	0.1	0.16	0.33	0.49	0.5
HARRIS	0.05	0.05	0.1	0.33	0.49
HARTUNG	0.1	0.1	0.16	0.25	0.49
VAN CLEAVE	0.33	0.49	0.49	0.6	0.8
WEBB	0.1	0.1	0.1	0.5	0.9
MEDIAN	**0.10**	**0.16**	**0.33**	**0.50**	**0.60**

6.4.3 Life Cycle Analysis

The consequences of events are related to their probabilities of occurrence in the life cycle analysis. A spreadsheet-type life cycle analysis that calculates the expected costs of distress, emergency action, and failure of the dam was used for this evaluation. The consequences include distress repair costs, flood damage of the downstream area, foregone recreation benefits, and rebuilding costs. The present value of costs were computed using the appropriate present worth factor for the year of occurrence in the life cycle, and a discount rate of 5.625%. These were then summed to get the cumulative present value. The cumulative present value was converted into an average annual equivalent cost using the discount rate of 5.625% and a 50-year economic life.

6.4.4 Monte Carlo Sampling

Monte Carlo sampling, an entirely random sampling technique, was performed for values of pool elevation (based on cumulative distribution of peak pool elevations), the occurrence of distress (given its probability based on pool elevation), the occurrence of failure (given its probability based on pool elevation), annual recreation value (based on uniform distribution of recreation benefit), dam repair cost (based on uniform distribution of costs discussed in section 6.1.5), and dam replacement cost (based on uniform distribution of cost discussed in section 6.1.6).

For the base condition, for each year, a pool elevation was drawn from the cumulative distribution function of past H&H data. That elevation was held constant across all conditions for each year. Given a pool elevation, the model assigned the median expert-elicited probability of emergency action for each condition. The model then performed a binary trial based on the assigned probability. If the result of the binary trial in a condition equaled “1,” then the model calculated “distress repair” costs and assigned the median expert-elicited probability of failure for that elevation and condition. The model then performed a second binary trial, based on the failure probability. If the result of the failure binary trial equaled “1,” then flood damages for that year’s pool elevation were calculated.

Flood damages for each pool elevation were interpolated from straight-line damage curves. For all conditions, without failure damages were interpolated from two segments: for pool elevations less than 581.5, damages were based on the equation of the line that includes the points (523, $0) and (581.5, $172,234,278). For pool elevations greater than 581.5, damages were based on the equation of the line that includes the points (581.5, $172,234,278) and (611, 181,379,762). For all conditions, with failure damages were interpolated from two segments: for pool elevations less than 581.5, damages were based on the equation of the line that includes the points (497, $0) and (581.5, $183,602,146). For pool elevations greater than 581.5, damages were based on the equation of the line that includes the points (581.5, 183,602,146) and (611, 199,930,667).

If the dam did not fail in the first year, then a pool elevation was drawn from the cumulative distribution function for year 2. The process continues in each condition until the dam fails.

Assumptions in the life cycle spreadsheets and Monte Carlo simulations include the following:

1. Flood outlines provided by hydrology and economic housing data based on 20 ft contour data.
2. Probability of distress for base condition = 1; Clearwater Dam currently meets the definition of distress.
3. Probability of distress for remediated conditions based on expert judgment. Table of probabilities provided.
4. Probability of failure given distress for base and remediated conditions based on expert judgment. Table of probabilities provided.
5. The dam will be repaired following a failure.
6. For 4 years after a dam failure, flood damage benefits foregone are 0% due to rebuilding time.
7. During the year of a dam failure, benefits foregone are limited to recreation benefits.
8. If a failure occurs during Monte Carlo simulation, there will not be another failure following repair of the dam for the remainder of the period of analysis.
9. There cannot be failure and non-failure consequences in the same year.
10. A temporary repair before rehabilitation does not improve the probability of failure of the dam.
11. There is no probability of failure of the dam during the construction period of the rehabilitation.

7.0 EVALUATION OF ALTERNATIVES

Alternatives were evaluated by comparing the expected total loss to the base condition’s expected total loss. The net change was calculated as “Net Benefit” then amortized over a 50-year period at 5 5/8%. Net benefits and benefit-to-cost ratios are provided in Table 26.

Table 26: Evaluation of Alternatives ($1,000s)

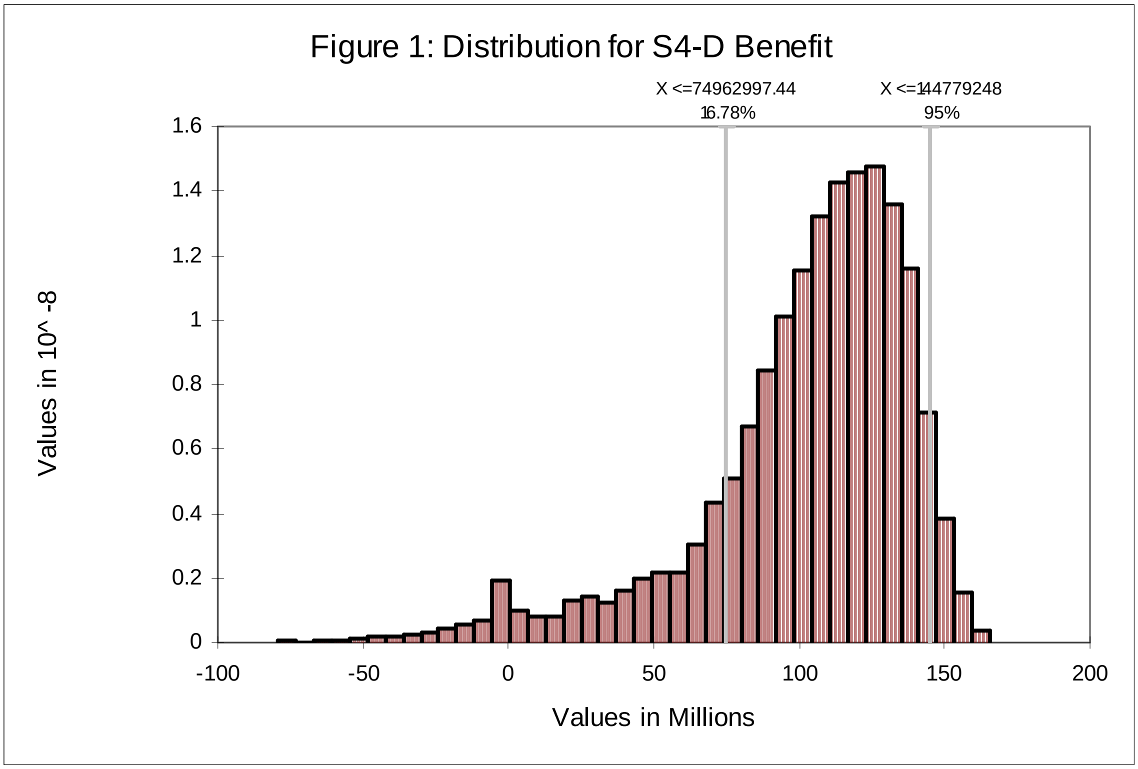
	S1	S2A	S2B	S2C	S3	S4A	S4B	S4C	S4D	S4E
Subtotal Construction	5,958	2,244	8,198	8,738	14,340	22,282	59,553	59,058	56,480	51,682
PED/EDC	357	135	820	699	1,728	1,114	1,191	1,181	1,130	1,034
S&A	596	337	984	1,049	1,728	2,674	4,466	4,429	4,236	3,876
First Cost	8,467	3,854	12,258	12,856	21,892	31,955	73,057	71,948	68,812	57,963
Interest During Construction	276	44	547	636	1,190	2,211	6,905	6,616	6,151	4,592
Gross Investment	8,743	3,898	12,805	13,492	23,082	34,166	79,962	78,563	74,963	62,556
Annualized (5-5/8%, 50 yrs)	526	234	770	812	1,388	2,055	4,810	4,725	4,509	3,763
Operation & Maintenance	-	-	-	-	-	-	-	-	-	-
Total Annual Cost	526	234	770	812	1,388	2,055	4,810	4,725	4,509	3,763
Expected Annual Benefits	502	1,292	2,252	2,250	3,351	2,279	3,357	5,782	6,161	3,509
Net Benefits	-24	1,058	1,482	1,438	1,963	224	-1,452	1,056	1,652	-254
Benefit/Cost Ratio	0.95	5.52	2.92	2.77	2.41	1.11	0.70	1.22	1.37	0.93

8.0 RESULTS OF ECONOMIC EVALUATION

A probabilistic, risk based economic analysis was performed in conducting this Major Rehabilitation Evaluation for Clearwater Dam. Event trees were constructed in order to model the possibilities of occurrences of the dam, given its current condition, and their economic consequences. Life cycle analyses were used to consider the impact of these consequences over the 50-year period of analysis of this evaluation.

Major Rehabilitation guidance requires estimation of total economic costs and benefits of the base condition and alternative solutions. Guidance also requires identification of the recommended plan. The recommended plan will identify the optimum investment, both in terms of proposed actions and timing of proposed actions, given the risk and uncertainty identified during the study. There may be circumstances where the risk and uncertainty is such that more than one plan of action may be considered to reasonably maximize net benefits.

Plan S-4D has net benefits of $102.4 million. Rehabilitation construction first costs are $68.8 million and would require four years to complete. Interest during construction was calculated and amortized along with first costs at 5.625%, the FY 2004 discount rate, over a 50-year period of analysis. The plan provides expected annual net benefits of $6.16 million. Total annual costs are $4.5 million. Net benefits of the plan are $751,000, with a benefit-to-cost ratio of 1.37 to 1. A histogram of the benefits of S-4D is shown in Figure 1. More than 80% of the time, benefits of Plan S-4D are greater than the total annual costs of rehabilitation.



9. OTHER CONSIDERATIONS

9.1 Loss of Life

A major reason for improving the safety of Clearwater Dam is to avoid the loss of life that would likely occur from a dam failure. The analyses explained in the following sections indicate that there is a potential threatened population for particular Clearwater Dam failure scenarios. Using inundation maps and the downstream flow profiles, population at risk (PAR) is estimated for various flood zones (depth of flooding) in each downstream reach. PAR, defined as those persons that would be exposed to injury by floodwater if they took no measures to evacuate, includes permanent and transient population. PAR may be adjusted by considering the season of year and time of day that a dam failure may occur to estimate the probable population at risk. The effectiveness of warnings and evacuation procedures are considered when estimating the loss of life. Key factors in these analyses are the elapsed times displayed in Appendix C, Tables C-8 and C-9.

9.1.1 Determination of the Population at Risk (PAR)

The determination of population at risk (PAR) is defined as those people who would be exposed to injury by floodwater if they took no measures to evacuate. PAR includes people who reside, work, or conduct other activities in the area that would be flooded in the event of a dam breach. For this analysis, PAR is considered for a seepage failure condition.

PAR was estimated using 2000 U.S. Census Bureau Census block population and housing data for the reaches in the impact area. Using a Geographic Information System

(GIS) program, the flooded area outline for each breach condition, land use coverage, and the Census blocks for the affected area were overlaid on aerial photos and USGS topographic quad maps of the study area. The total population in each Census block was recorded. If a Census block did not completely lie in the inundated area, the population was adjusted to exclude residents living outside the floodplain.

9.1.2 Seasonal and Transient PAR

PAR could vary based on the transient population in the area, the season of year, and the time of day. The total resident population in the study area is not expected to be likely to fluctuate significantly with the seasons. No adjustment was made to increase PAR by the number of workers in the area. Some of the residential population in the floodplain would be at work in affected businesses, and some would be elsewhere outside the floodplain. Some people who live outside the floodplain work in the floodplain. It is assumed that capturing these floodplain occupancy shifts would result in no significant change to the population at risk.

9.1.3 Warning Times and Systems

The time available to warn the people in each reach before the arrival of a flood wave is critical to reducing injury and loss of life from a rare flood event. The warning time is the difference in time from the point a public warning is initially disseminated until time the flood wave reaches each population center. Warning time is the most critical factor in reducing the threatened population and the potential for loss of life.

Clearwater Dam has a Flood Emergency Action Plan that outlines the steps that Corps personnel take to identify and respond to emergency conditions. Corps personnel at the project site monitor weather, river stages, and runoff forecasts, in addition to the structural integrity of the dam and its operating features. The Corps would initiate public warning with adequate time for the local emergency management officials to disseminate the warning and begin evacuation procedures in the study area. Telephone and radio would be the two primary methods of communication used to begin the warning procedure.

The Flood Emergency Action Plan also calls for increased discharges from the dam in situations where failure from the seepage or spillway condition could occur. The increased flows would make notification more credible, enhance the feeling of urgency, and compliment environmental clues like heavy rains, giving the public an understanding of the danger at hand. Sentimental attachment to homes, skepticism about the reality of danger, and isolation from mass media and educational level of residents are also aspects linked to the likelihood of acting appropriately when warned of a dam failure. The farther downstream the population centers are, the greater the chance that warnings will be heeded. These people will have more time to evacuate the area and will have verification from conversations with people upstream and media reports.

Problems could occur if communication and transportation links are severed. Heavy rains or river flows may destroy roads, bridges, and electrical and telephone lines, making normal communications and transportation unreliable. For this study, the estimated warning time has been based on the time lapse between the failure event and the arrival of the breach flood wave at the various locations along the river.

9.1.4 Probable Population at Risk

The values for Population At Risk shown in Table 26 assume that the flood event occurs during the year, but are also conditional on the season and time of day. Probabilities that the flood event occurs in a particular season and time of day are required to derive the probable PAR estimates. For this analysis, it was assumed that a dam breach event has an equal probability of occurring during any given time of year. It was also assumed that PAR is constant between times of day. Consequently, it is assumed that PAR displayed in Table 13 represents those working and living in the area at any given time of day or season of the year. Thus, for the purposes of this analysis, PAR is based on the estimated residential population in the inundated area.

Table 26: Population At Risk (Par) With And Without Dam Failure

Reach	Percent PMF	PAR With Failure	PAR Without Failure	Incremental Difference
1	20	895	466	429
	100	1260	779	480
2	20	292	32	260
	100	477	244	233
3	20	7185	7019	166
	100	7307	7229	78
Subtotals	20	8372	7517	856
	100	9043	8252	791

9.1.5 Threatened Population and Loss of Life

The threatened population is determined by adjusting the population at risk with warning time consideration. Determination of the loss of life is based on the total population at risk, warning time, and evacuation. In the ideal situation, the total PAR would receive a warning with sufficient time to evacuate the flooded area and thus there would be no loss of life. However, with a major rain event in the area, the effectiveness of communication, warning systems, and evacuation plans could be severely hampered and there would be a high risk for loss of life, particularly in the areas just below Clearwater Dam. Additionally, in rural areas where the population is widely scattered, it is not possible that every single person would receive a warning. Additionally some would not heed the warning and would choose to remain in the flood-prone area. Even with adequate warning, loss of life could occur among the population.

In July 2002, IWR published "Estimating Life Loss for Dam Safety Risk Assessment – A Review and New Approach." The report suggests using loss of life guidance from the Bureau of Reclamation. The Bureau of Reclamation (BOR) published guidance entitled "A Procedure for Estimating Loss of Life Caused by Dam Failure," DSO-99-06, September

1999. The BOR methodology is based on flood severity, amount of warning time, and the understanding of the severity of the flood. This methodology was used in estimating loss of life for this study. Table 7 in the BOR guidance document was used to estimate loss of life percentages. Professional judgment, supported by hydraulic information of velocity and water surface elevation, was used in describing each reach for each breach condition in the following categories.

Flood Severity. According to the BOR guidance, "Low severity occurs when no buildings are washed off their foundations. Medium severity occurs when homes are destroyed but trees or mangled homes remain for people to seek refuge in or on. High severity occurs when the flood sweeps the area clean and nothing remains." Estimates of flood severity were made for each condition, for each reach in the study area. See Table 27 for estimates.

Warning Time and Understanding of Flood Severity. According to the BOR guidance, "Adequate warning means officials or the media begin warning in the particular area more than 60 minutes before flood water arrives." For the spillway erosion and seepage conditions in all reaches, warning time is more than 60 minutes. Environmental clues, such as long periods of rainfall, would provide the population with more than a day of warning.

According to the BOR guidance, "Vague Understanding of Flood Severity" means that the warning issuers have not yet seen an actual dam failure or do not comprehend the true magnitude of the flooding. "Precise Understanding of Flood Severity" means that the warning issuers have an excellent understanding of the flooding due to observations of the flooding made by themselves or others." It is assumed that the reach closest to the dam will have the least likelihood of precise and accurate understanding. A warning of a potential flood may be difficult to describe. Therefore, recipients of the earliest warnings may not obtain an accurate understanding of the flooding about to occur. It is assumed that the reach farthest from the dam will have the greater likelihood of precise and accurate understanding. People upstream have seen the damage potential, and any warnings have been updated to reflect more accurate information of the actual danger.

Table 27: Flood Designation by Condition

		100 Seep	100 Exist	20 Seep	20 Exist
Reach 1	Severity	Medium	Low	Medium	Low
	Warning Time	>60 min	>60 min	>60 min	>60 min
	Understanding	Vague	Vague	Vague	Vague
	Factor	.03	.0003	.03	.0003
Reach 2	Severity	Medium	Low	Medium	Low
	Warning Time	>60 min	>60 min	>60 min	>60 min
	Understanding	Precise	Precise	Precise	Precise
	Factor	.01	.0002	.01	.0002
Reach 3	Severity	High	Low	High	Low
	Warning Time	>60 min	>60 min	>60 min	>60 min
	Understanding	Precise	Precise	Precise	Precise
	Factor	.05	.0002	.05	.0002

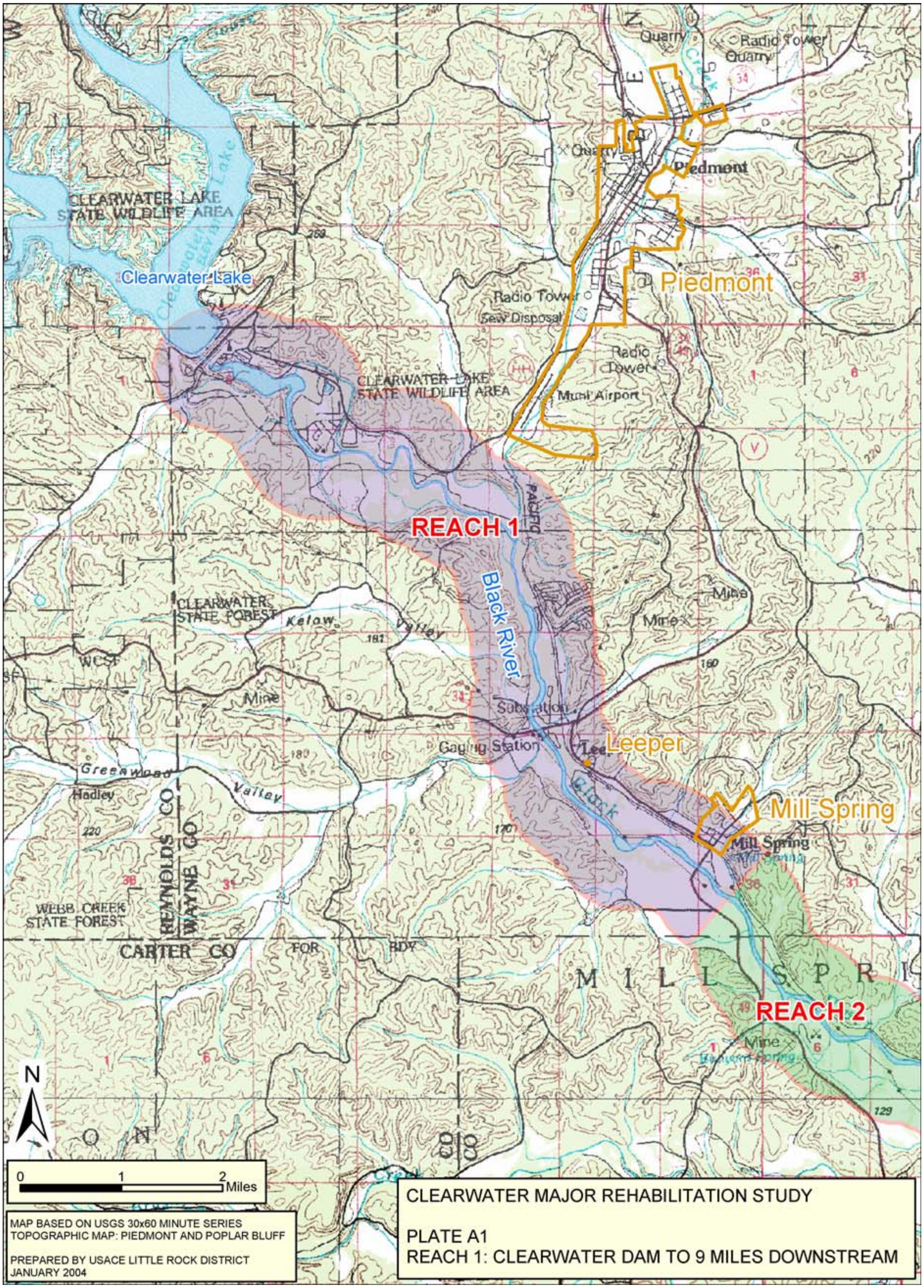
Using the information presented in Table 14, loss of life percentages were obtained from the BOR guidance. The percentages were applied to population at risk to determine loss of life. Table 28 displays the potential loss of life estimates by reach.

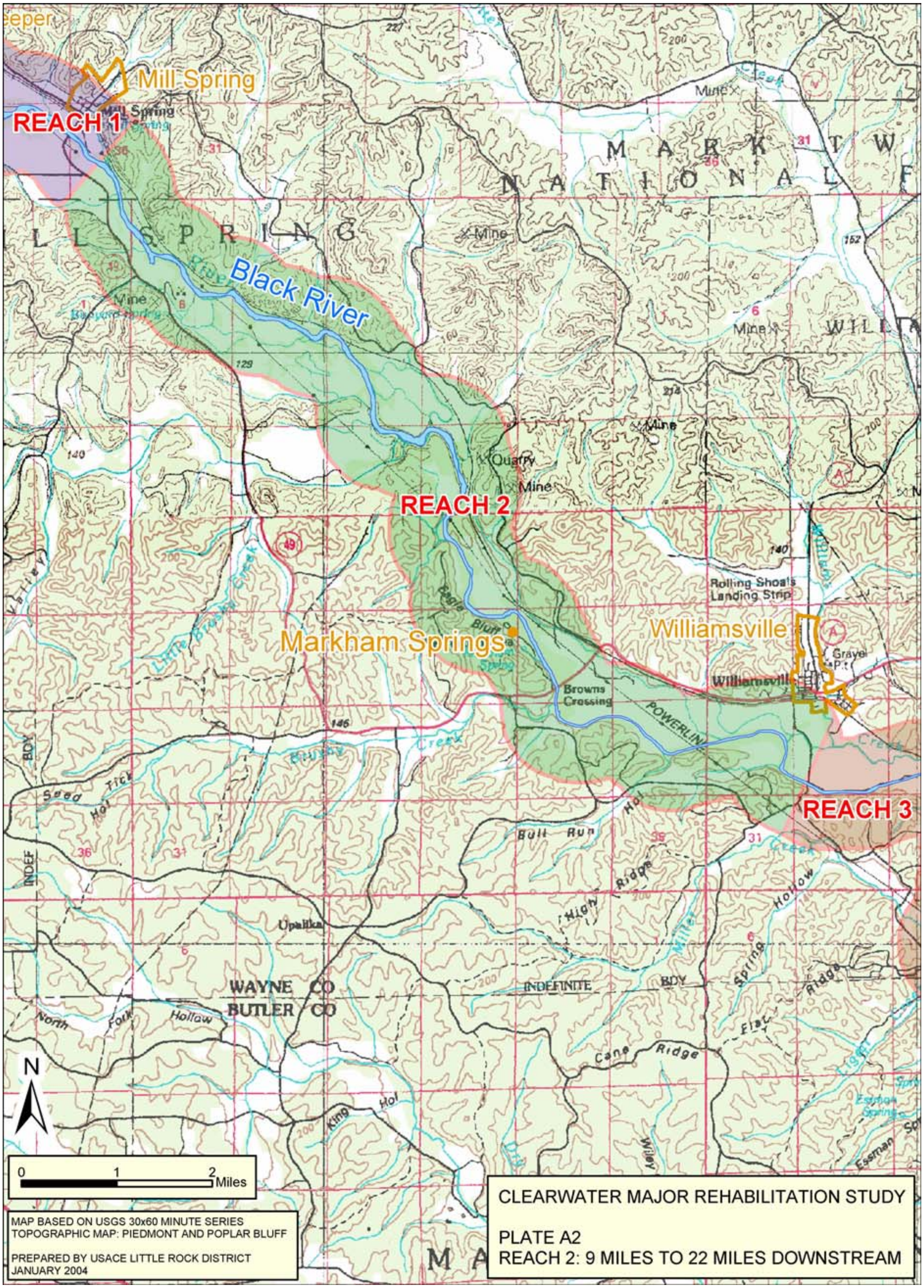
Table 28: Loss of Life (LOL) With and Without Dam Failure

Reach	Percent PMF	LOL With Failure	LOL Without Failure	Incremental Difference
1	20	27	0	27
	100	38	0	38
2	20	3	0	3
	100	5	0	5
3	20	347	1	346
	100	348	1	347
Subtotals	20	377	1	376
	100	391	1	390

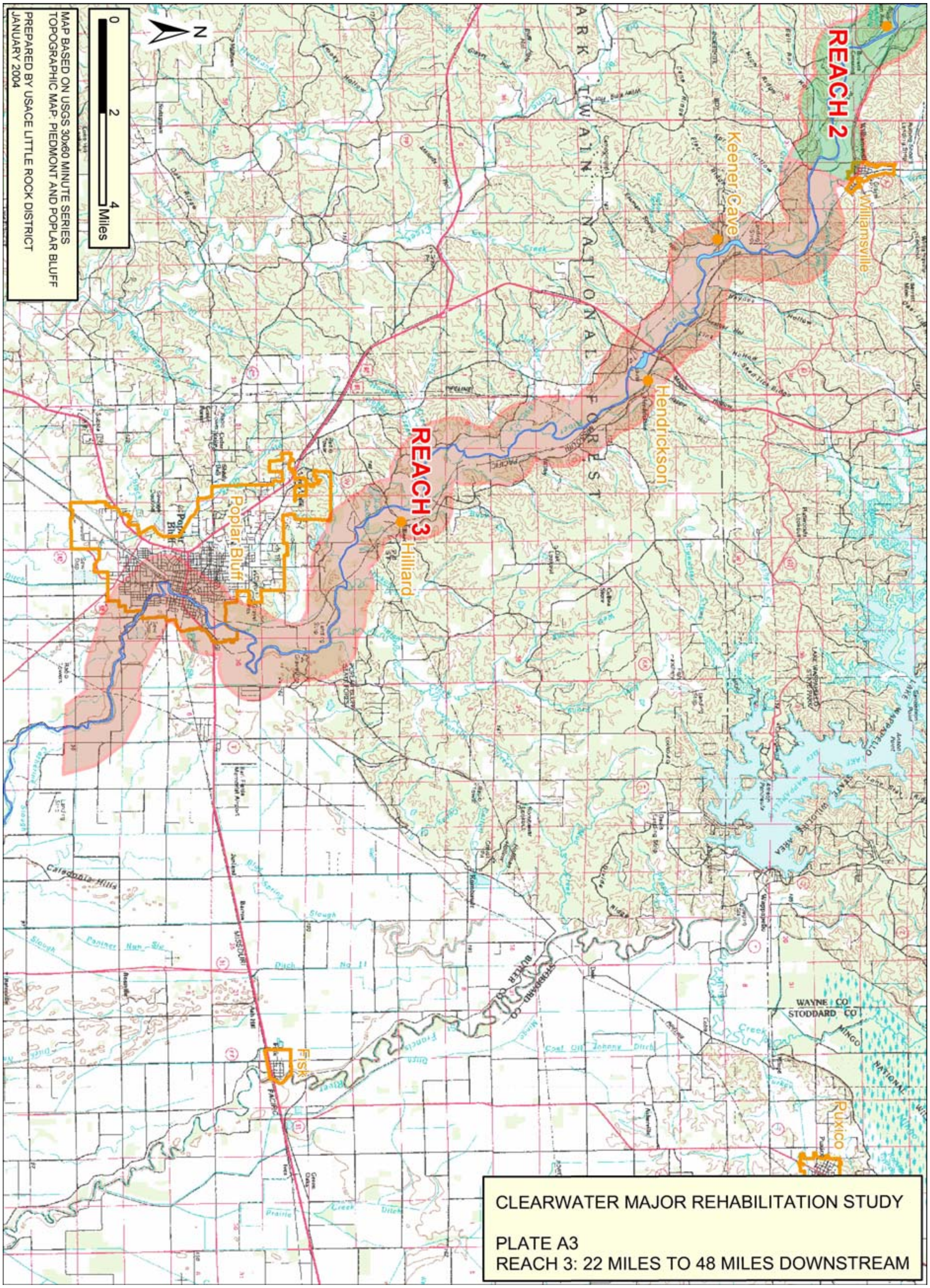
10.0 RECOMMENDATIONS

A catastrophic failure of the Clearwater Dam and sudden loss of reservoir pool will have extremely serious consequences for the downstream communities. The population at risk has been estimated at over 8,000. Failure from a 20% PMF produces potential for loss of life of 377 and economic losses of $183.6 million. The dam has prevented almost $233 million in damages over 56 years. The total cost of S-4D is estimated at $75 million. It produces $6.16 million in expected annual benefits and has a benefit/cost ratio of 1.37 to 1.


Clearwater Lake
CLEARWATER LAKE STATE WILDLIFE AREA
Piedmont
Radio Tower
Sew Disposal
Muni Airport
Quarry
REACH 1
Black River
PACIFIC
CLEARWATER STATE FOREST
Kelow Valley
Mine
Substation
Gaging Station
Leeper
Mill Spring
Greenwood Valley
Hadley
REYNOLDS CO
WAYNE CO
WEBB CREEK STATE FOREST
CARTER CO
FOR BDY
M I L L S P R
REACH 2
N
0 1 2 Miles
MAP BASED ON USGS 30x60 MINUTE SERIES TOPOGRAPHIC MAP: PIEDMONT AND POPLAR BLUFF
PREPARED BY USACE LITTLE ROCK DISTRICT JANUARY 2004
CLEARWATER MAJOR REHABILITATION STUDY
PLATE A1
REACH 1: CLEARWATER DAM TO 9 MILES DOWNSTREAM

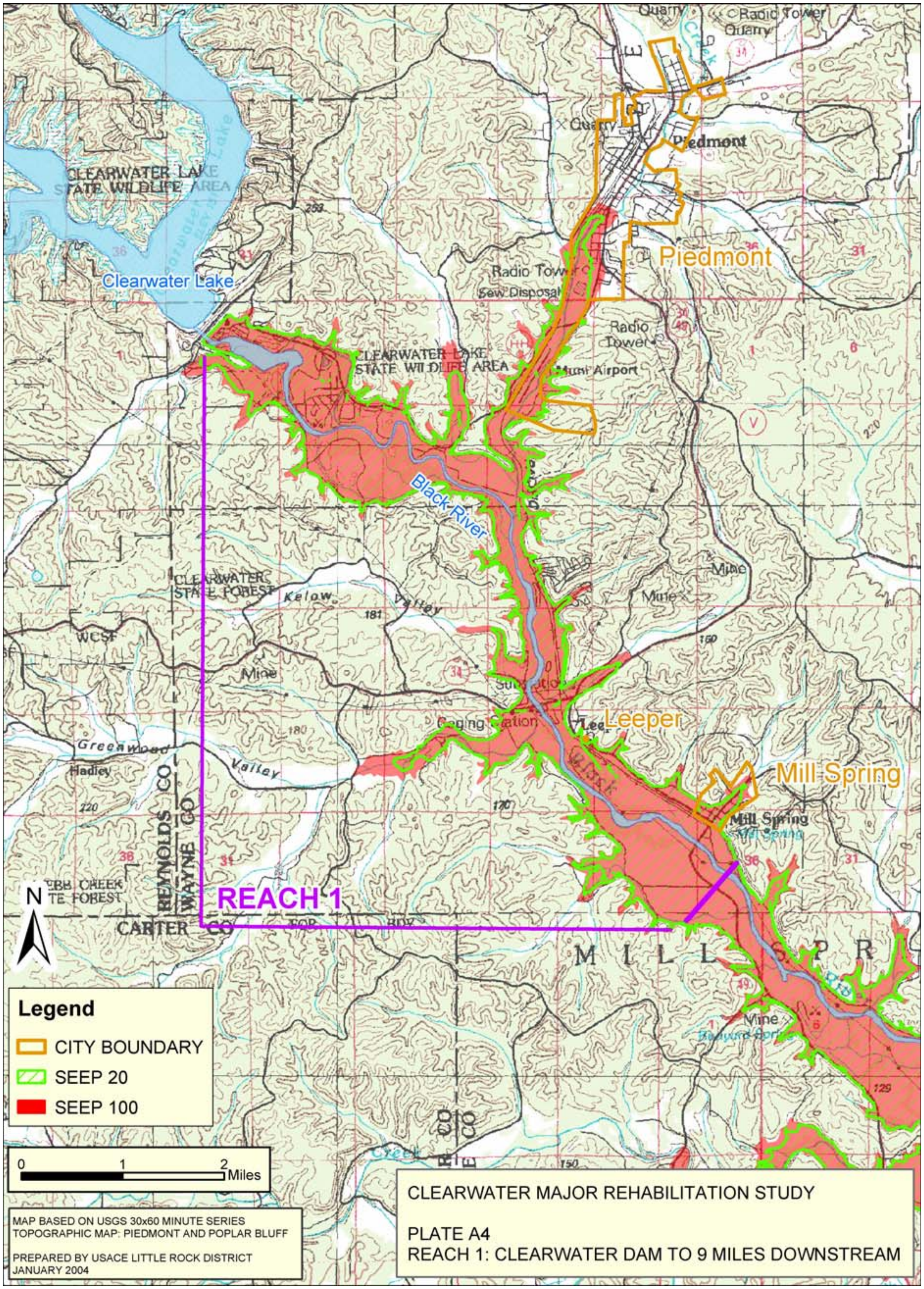


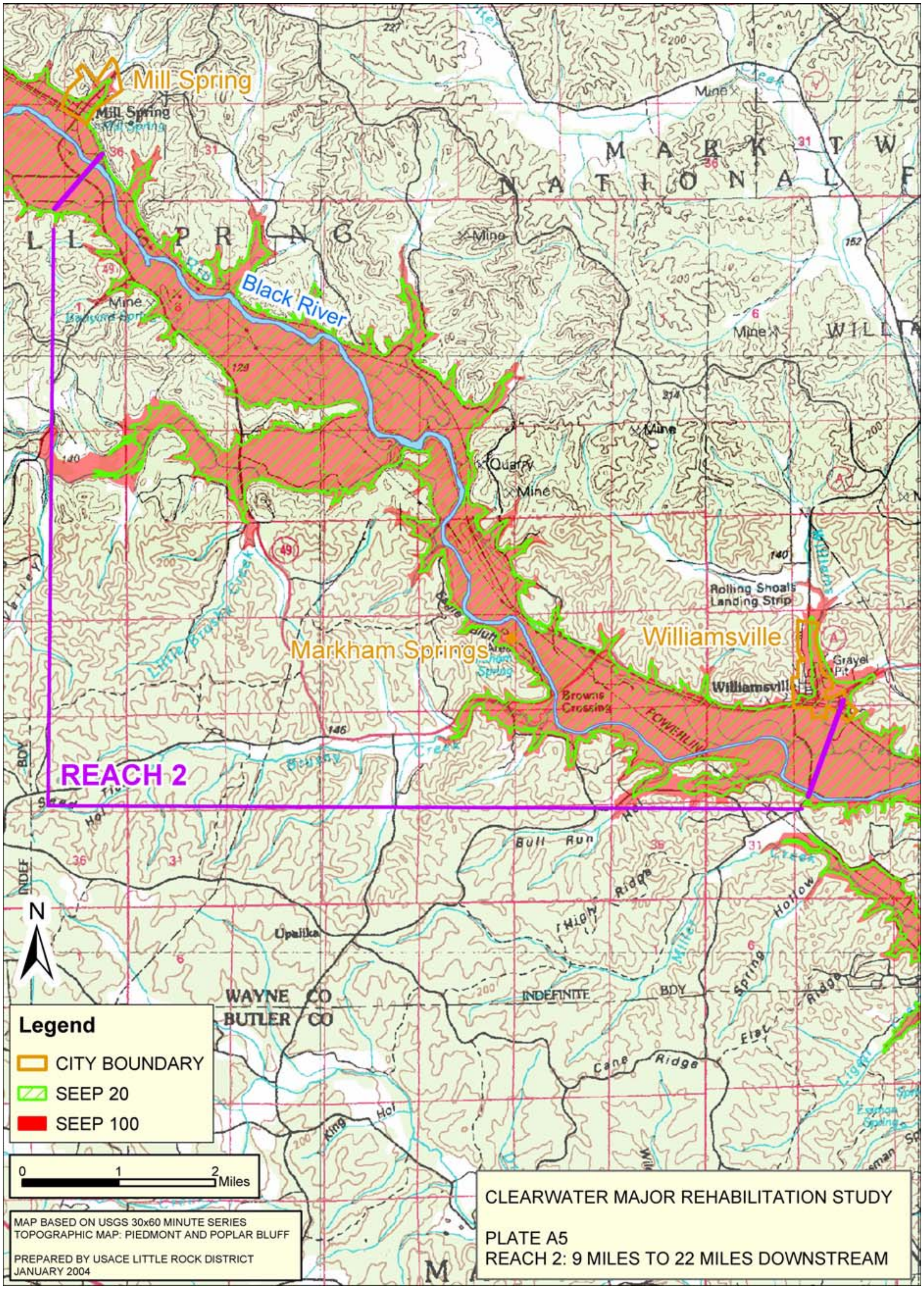
Mill Spring
REACH 1
Black River
REACH 2
Markham Springs
Williamsville
REACH 3
N
0 1 2 Miles
MAP BASED ON USGS 30x60 MINUTE SERIES TOPOGRAPHIC MAP: PIEDMONT AND POPLAR BLUFF
PREPARED BY USACE LITTLE ROCK DISTRICT JANUARY 2004
CLEARWATER MAJOR REHABILITATION STUDY
PLATE A2
REACH 2: 9 MILES TO 22 MILES DOWNSTREAM



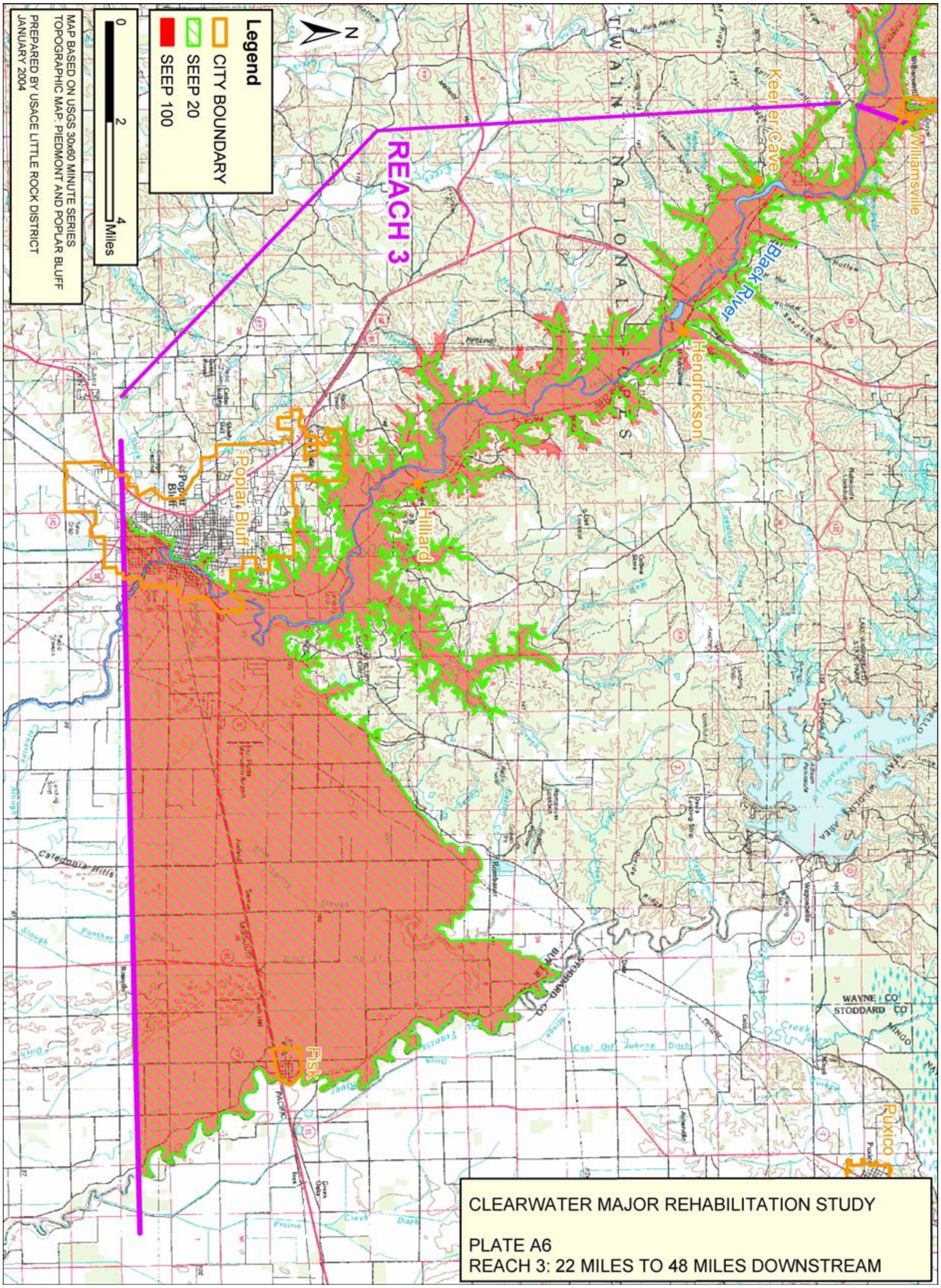
CLEARWATER MAJOR REHABILITATION STUDY

PLATE A3
REACH 3: 22 MILES TO 48 MILES DOWNSTREAM


Legend
CITY BOUNDARY
SEEP 20
SEEP 100
0 1 2 Miles
MAP BASED ON USGS 30x60 MINUTE SERIES
TOPOGRAPHIC MAP: PIEDMONT AND POPLAR BLUFF
PREPARED BY USACE LITTLE ROCK DISTRICT
JANUARY 2004
CLEARWATER MAJOR REHABILITATION STUDY
PLATE A4
REACH 1: CLEARWATER DAM TO 9 MILES DOWNSTREAM
REACH 1
Clearwater Lake
Piedmont
Leeper
Mill Spring
Black River
N

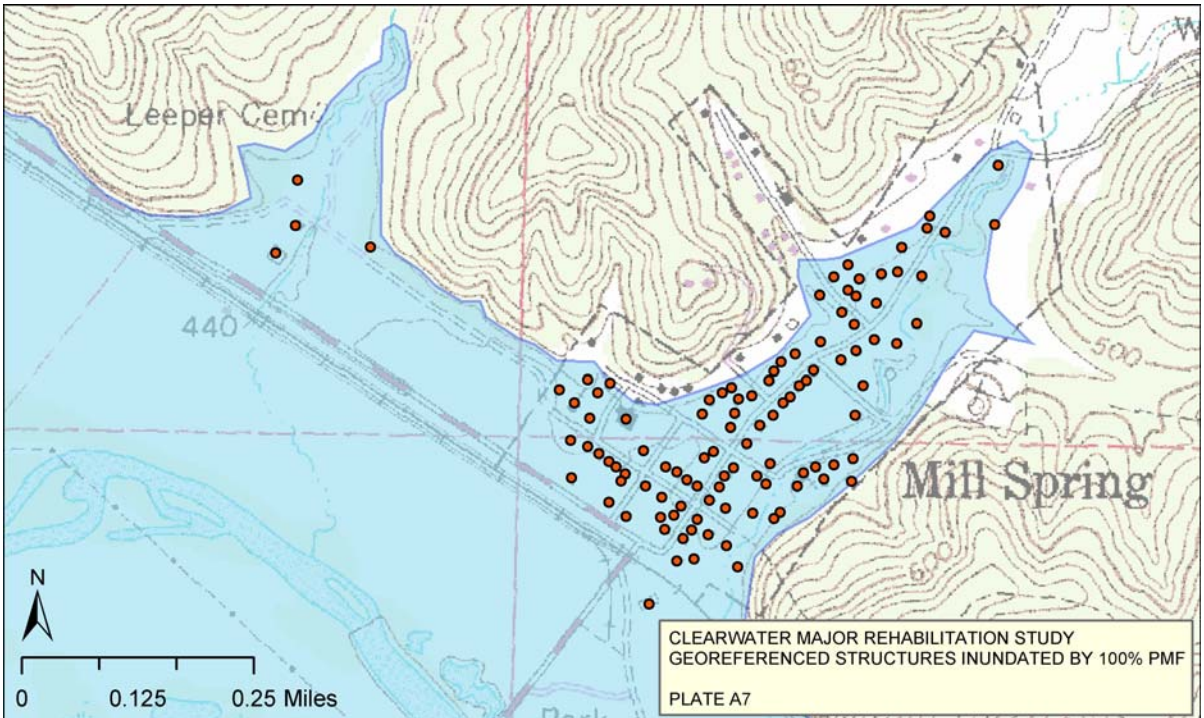


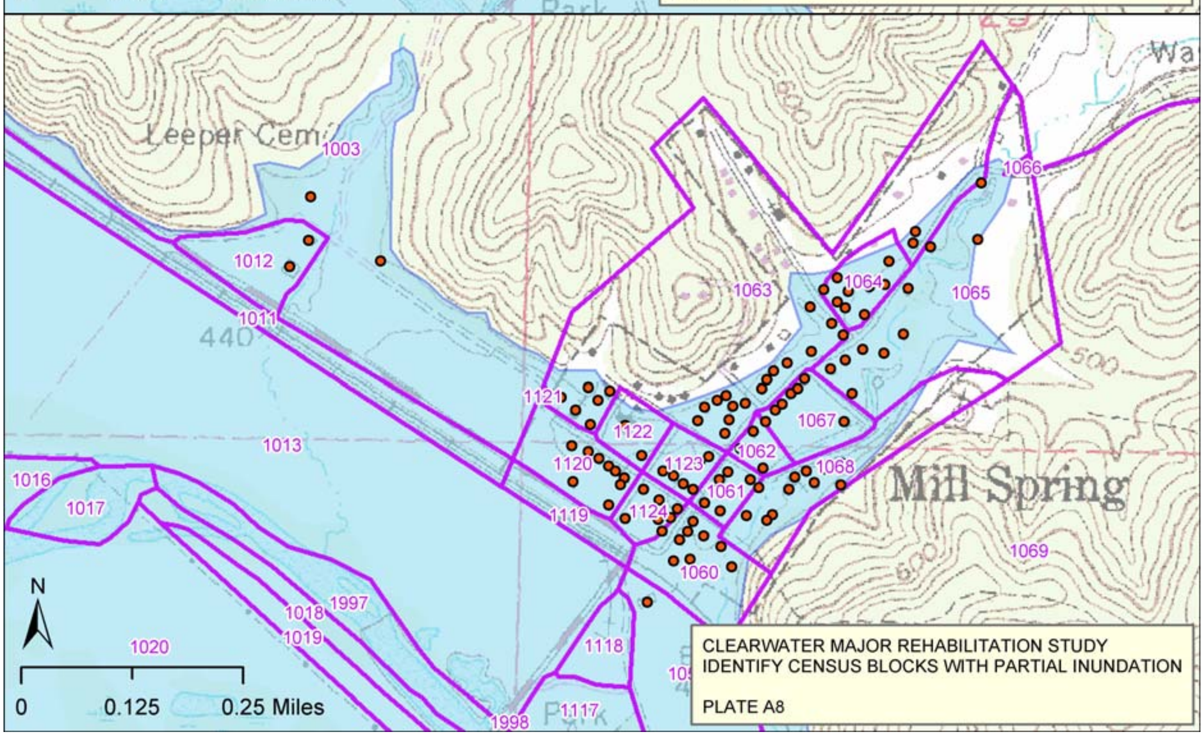
Mill Spring
Black River
Markham Springs
Williamsville
REACH 2
Legend
CITY BOUNDARY
SEEP 20
SEEP 100
0 1 2 Miles
MAP BASED ON USGS 30x60 MINUTE SERIES TOPOGRAPHIC MAP: PIEDMONT AND POPLAR BLUFF
PREPARED BY USACE LITTLE ROCK DISTRICT JANUARY 2004
CLEARWATER MAJOR REHABILITATION STUDY
PLATE A5
REACH 2: 9 MILES TO 22 MILES DOWNSTREAM

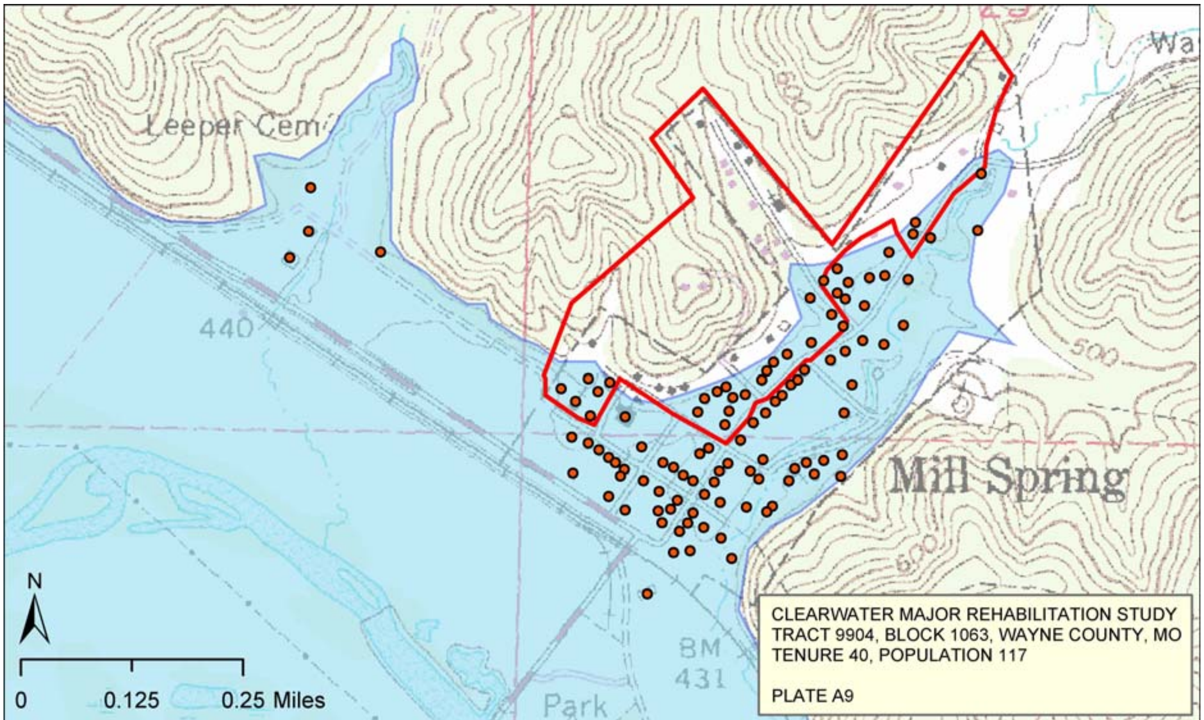


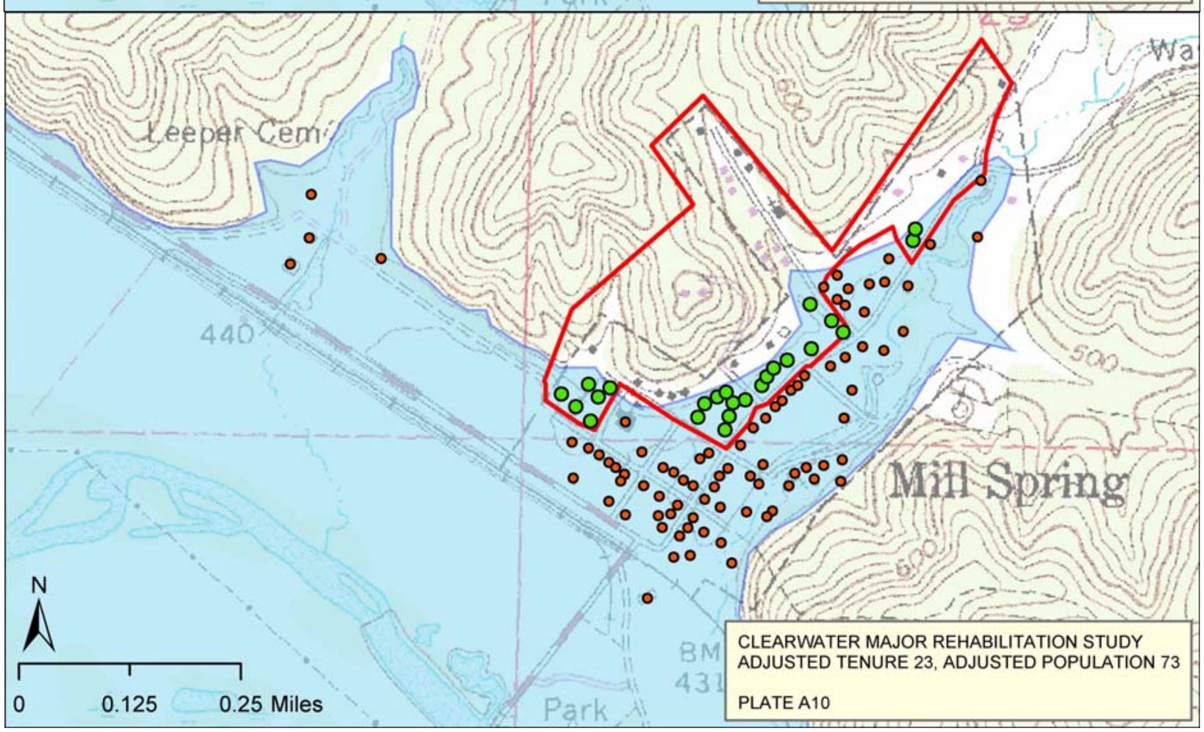
CLEARWATER MAJOR REHABILITATION STUDY

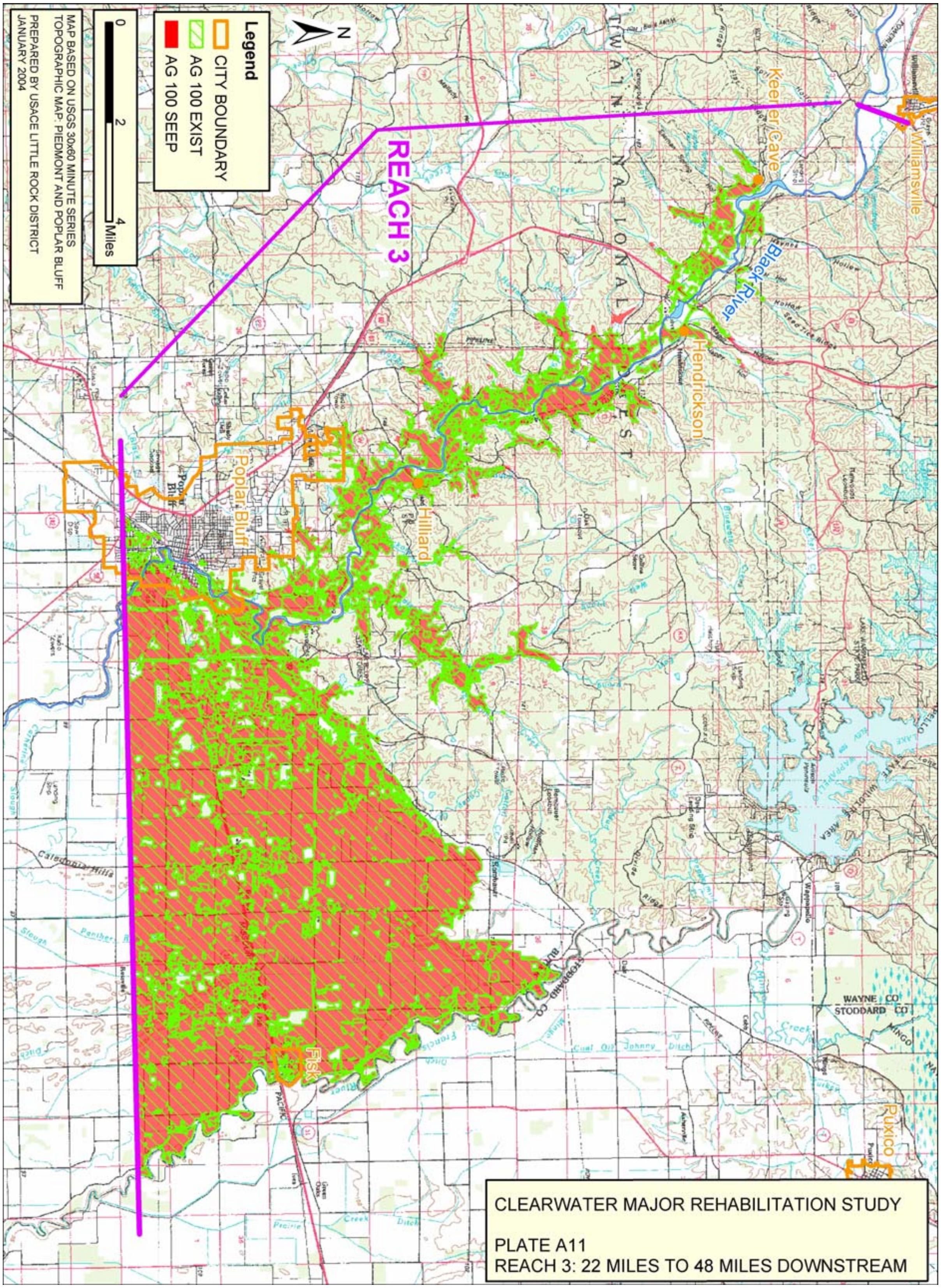
PLATE A6
REACH 3: 22 MILES TO 48 MILES DOWNSTREAM


Leeper Cem
440
Mill Spring
N
0
0.125
0.25 Miles
CLEARWATER MAJOR REHABILITATION STUDY
GEOREFERENCED STRUCTURES INUNDATED BY 100% PMF
PLATE A7


Leeper Cem
440
Mill Spring
1003
1012
1011
1013
1016
1017
1020
1018
1019
1997
1998
1063
1064
1065
1066
1067
1068
1069
1121
1122
1120
1123
1062
1061
1119
1124
1060
1118
1117
N
0
0.125
0.25 Miles
CLEARWATER MAJOR REHABILITATION STUDY
IDENTIFY CENSUS BLOCKS WITH PARTIAL INUNDATION
PLATE A8

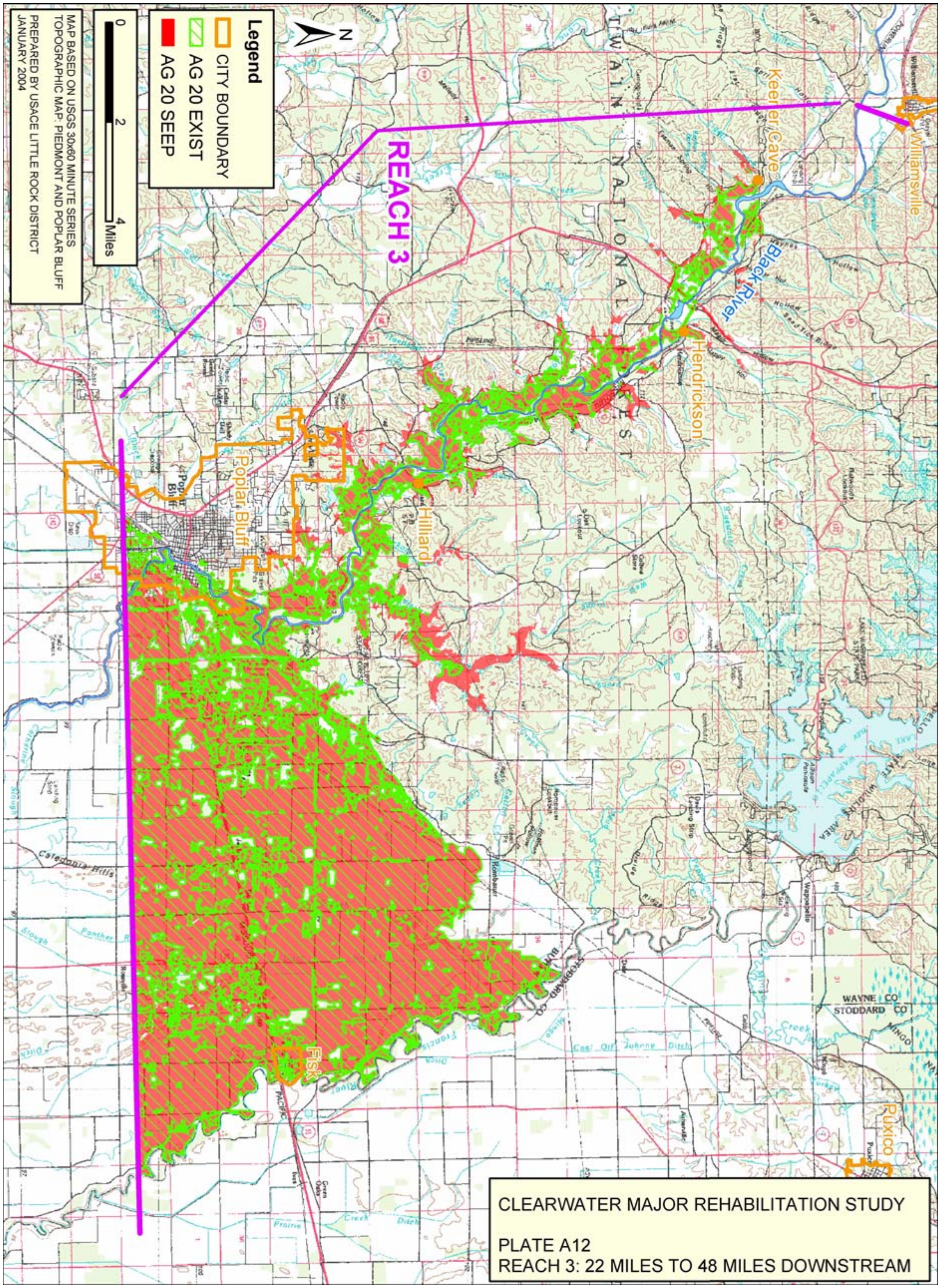

Leeper Cem
440
Mill Spring
BM
431
Park
N
0
0.125
0.25 Miles
CLEARWATER MAJOR REHABILITATION STUDY
TRACT 9904, BLOCK 1063, WAYNE COUNTY, MO
TENURE 40, POPULATION 117
PLATE A9


Leeper Cem
440
Mill Spring
BM
431
Park
N
0
0.125
0.25 Miles
CLEARWATER MAJOR REHABILITATION STUDY
ADJUSTED TENURE 23, ADJUSTED POPULATION 73
PLATE A10



CLEARWATER MAJOR REHABILITATION STUDY

PLATE A11
REACH 3: 22 MILES TO 48 MILES DOWNSTREAM


CLEARWATER MAJOR REHABILITATION STUDY
PLATE A12
REACH 3: 22 MILES TO 48 MILES DOWNSTREAM
Legend
CITY BOUNDARY
AG 20 EXIST
AG 20 SEEP
0 2 4 Miles
MAP BASED ON USGS 30x60 MINUTE SERIES
TOPOGRAPHIC MAP: PIEDMONT AND POPLAR BLUFF
PREPARED BY USACE LITTLE ROCK DISTRICT
JANUARY 2004
REACH 3
Williamsville
Keener Cave
Black River
Hendrickson
Hilliard
Poplar Bluff
Fisk
Puxico
WAYNE CO
STODDARD CO

Base Condition Event

Pool Elevation / Probability	Emergency Action / Probability	Failure Probability	Branch Probability
> 575 0.0075	Distress 1.00	Failure 0.70	0.00525
		No Failure 0.30	0.00225
	No Distress 0.00		0
550 - 575 0.0505	Distress 1.00	Failure 0.60	0.0303
		No Failure 0.40	0.0202
	No Distress 0.00		0
525 - 550 0.2570	Distress 1.00	Failure 0.49	0.12593
		No Failure 0.51	0.13107
	No Distress 0.00		0
500 - 525 0.5470	Distress 1.00	Failure 0.16	0.08752
		No Failure 0.84	0.45948
	No Distress 0.00		0
< 500 0.1380	Distress 1.00	Failure 0.10	0.0138
		No Failure 0.90	0.1242
	No Distress 0.00		0

PLATE A13

Remediated Condition Event Tree - S1

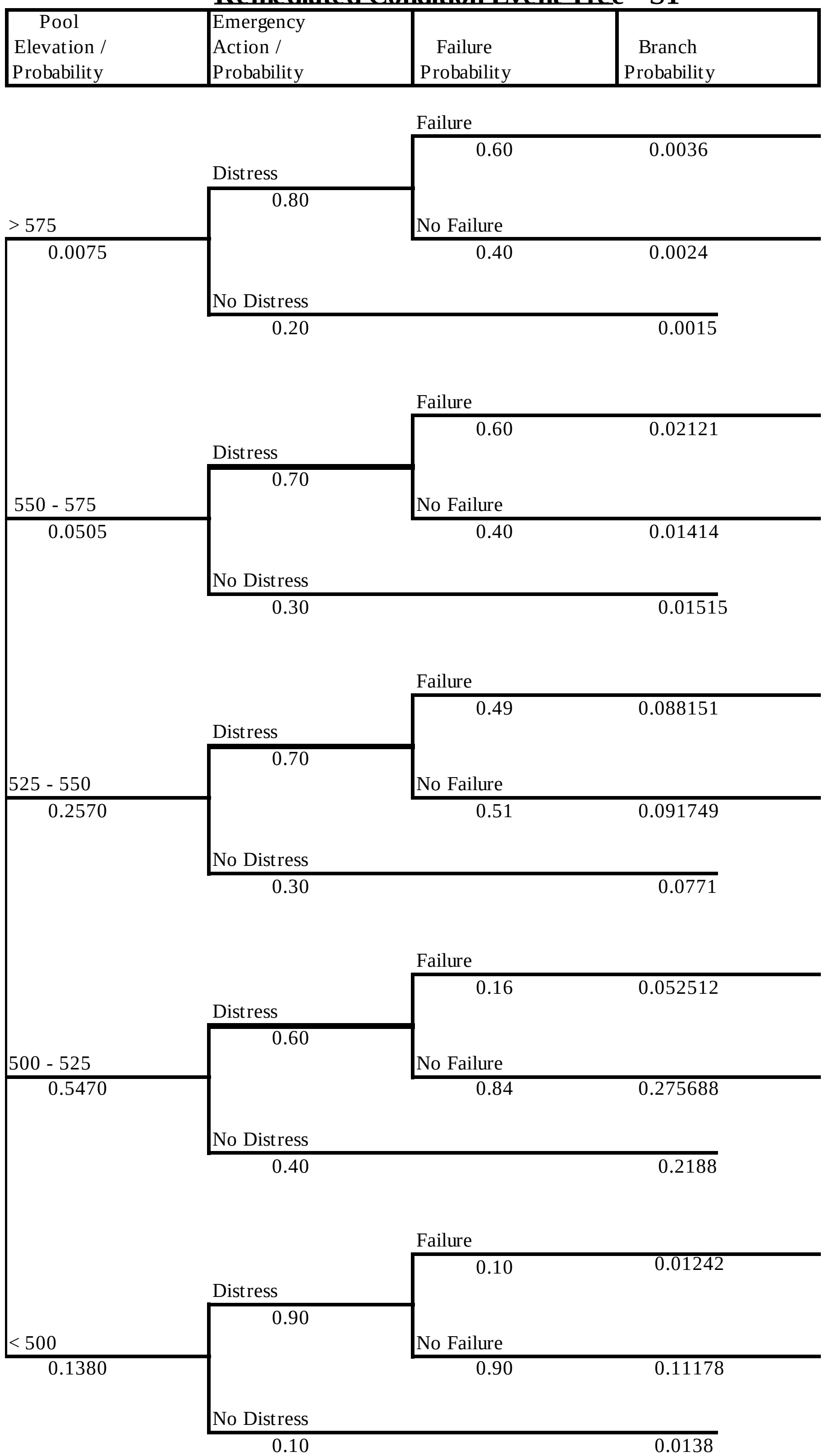


PLATE A14

Remediated Condition Event Tree - S2-A

Pool Elevation / Probability	Emergency Action / Probability	Failure Probability	Branch Probability
> 575 0.0075	Distress 0.90	Failure 0.80	0.0054
		No Failure 0.20	0.00135
	No Distress 0.10		0.00075
550 - 575 0.0505	Distress 0.70	Failure 0.60	0.02121
		No Failure 0.40	0.01414
	No Distress 0.30		0.01515
525 - 550 0.2570	Distress 0.49	Failure 0.49	0.0617057
		No Failure 0.51	0.0642243
	No Distress 0.51		0.13107
500 - 525 0.5470	Distress 0.33	Failure 0.16	0.0288816
		No Failure 0.84	0.1516284
	No Distress 0.67		0.36649
< 500 0.1380	Distress 0.33	Failure 0.10	0.004554
		No Failure 0.90	0.040986
	No Distress 0.67		0.09246

PLATE A15

Remediated Condition Event Tree - S2-B

Pool Elevation / Probability	Emergency Action / Probability	Failure Probability	Branch Probability
> 575 0.0075	Distress 0.70	Failure 0.70	0.003675
		No Failure 0.30	0.001575
	No Distress 0.30		0.00225
550 - 575 0.0505	Distress 0.50	Failure 0.60	0.01515
		No Failure 0.40	0.0101
	No Distress 0.50		0.02525
525 - 550 0.2570	Distress 0.33	Failure 0.49	0.0415569
		No Failure 0.51	0.0432531
	No Distress 0.67		0.17219
500 - 525 0.5470	Distress 0.16	Failure 0.16	0.0140032
		No Failure 0.84	0.0735168
	No Distress 0.84		0.45948
< 500 0.1380	Distress 0.16	Failure 0.10	0.002208
		No Failure 0.90	0.019872
	No Distress 0.84		0.11592

PLATE A16

Remediated Condition Event Tree - S2-C

Pool Elevation / Probability	Emergency Action / Probability	Failure Probability	Branch Probability
> 575 0.0075	Distress 0.70	Failure 0.70	0.003675
		No Failure 0.30	0.001575
	No Distress 0.30		0.00225
550 - 575 0.0505	Distress 0.50	Failure 0.60	0.01515
		No Failure 0.40	0.0101
	No Distress 0.50		0.02525
525 - 550 0.2570	Distress 0.33	Failure 0.49	0.0415569
		No Failure 0.51	0.0432531
	No Distress 0.67		0.17219
500 - 525 0.5470	Distress 0.16	Failure 0.16	0.0140032
		No Failure 0.84	0.0735168
	No Distress 0.84		0.45948
< 500 0.1380	Distress 0.10	Failure 0.10	0.00138
		No Failure 0.90	0.01242
	No Distress 0.90		0.1242

PLATE A17

Remediated Condition Event Tree - S3

Pool Elevation / Probability	Emergency Action / Probability	Failure Probability	Branch Probability
> 575 0.0075	Distress 0.70	Failure 0.70	0.003675
		No Failure 0.30	0.001575
	No Distress 0.30		0.00225
550 - 575 0.0505	Distress 0.50	Failure 0.60	0.01515
		No Failure 0.40	0.0101
	No Distress 0.50		0.02525
525 - 550 0.2570	Distress 0.16	Failure 0.49	0.0201488
		No Failure 0.51	0.0209712
	No Distress 0.84		0.21588
500 - 525 0.5470	Distress 0.10	Failure 0.16	0.008752
		No Failure 0.84	0.045948
	No Distress 0.90		0.4923
< 500 0.1380	Distress 0.10	Failure 0.10	0.00138
		No Failure 0.90	0.01242
	No Distress 0.90		0.1242

PLATE A18

Remediated Condition Event Tree - S4-A

Pool Elevation / Probability	Emergency Action / Probability	Failure Probability	Branch Probability
> 575 0.0075	Distress 0.70	Failure 0.70	0.003675
		No Failure 0.30	0.001575
	No Distress 0.30		0.00225
550 - 575 0.0505	Distress 0.50	Failure 0.60	0.01515
		No Failure 0.40	0.0101
	No Distress 0.50		0.02525
525 - 550 0.2570	Distress 0.33	Failure 0.49	0.0415569
		No Failure 0.51	0.0432531
	No Distress 0.67		0.17219
500 - 525 0.5470	Distress 0.16	Failure 0.16	0.0140032
		No Failure 0.84	0.0735168
	No Distress 0.84		0.45948
< 500 0.1380	Distress 0.10	Failure 0.10	0.00138
		No Failure 0.90	0.01242
	No Distress 0.90		0.1242

PLATE A19

Remediated Condition Event Tree - S4-B

Pool Elevation / Probability	Emergency Action / Probability	Failure Probability	Branch Probability
> 575 0.0075	Distress 0.60	Failure 0.70	0.00315
		No Failure 0.30	0.00135
	No Distress 0.40		0.003
550 - 575 0.0505	Distress 0.49	Failure 0.60	0.014847
		No Failure 0.40	0.009898
	No Distress 0.51		0.025755
525 - 550 0.2570	Distress 0.16	Failure 0.49	0.0201488
		No Failure 0.51	0.0209712
	No Distress 0.84		0.21588
500 - 525 0.5470	Distress 0.10	Failure 0.16	0.008752
		No Failure 0.84	0.045948
	No Distress 0.90		0.4923
< 500 0.1380	Distress 0.10	Failure 0.10	0.00138
		No Failure 0.90	0.01242
	No Distress 0.90		0.1242

PLATE A20

Remediated Condition Event Tree - S4-C

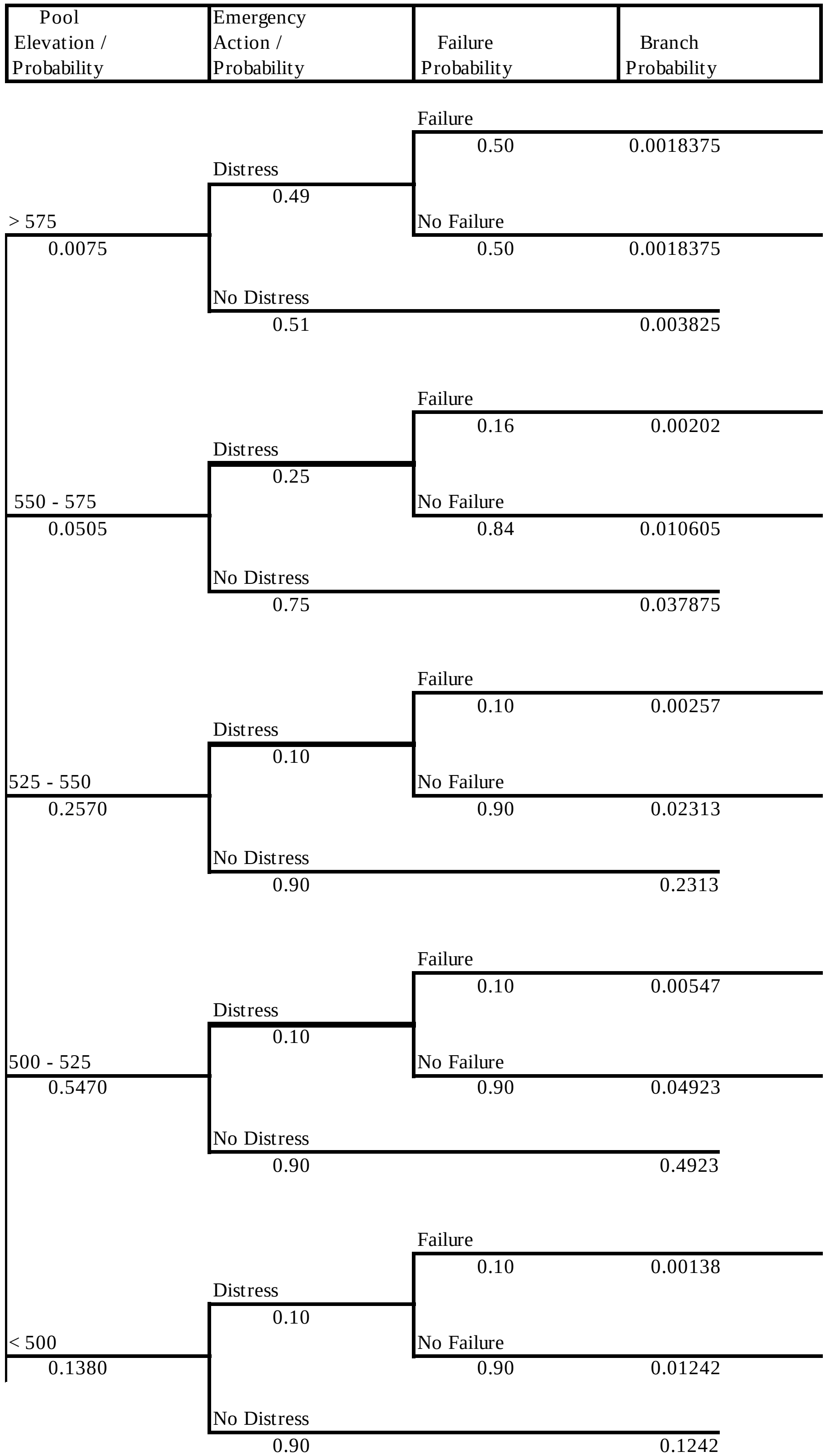


PLATE A21

Remediated Condition Event Tree - S4-D

Pool Elevation / Probability	Emergency Action / Probability	Failure Probability	Branch Probability
> 575 0.0075	Distress 0.25	Failure 0.25	0.0004688
		No Failure 0.75	0.0014063
	No Distress 0.75		0.005625
550 - 575 0.0505	Distress 0.16	Failure 0.16	0.0012928
		No Failure 0.84	0.0067872
	No Distress 0.84		0.04242
525 - 550 0.2570	Distress 0.10	Failure 0.10	0.00257
		No Failure 0.90	0.02313
	No Distress 0.90		0.2313
500 - 525 0.5470	Distress 0.05	Failure 0.05	0.0013675
		No Failure 0.95	0.0259825
	No Distress 0.95		0.51965
< 500 0.1380	Distress 0.05	Failure 0.05	0.000345
		No Failure 0.95	0.006555
	No Distress 0.95		0.1311

PLATE A22

Remediated Condition Event Tree - S4-E

Pool Elevation / Probability	Emergency Action / Probability	Failure Probability	Branch Probability
> 575 0.0075	Distress 0.80	Failure 0.60	0.0036
		No Failure 0.40	0.0024
	No Distress 0.20		0.0015
550 - 575 0.0505	Distress 0.50	Failure 0.50	0.012625
		No Failure 0.50	0.012625
	No Distress 0.50		0.02525
525 - 550 0.2570	Distress 0.16	Failure 0.33	0.0135696
		No Failure 0.67	0.0275504
	No Distress 0.84		0.21588
500 - 525 0.5470	Distress 0.16	Failure 0.16	0.0140032
		No Failure 0.84	0.0735168
	No Distress 0.84		0.45948
< 500 0.1380	Distress 0.16	Failure 0.10	0.002208
		No Failure 0.90	0.019872
	No Distress 0.84		0.11592

PLATE A23

Base Condition

Elevation	Cumulative Freq	PrDist	PF|Dist
497	0	1	0.1
500	0.138	1	0.16
505	0.182	1	0.16
525	0.6850	1	0.49
550	0.9420	1	0.6
567	0.9850	1	0.6
575	0.9925	1	0.7
581.5	0.9955	1	0.7
611	1	1	0.7

r =	0.05625	
		0% property
rec	2,125,973	2,125,973
flood	4,273,763	0
total	6,399,736	2,125,973
93,967,603	Failure Repair	

	PrDist
distress<500	1
distress500-525	1
distress525-550	1
distress550575	1
distress>575	1

	PF|Dist
failure<500	0.1
failure500525	0.16
failure525550	0.49
failure550575	0.6
failure>575	0.7

LoL	280	PV Property	$21,468,539	SumPV_BFG	$5,969,619	SumPV_Repair	77,726,107	Total $ Loss	$105,164,264

survive	Time	Elevation	PrDist	Distress	Pf|Dist	Fail	PropertyFail	Propertry NoFail	Property $	LOL Fail	PV Property	PV BenefitsFG	Distress Repair	Dam Repair	PV Repair
1	0	499	1	1	0.1	0	0	0	0	0	0	0	1,457,983	0	1,457,983
1	1	524	1	1	0.16	0	0	0	0	0	0	0	2,037,515	0	1,929,008
1	2	513	1	1	0.16	0	0	0	0	0	0	0	2,059,718	0	1,846,181
1	3	509	1	1	0.16	0	0	0	0	0	0	0	550,535	0	467,180
1	4	538	1	1	0.49	0	0	0	0	0	0	0	687,499	0	552,339
0	5	560	1	1	0.6	1	136,123,385	107,898,246	28,225,139	280	21,468,539	1,617,053	0	93,967,603	71,473,416
0	6	566	0	0	0	0	0	0	0	0	0	1,530,937	0	0	0
0	7	498	0	0	0	0	0	0	0	0	0	1,449,408	0	0	0
0	8	520	0	0	0	0	0	0	0	0	0	1,372,221	0	0	0
0	9	499	0	0	0	0	0	0	0	0	0	0	0	0	0
0	10	510	0	0	0	0	0	0	0	0	0	0	0	0	0
0	11	564	0	0	0	0	0	0	0	0	0	0	0	0	0
0	12	540	0	0	0	0	0	0	0	0	0	0	0	0	0
0	13	498	0	0	0	0	0	0	0	0	0	0	0	0	0
0	14	499	0	0	0	0	0	0	0	0	0	0	0	0	0
0	15	508	0	0	0	0	0	0	0	0	0	0	0	0	0
0	16	546	0	0	0	0	0	0	0	0	0	0	0	0	0
0	17	513	0	0	0	0	0	0	0	0	0	0	0	0	0
0	18	497	0	0	0	0	0	0	0	0	0	0	0	0	0
0	19	506	0	0	0	0	0	0	0	0	0	0	0	0	0
0	20	519	0	0	0	0	0	0	0	0	0	0	0	0	0
0	21	519	0	0	0	0	0	0	0	0	0	0	0	0	0
0	22	531	0	0	0	0	0	0	0	0	0	0	0	0	0
0	23	547	0	0	0	0	0	0	0	0	0	0	0	0	0
0	24	521	0	0	0	0	0	0	0	0	0	0	0	0	0
0	25	524	0	0	0	0	0	0	0	0	0	0	0	0	0
0	26	516	0	0	0	0	0	0	0	0	0	0	0	0	0
0	27	510	0	0	0	0	0	0	0	0	0	0	0	0	0
0	28	521	0	0	0	0	0	0	0	0	0	0	0	0	0
0	29	520	0	0	0	0	0	0	0	0	0	0	0	0	0
0	30	518	0	0	0	0	0	0	0	0	0	0	0	0	0
0	31	508	0	0	0	0	0	0	0	0	0	0	0	0	0
0	32	541	0	0	0	0	0	0	0	0	0	0	0	0	0
0	33	535	0	0	0	0	0	0	0	0	0	0	0	0	0
0	34	516	0	0	0	0	0	0	0	0	0	0	0	0	0
0	35	524	0	0	0	0	0	0	0	0	0	0	0	0	0
0	36	515	0	0	0	0	0	0	0	0	0	0	0	0	0
0	37	509	0	0	0	0	0	0	0	0	0	0	0	0	0
0	38	521	0	0	0	0	0	0	0	0	0	0	0	0	0
0	39	536	0	0	0	0	0	0	0	0	0	0	0	0	0
0	40	526	0	0	0	0	0	0	0	0	0	0	0	0	0
0	41	513	0	0	0	0	0	0	0	0	0	0	0	0	0
0	42	539	0	0	0	0	0	0	0	0	0	0	0	0	0
0	43	536	0	0	0	0	0	0	0	0	0	0	0	0	0
0	44	527	0	0	0	0	0	0	0	0	0	0	0	0	0
0	45	533	0	0	0	0	0	0	0	0	0	0	0	0	0
0	46	511	0	0	0	0	0	0	0	0	0	0	0	0	0
0	47	521	0	0	0	0	0	0	0	0	0	0	0	0	0
0	48	554	0	0	0	0	0	0	0	0	0	0	0	0	0
0	49	545	0	0	0	0	0	0	0	0	0	0	0	0	0

PLATE 24

S1: Extend Blanket

Elevation	Cumulative Freq	PrDist	PF|Dist
497	0	0.6	0.1
500	0.138	0.7	0.16
505	0.182	0.7	0.16
525	0.6850	0.7	0.49
550	0.9420	0.8	0.6
567	0.9850	0.8	0.6
575	0.9925	0.9	0.6
581.5	0.9955	0.9	0.6
611	1	0.9	0.6

r =	0.05625		
		0% property	
rec	2,125,973	2,125,973	
flood	4,273,763	0	
total	6,399,736	2,125,973	
93,967,603	Failure Repair		

	PrDist
distress<500	0.6
distress500-525	0.7
distress525-550	0.7
distress550575	0.8
distress>575	0.9

	PF|Dist
failure<500	0.1
failure500525	0.16
failure525550	0.49
failure550575	0.6
failure>575	0.6

LoL	183	PV Property	$36,137,523	SumPV_BFG	$6,305,410
SumPV_Repair	78,880,787	Total $ Loss	$121,323,720		

survive	Time	Elevation	PrDist	Distress	Pf|Dist	Binomial	Fail	PropertyFail	Propertry NoFail	Property $	LOL Fail	PV Property	PV BenefitsFG	Distress Repair	Dam Repair	PV Repair
1	0	499	0.6	1	0.1	0	0	0	0	0	0	0	0	1,457,983	0	1,457,983
1	1	524	0.7	1	0.16	0	0	0	0	0	0	0	0	2,037,515	0	1,929,008
1	2	513	0.7	0	0	0	0	0	0	0	0	0	0	0	0	0
1	3	509	0.7	0	0	0	0	0	0	0	0	0	0	0	0	0
0	4	538	0.7	1	0.49	1	1	88,924,150	43,943,546	44,980,603	183	36,137,523	1,708,012	0	93,967,603	75,493,796
0	5	560	0	0	0	0	0	0	0	0	0	0	1,617,053	0	0	0
0	6	566	0	0	0	0	0	0	0	0	0	0	1,530,937	0	0	0
0	7	498	0	0	0	0	0	0	0	0	0	0	1,449,408	0	0	0
0	8	520	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	9	499	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	10	510	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	11	564	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	12	540	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	13	498	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	14	499	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	15	508	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	16	546	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	17	513	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	18	497	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	19	506	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	20	519	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	21	519	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	22	531	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	23	547	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	24	521	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	25	524	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	26	516	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	27	510	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	28	521	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	29	520	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	30	518	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	31	508	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	32	541	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	33	535	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	34	516	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	35	524	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	36	515	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	37	509	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	38	521	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	39	536	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	40	526	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	41	513	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	42	539	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	43	536	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	44	527	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	45	533	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	46	511	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	47	521	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	48	554	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	49	545	0	0	0	0	0	0	0	0	0	0	0	0	0	0

PLATE 25

S2-A: Slurry Cutoff Wall 500 feet Upstream Without Blanket

Elevation	Cumulative Freq	PrDist	PF|Dist
497	0	0.33	0.1
500	0.138	0.33	0.16
505	0.182	0.33	0.16
525	0.6850	0.49	0.49
550	0.9420	0.7	0.6
567	0.9850	0.7	0.6
575	0.9925	0.9	0.8
581.5	0.9955	0.9	0.8
611	1	0.9	0.8

r =	0.05625	
		0% property
rec	2,125,973	2,125,973
flood	4,273,763	0
total	6,399,736	2,125,973

93,967,603	Failure Repair

	PrDist
distress<500	0.33
distress500-525	0.33
distress525-550	0.49
distress550575	0.7
distress>575	0.9

	PF|Dist
failure<500	0.1
failure500525	0.16
failure525550	0.49
failure550575	0.6
failure>575	0.8

LoL	280	PV Property	$21,468,539	SumPV_BFG	$5,969,619	SumPV_Repair	75,327,588	Total $ Loss	$102,765,745

survive	Time	Elevation	PrDist	Distress	Pf|Dist	Binomial	Fail	PropertyFail	Propertry NoFail	Property $	LOL Fail	PV Property	PV BenefitsFG	Distress Repair	Dam Repair	PV Repair
1	0	499	0.33	1	0.1	0	0	0	0	0	0	0	0	1,457,983	0	1,457,983
1	1	524	0.33	1	0.16	0	0	0	0	0	0	0	0	2,037,515	0	1,929,008
1	2	513	0.33	0	0	0	0	0	0	0	0	0	0	0	0	0
1	3	509	0.33	1	0.16	0	0	0	0	0	0	0	0	550,535	0	467,180
1	4	538	0.49	0	0	0	0	0	0	0	0	0	0	0	0	0
0	5	560	0.7	1	0.6	1	1	136,123,385	107,898,246	28,225,139	280	21,468,539	1,617,053	0	93,967,603	71,473,416
0	6	566	0	0	0	0	0	0	0	0	0	0	1,530,937	0	0	0
0	7	498	0	0	0	0	0	0	0	0	0	0	1,449,408	0	0	0
0	8	520	0	0	0	0	0	0	0	0	0	0	1,372,221	0	0	0
0	9	499	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	10	510	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	11	564	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	12	540	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	13	498	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	14	499	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	15	508	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	16	546	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	17	513	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	18	497	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	19	506	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	20	519	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	21	519	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	22	531	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	23	547	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	24	521	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	25	524	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	26	516	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	27	510	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	28	521	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	29	520	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	30	518	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	31	508	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	32	541	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	33	535	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	34	516	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	35	524	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	36	515	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	37	509	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	38	521	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	39	536	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	40	526	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	41	513	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	42	539	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	43	536	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	44	527	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	45	533	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	46	511	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	47	521	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	48	554	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	49	545	0	0	0	0	0	0	0	0	0	0	0	0	0	0

PLATE 26

S2-B: Slurry Cutoff Wall 500 feet Upstream With Blanket

Elevation	Cumulative Freq	PrDist	PF|Dist
497	0	0.16	0.1
500	0.138	0.16	0.16
505	0.182	0.16	0.16
525	0.6850	0.33	0.49
550	0.9420	0.5	0.6
567	0.9850	0.5	0.6
575	0.9925	0.7	0.7
581.5	0.9955	0.7	0.7
611	1	0.7	0.7

r =	0.05625		
		0% property	
rec	2,125,973	2,125,973	
flood	4,273,763	0	
total	6,399,736	2,125,973	
93,967,603	Failure Repair		

	PrDist
distress<500	0.16
distress500-525	0.16
distress525-550	0.33
distress550575	0.5
distress>575	0.7
	PF|Dist
failure<500	0.1
failure500525	0.16
failure525550	0.49
failure550575	0.6
failure>575	0.7

LoL 309 | PV Property $16,600,435 | SumPV_BFG $5,651,710 | SumPV_Repair 69,513,320 | Total $ Loss $91,765,465

survive	Time	Elevation	PrDist	Distress	Pf|Dist	Binomial	Fail	PropertyFail	Propertry NoFail	Property $	LOL Fail	PV Property	PV BenefitsFG	Distress Repair	Dam Repair	PV Repair
1	0	499	0.16	0	0	0	0	0	0	0	0	0	0	0	0	0
1	1	524	0.16	0	0	0	0	0	0	0	0	0	0	0	0	0
1	2	513	0.16	1	0.16	0	0	0	0	0	0	0	0	2,059,718	0	1,846,181
1	3	509	0.16	0	0	0	0	0	0	0	0	0	0	0	0	0
1	4	538	0.33	0	0	0	0	0	0	0	0	0	0	0	0	0
1	5	560	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0
0	6	566	0.5	1	0.6	1	1	150,694,167	127,641,573	23,052,593	309	16,600,435	1,530,937	0	93,967,603	67,667,139
0	7	498	0	0	0	0	0	0	0	0	0	0	1,449,408	0	0	0
0	8	520	0	0	0	0	0	0	0	0	0	0	1,372,221	0	0	0
0	9	499	0	0	0	0	0	0	0	0	0	0	1,299,144	0	0	0
0	10	510	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	11	564	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	12	540	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	13	498	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	14	499	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	15	508	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	16	546	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	17	513	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	18	497	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	19	506	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	20	519	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	21	519	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	22	531	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	23	547	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	24	521	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	25	524	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	26	516	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	27	510	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	28	521	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	29	520	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	30	518	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	31	508	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	32	541	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	33	535	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	34	516	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	35	524	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	36	515	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	37	509	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	38	521	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	39	536	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	40	526	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	41	513	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	42	539	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	43	536	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	44	527	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	45	533	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	46	511	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	47	521	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	48	554	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	49	545	0	0	0	0	0	0	0	0	0	0	0	0	0	0

PLATE 27

S2-C: Slurry Cutoff Wall at Toe With Blanket

Elevation	Cumulative Freq	PrDist	PF|Dist
497	0	0.1	0.1
500	0.138	0.16	0.16
505	0.182	0.16	0.16
525	0.6850	0.33	0.49
550	0.9420	0.5	0.6
567	0.9850	0.5	0.6
575	0.9925	0.7	0.7
581.5	0.9955	0.7	0.7
611	1	0.7	0.7

r =	0.05625	
		0% property
rec	2,125,973	2,125,973
flood	4,273,763	0
total	6,399,736	2,125,973
93,967,603	Failure Repair	

	PrDist
distress<500	0.1
distress500-525	0.16
distress525-550	0.33
distress550575	0.5
distress>575	0.7
	PF|Dist
failure<500	0.1
failure500525	0.16
failure525550	0.49
failure550575	0.6
failure>575	0.7

LoL	183	PV Property	$36,137,523	SumPV_BFG	$6,305,410	SumPV_Repair	76,951,779
Total $ Loss	$119,394,712						

survive	Time	Elevation	PrDist	Distress	Pf|Dist	Binomial	Fail	PropertyFail	Propertry NoFail	Property $	LOL Fail	PV Property	PV BenefitsFG	Distress Repair	Dam Repair	PV Repair
1	0	499	0.1	1	0.1	0	0	0	0	0	0	0	0	1,457,983	0	1,457,983
1	1	524	0.16	0	0	0	0	0	0	0	0	0	0	0	0	0
1	2	513	0.16	0	0	0	0	0	0	0	0	0	0	0	0	0
1	3	509	0.16	0	0	0	0	0	0	0	0	0	0	0	0	0
0	4	538	0.33	1	0.49	1	1	88,924,150	43,943,546	44,980,603	183	36,137,523	1,708,012	0	93,967,603	75,493,796
0	5	560	0	0	0	0	0	0	0	0	0	0	1,617,053	0	0	0
0	6	566	0	0	0	0	0	0	0	0	0	0	1,530,937	0	0	0
0	7	498	0	0	0	0	0	0	0	0	0	0	1,449,408	0	0	0
0	8	520	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	9	499	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	10	510	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	11	564	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	12	540	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	13	498	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	14	499	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	15	508	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	16	546	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	17	513	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	18	497	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	19	506	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	20	519	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	21	519	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	22	531	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	23	547	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	24	521	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	25	524	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	26	516	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	27	510	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	28	521	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	29	520	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	30	518	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	31	508	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	32	541	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	33	535	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	34	516	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	35	524	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	36	515	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	37	509	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	38	521	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	39	536	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	40	526	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	41	513	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	42	539	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	43	536	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	44	527	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	45	533	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	46	511	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	47	521	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	48	554	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	49	545	0	0	0	0	0	0	0	0	0	0	0	0	0	0

PLATE 28

S3: Slurry Cutoff Wall 500 feet Upstream With Blanket and Deep Panels

Elevation	Cumulative Freq	PrDist	PF|Dist
497	0	0.1	0.1
500	0.138	0.1	0.16
505	0.182	0.1	0.16
525	0.6850	0.16	0.49
550	0.9420	0.5	0.6
567	0.9850	0.5	0.6
575	0.9925	0.7	0.7
581.5	0.9955	0.7	0.7
611	1	0.7	0.7

r =	0.05625	
		0% property
rec	2,125,973	2,125,973
flood	4,273,763	0
total	6,399,736	2,125,973
93,967,603	Failure Repair	

	PrDist
distress<500	0.1
distress500-525	0.1
distress525-550	0.16
distress550575	0.5
distress>575	0.7

	PF|Dist
failure<500	0.1
failure500525	0.16
failure525550	0.49
failure550575	0.6
failure>575	0.7

LoL	183	PV Property	$36,137,523	SumPV_BFG	$6,305,410	SumPV_Repair	75,493,796	Total $ Loss	$117,936,729

survive	Time	Elevation	PrDist	Distress	Pf|Dist	Binomial	Fail	PropertyFail	Propertry NoFail	Property $	LOL Fail	PV Property	PV BenefitsFG	Distress Repair	Dam Repair	PV Repair
1	0	499	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0
1	1	524	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0
1	2	513	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0
1	3	509	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0
0	4	538	0.16	1	0.49	1	1	88,924,150	43,943,546	44,980,603	183	36,137,523	1,708,012	0	93,967,603	75,493,796
0	5	560	0	0	0	0	0	0	0	0	0	0	1,617,053	0	0	0
0	6	566	0	0	0	0	0	0	0	0	0	0	1,530,937	0	0	0
0	7	498	0	0	0	0	0	0	0	0	0	0	1,449,408	0	0	0
0	8	520	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	9	499	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	10	510	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	11	564	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	12	540	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	13	498	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	14	499	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	15	508	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	16	546	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	17	513	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	18	497	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	19	506	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	20	519	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	21	519	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	22	531	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	23	547	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	24	521	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	25	524	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	26	516	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	27	510	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	28	521	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	29	520	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	30	518	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	31	508	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	32	541	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	33	535	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	34	516	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	35	524	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	36	515	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	37	509	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	38	521	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	39	536	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	40	526	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	41	513	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	42	539	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	43	536	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	44	527	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	45	533	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	46	511	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	47	521	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	48	554	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	49	545	0	0	0	0	0	0	0	0	0	0	0	0	0	0

PLATE 29

S4-A: Concrete Cutoff Wall to Rock at Toe With Blanket

Elevation	Cumulative Freq	PrDist	PF|Dist
497	0	0.1	0.1
500	0.138	0.16	0.16
505	0.182	0.16	0.16
525	0.6850	0.33	0.49
550	0.9420	0.5	0.6
567	0.9850	0.5	0.6
575	0.9925	0.7	0.7
581.5	0.9955	0.7	0.7
611	1	0.7	0.7

		0% property
r =	0.05625	
rec	2,125,973	2,125,973
flood	4,273,763	0
total	6,399,736	2,125,973
93,967,603	Failure Repair	

	PrDist
distress<500	0.1
distress500-525	0.16
distress525-550	0.33
distress550575	0.5
distress>575	0.7

	PF|Dist
failure<500	0.1
failure500525	0.16
failure525550	0.49
failure550575	0.6
failure>575	0.7

LoL	280	PV Property	$21,468,539	SumPV_BFG	$5,969,619	SumPV_Repair	73,319,597
Total $ Loss	$100,757,754						

survive	Time	Elevation	PrDist	Distress	Pf|Dist	Binomial	Fail	PropertyFail	Propertry NoFail	Property $	LOL Fail	PV Property	PV BenefitsFG	Distress Repair	Dam Repair	PV Repair
1	0	499	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0
1	1	524	0.16	0	0	0	0	0	0	0	0	0	0	0	0	0
1	2	513	0.16	1	0.16	0	0	0	0	0	0	0	0	2,059,718	0	1,846,181
1	3	509	0.16	0	0	0	0	0	0	0	0	0	0	0	0	0
1	4	538	0.33	0	0	0	0	0	0	0	0	0	0	0	0	0
0	5	560	0.5	1	0.6	1	1	136,123,385	107,898,246	28,225,139	280	21,468,539	1,617,053	0	93,967,603	71,473,416
0	6	566	0	0	0	0	0	0	0	0	0	0	1,530,937	0	0	0
0	7	498	0	0	0	0	0	0	0	0	0	0	1,449,408	0	0	0
0	8	520	0	0	0	0	0	0	0	0	0	0	1,372,221	0	0	0
0	9	499	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	10	510	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	11	564	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	12	540	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	13	498	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	14	499	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	15	508	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	16	546	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	17	513	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	18	497	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	19	506	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	20	519	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	21	519	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	22	531	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	23	547	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	24	521	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	25	524	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	26	516	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	27	510	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	28	521	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	29	520	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	30	518	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	31	508	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	32	541	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	33	535	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	34	516	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	35	524	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	36	515	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	37	509	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	38	521	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	39	536	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	40	526	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	41	513	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	42	539	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	43	536	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	44	527	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	45	533	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	46	511	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	47	521	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	48	554	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	49	545	0	0	0	0	0	0	0	0	0	0	0	0	0	0

PLATE 30

S4-B: Concrete Cutoff Wall Into Rock at Toe With Blanket

Elevation	Cumulative Freq	PrDist	PF|Dist
497	0	0.1	0.1
500	0.138	0.1	0.16
505	0.182	0.1	0.16
525	0.6850	0.16	0.49
550	0.9420	0.49	0.6
567	0.9850	0.49	0.6
575	0.9925	0.6	0.7
581.5	0.9955	0.6	0.7
611	1	0.6	0.7

r =	0.05625	
		0% property
rec	2,125,973	2,125,973
flood	4,273,763	0
total	6,399,736	2,125,973
93,967,603	Failure Repair	

	PrDist
distress<500	0.1
distress500-525	0.1
distress525-550	0.16
distress550575	0.49
distress>575	0.6

	PF|Dist
failure<500	0.1
failure500525	0.16
failure525550	0.49
failure550575	0.6
failure>575	0.7

LoL	183
PV Property	$36,137,523
SumPV_BFG	$6,305,410
SumPV_Repair	75,493,796
Total $ Loss	$117,936,729

survive	Time	Elevation	PrDist	Distress	Pf|Dist	Binomial	Fail	PropertyFail	Propertry NoFail	Property $	LOL Fail	PV Property	PV BenefitsFG	Distress Repair	Dam Repair	PV Repair
1	0	499	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0
1	1	524	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0
1	2	513	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0
1	3	509	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0
0	4	538	0.16	1	0.49	1	1	88,924,150	43,943,546	44,980,603	183	36,137,523	1,708,012	0	93,967,603	75,493,796
0	5	560	0	0	0	0	0	0	0	0	0	0	1,617,053	0	0	0
0	6	566	0	0	0	0	0	0	0	0	0	0	1,530,937	0	0	0
0	7	498	0	0	0	0	0	0	0	0	0	0	1,449,408	0	0	0
0	8	520	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	9	499	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	10	510	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	11	564	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	12	540	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	13	498	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	14	499	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	15	508	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	16	546	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	17	513	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	18	497	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	19	506	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	20	519	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	21	519	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	22	531	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	23	547	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	24	521	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	25	524	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	26	516	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	27	510	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	28	521	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	29	520	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	30	518	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	31	508	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	32	541	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	33	535	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	34	516	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	35	524	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	36	515	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	37	509	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	38	521	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	39	536	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	40	526	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	41	513	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	42	539	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	43	536	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	44	527	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	45	533	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	46	511	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	47	521	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	48	554	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	49	545	0	0	0	0	0	0	0	0	0	0	0	0	0	0

PLATE 31

S4-C: Concrete Wall Into Rock Centerline Clay Core Trench With Blanket

Elevation	Cumulative Freq	PrDist	PF|Dist
497	0	0.1	0.1
500	0.138	0.1	0.1
505	0.182	0.1	0.1
525	0.6850	0.1	0.1
550	0.9420	0.25	0.16
567	0.9850	0.25	0.16
575	0.9925	0.49	0.5
581.5	0.9955	0.49	0.5
611	1	0.49	0.5

r =	0.05625		
		0% property	
rec	2,125,973	2,125,973	
flood	4,273,763	0	
total	6,399,736	2,125,973	
93,967,603	Failure Repair		

	PrDist
distress<500	0.1
distress500-525	0.1
distress525-550	0.1
distress550575	0.25
distress>575	0.49

	PF|Dist
failure<500	0.1
failure500525	0.1
failure525550	0.1
failure550575	0.16
failure>575	0.5

LoL	280	PV Property	$21,468,539	SumPV_BFG	$5,969,619	SumPV_Repair	71,473,416
Total $ Loss	$98,911,573						

survive	Time	Elevation	PrDist	Distress	Pf|Dist	Binomial	Fail	PropertyFail	Propertry NoFail	Property $	LOL Fail	PV Property	PV BenefitsFG	Distress Repair	Dam Repair	PV Repair
1	0	499	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0
1	1	524	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0
1	2	513	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0
1	3	509	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0
1	4	538	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0
0	5	560	0.25	1	0.16	1	1	136,123,385	107,898,246	28,225,139	280	21,468,539	1,617,053	0	93,967,603	71,473,416
0	6	566	0	0	0	0	0	0	0	0	0	0	1,530,937	0	0	0
0	7	498	0	0	0	0	0	0	0	0	0	0	1,449,408	0	0	0
0	8	520	0	0	0	0	0	0	0	0	0	0	1,372,221	0	0	0
0	9	499	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	10	510	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	11	564	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	12	540	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	13	498	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	14	499	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	15	508	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	16	546	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	17	513	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	18	497	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	19	506	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	20	519	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	21	519	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	22	531	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	23	547	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	24	521	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	25	524	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	26	516	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	27	510	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	28	521	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	29	520	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	30	518	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	31	508	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	32	541	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	33	535	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	34	516	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	35	524	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	36	515	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	37	509	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	38	521	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	39	536	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	40	526	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	41	513	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	42	539	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	43	536	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	44	527	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	45	533	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	46	511	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	47	521	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	48	554	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	49	545	0	0	0	0	0	0	0	0	0	0	0	0	0	0

PLATE 32

S4-D: Concrete Wall to Rock Centerline Without Blanket

Elevation	Cumulative Freq	PrDist	PF|Dist
497	0	0.05	0.05
500	0.138	0.05	0.05
505	0.182	0.05	0.05
525	0.6850	0.1	0.1
550	0.9420	0.16	0.16
567	0.9850	0.16	0.16
575	0.9925	0.25	0.25
581.5	0.9955	0.25	0.25
611	1	0.25	0.25

Highway HH		
Days of Delay	1000	
# Vehicles/Day	1,543.36	
Median Hourly Income	$14.48	
Time of Delay	17.58	value per hour
% of traffic - work	0.652	$7.79
% of traffic - recreation/social	0.121	$8.69
% of traffic - other	0.227	$9.34
Total Traffic Delay Cost	$3,731,355.26	

r =	0.05625	
		0% property
rec	2,125,973	2,125,973
flood	4,273,763	0
total	6,399,736	2,125,973
93,967,603	Failure Repair	

	PrDist
distress<500	0.05
distress500-525	0.05
distress525-550	0.1
distress550575	0.16
distress>575	0.25

	PF|Dist
failure<500	0.05
failure500525	0.05
failure525550	0.1
failure550575	0.16
failure>575	0.25

LoL	0	PV Property	$0	SumPV_BFG	$0	SumPV_Repair	0

Total $ Loss	$3,731,355

survive	Time	Elevation	PrDist	Distress	Pf|Dist	Binomial	Fail	PropertyFail	Propertry NoFail	Property $	LOL Fail	PV Property	PV BenefitsFG	Distress Repair	Dam Repair	PV Repair
1	0	499	0.05	0	0	0	0	0	0	0	0	0	0	0	0	0
1	1	524	0.05	0	0	0	0	0	0	0	0	0	0	0	0	0
1	2	513	0.05	0	0	0	0	0	0	0	0	0	0	0	0	0
1	3	509	0.05	0	0	0	0	0	0	0	0	0	0	0	0	0
1	4	538	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0
1	5	560	0.16	0	0	0	0	0	0	0	0	0	0	0	0	0
1	6	566	0.16	0	0	0	0	0	0	0	0	0	0	0	0	0
1	7	498	0.05	0	0	0	0	0	0	0	0	0	0	0	0	0
1	8	520	0.05	0	0	0	0	0	0	0	0	0	0	0	0	0
1	9	499	0.05	0	0	0	0	0	0	0	0	0	0	0	0	0
1	10	510	0.05	0	0	0	0	0	0	0	0	0	0	0	0	0
1	11	564	0.16	0	0	0	0	0	0	0	0	0	0	0	0	0
1	12	540	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0
1	13	498	0.05	0	0	0	0	0	0	0	0	0	0	0	0	0
1	14	499	0.05	0	0	0	0	0	0	0	0	0	0	0	0	0
1	15	508	0.05	0	0	0	0	0	0	0	0	0	0	0	0	0
1	16	546	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0
1	17	513	0.05	0	0	0	0	0	0	0	0	0	0	0	0	0
1	18	497	0.05	0	0	0	0	0	0	0	0	0	0	0	0	0
1	19	506	0.05	0	0	0	0	0	0	0	0	0	0	0	0	0
1	20	519	0.05	0	0	0	0	0	0	0	0	0	0	0	0	0
1	21	519	0.05	0	0	0	0	0	0	0	0	0	0	0	0	0
1	22	531	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0
1	23	547	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0
1	24	521	0.05	0	0	0	0	0	0	0	0	0	0	0	0	0
1	25	524	0.05	0	0	0	0	0	0	0	0	0	0	0	0	0
1	26	516	0.05	0	0	0	0	0	0	0	0	0	0	0	0	0
1	27	510	0.05	0	0	0	0	0	0	0	0	0	0	0	0	0
1	28	521	0.05	0	0	0	0	0	0	0	0	0	0	0	0	0
1	29	520	0.05	0	0	0	0	0	0	0	0	0	0	0	0	0
1	30	518	0.05	0	0	0	0	0	0	0	0	0	0	0	0	0
1	31	508	0.05	0	0	0	0	0	0	0	0	0	0	0	0	0
1	32	541	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0
1	33	535	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0
1	34	516	0.05	0	0	0	0	0	0	0	0	0	0	0	0	0
1	35	524	0.05	0	0	0	0	0	0	0	0	0	0	0	0	0
1	36	515	0.05	0	0	0	0	0	0	0	0	0	0	0	0	0
1	37	509	0.05	0	0	0	0	0	0	0	0	0	0	0	0	0
1	38	521	0.05	0	0	0	0	0	0	0	0	0	0	0	0	0
1	39	536	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0
1	40	526	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0
1	41	513	0.05	0	0	0	0	0	0	0	0	0	0	0	0	0
1	42	539	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0
1	43	536	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0
1	44	527	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0
1	45	533	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0
1	46	511	0.05	0	0	0	0	0	0	0	0	0	0	0	0	0
1	47	521	0.05	0	0	0	0	0	0	0	0	0	0	0	0	0
1	48	554	0.16	0	0	0	0	0	0	0	0	0	0	0	0	0
1	49	545	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0

PLATE 33

S4-E: Concrete Cutoff Into Rock Centerline Clay Core Trench Sinkhole to Left With Blanket

Elevation	Cumulative Freq	PrDist	PF|Dist
497	0	0.16	0.1
500	0.138	0.16	0.16
505	0.182	0.16	0.16
525	0.6850	0.16	0.33
550	0.9420	0.5	0.5
567	0.9850	0.5	0.5
575	0.9925	0.8	0.6
581.5	0.9955	0.8	0.6
611	1	0.8	0.6

r =	0.05625	
		0% property
rec	2,125,973	2,125,973
flood	4,273,763	0
total	6,399,736	2,125,973
93,967,603	Failure Repair	

	PrDist
distress<500	0.16
distress500-525	0.16
distress525-550	0.16
distress550575	0.5
distress>575	0.8

	PF|Dist
failure<500	0.1
failure500525	0.16
failure525550	0.33
failure550575	0.5
failure>575	0.6

LoL	280	PV Property	$21,468,539	SumPV_BFG	$5,969,619	SumPV_Repair	72,492,935
Total $ Loss	$99,931,092						

survive	Time	Elevation	PrDist	Distress	Pf|Dist	Binomial	Fail	PropertyFail	Propertry NoFail	Property $	LOL Fail	PV Property	PV BenefitsFG	Distress Repair	Dam Repair	PV Repair
1	0	499	0.16	0	0	0	0	0	0	0	0	0	0	0	0	0
1	1	524	0.16	0	0	0	0	0	0	0	0	0	0	0	0	0
1	2	513	0.16	0	0	0	0	0	0	0	0	0	0	0	0	0
1	3	509	0.16	1	0.16	0	0	0	0	0	0	0	0	550,535	0	467,180
1	4	538	0.16	1	0.33	0	0	0	0	0	0	0	0	687,499	0	552,339
0	5	560	0.5	1	0.5	1	1	136,123,385	107,898,246	28,225,139	280	21,468,539	1,617,053	0	93,967,603	71,473,416
0	6	566	0	0	0	0	0	0	0	0	0	0	1,530,937	0	0	0
0	7	498	0	0	0	0	0	0	0	0	0	0	1,449,408	0	0	0
0	8	520	0	0	0	0	0	0	0	0	0	0	1,372,221	0	0	0
0	9	499	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	10	510	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	11	564	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	12	540	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	13	498	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	14	499	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	15	508	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	16	546	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	17	513	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	18	497	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	19	506	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	20	519	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	21	519	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	22	531	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	23	547	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	24	521	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	25	524	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	26	516	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	27	510	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	28	521	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	29	520	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	30	518	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	31	508	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	32	541	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	33	535	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	34	516	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	35	524	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	36	515	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	37	509	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	38	521	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	39	536	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	40	526	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	41	513	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	42	539	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	43	536	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	44	527	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	45	533	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	46	511	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	47	521	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	48	554	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	49	545	0	0	0	0	0	0	0	0	0	0	0	0	0	0

PLATE 34