Crazy Mountain

Reservoir Regulation Manual

January 2009

Reservoir System Analysis
Hydrologic Engineering Center
Davis, CA

Crazy Mountain
Reservoir Regulation Manual
PERTINENT DATA

General:

Location of Dam:	Rodgers County on Ventura River, 95 miles above the mouth
Drainage Area above Dam:	3,115 square miles 1 inch of runoff = 177,000 acre-feet
Time of Water Travel:	From headwaters to dam = 9 days From dam to River Pointe = 32 hours
Channel Capacity below Dam:	10,000 cfs from 15 December to 30 April 6,000 cfs from 1 May to 14 December
Estimated Costs:	A bunch of money (1957)
Purpose:	Flood Control, Water Supply, Hydropower, ResSim Instruction

Dam:

Type:	Rolled, earth-filled	Crest Elevation:	743 ft, NGVD
Length:	1,400 ft	Top Width:	26 ft
Height:	101 ft		

Spillway:

Type:	Chute spillway with uncontrolled concrete weir		
Crest Elevation:	712 ft, NGVD	Length:	500 ft
Maximum design discharge at elevation 718.0 feet:	24,700 cfs		

Outlet Works:

Type:	1 circular concrete conduit	Diameter:	23 ft
Gates:	Electric drum hoist operated slide gate		
Maximum design discharge at elevation 712.0 feet:	20,000 cfs		

Power Plant:

Installed capacity:	80 megawatts (overload factor of 1.15)		
Efficiency:	87%, constant, based on constant tailwater elevation of 640.8 ft		
Station Use Flow	2.3 cfs	Penstock Head Loss	1.5 ft
Maximum design discharge at elevation 712.0 feet:	20,000 cfs		

Reservoir:

Pool	Elevations (feet m.s.l.)	Storage (ac-ft)
Major Flood Control	712	420,960
Normal Flood Control	707	309,146
Seasonal Conservation	679-686	15,746-42,560
Drought Contingency	677	11,798
Inactive	646	0

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Section I

DESCRIPTION OF PROJECT

Location:
Crazy Mountain Reservoir is located on the headwaters of the Ventura River, 95 miles upstream of its mouth, in Rodgers County.

Purpose:
Public Law 177-95 authorized the reservoir for flood control and water supply in 1957. Public Laws 234-12 and 257-79 authorized recreation and fish and wildlife enhancement, respectively, in 1972. Hydropower was authorized in 2002 by Public Law 362-43.

Physical Components:

a. Embankment: The embankment is a rolled, filled-earth structure, containing a whole lot of material, with an impervious core and pervious flanks. The maximum height above the riverbed is 101 ft. The length of the crest is 1,400 ft at an elevation of 743 ft NGVD, and the maximum base width is approximately 670 ft. The upstream slope is 1 on 3.5 below, and 1 on 2.5 above, an elevation of 712 ft. The downstream slope is 1 on 2.5. Upstream and downstream faces are covered with riprap over gravel.
b. Spillway: The chute spillway is located in the right bluff. The weir is curved, has an ogee section, is 500 ft in length, and its crest is at elevation 712.0 ft NGVD. The spillway channel downstream from the weir for a distance of approximately 600 ft is paved with concrete and concrete training walls protect the sides of the channel. The spillway discharge curve is provided in Appendix C.
c. Outlet Works: Normal discharge from the reservoir is accomplished by means of a gated conduit beneath the earth embankment at the toe of the left bluff. The conduit is a single reinforced-concrete tube 23 ft in diameter. The length, including the intake structure and transition section, is 410 ft. One gate, operated by an electrically driven drum hoist, is located in the intake structure. The high discharge velocities from the conduit are reduced in a stilling basin, which is 180.33 ft in length and 75.35 ft wide at the downstream end. The capacity of the outlet structure is about 20,000 cfs when the reservoir is filled to spillway crest level. The outlet discharge capacity curve is provided in Appendix B. This outlet is also the penstock to the power plant.
d. Power Plant: Commissioned in 2002 to produce power for the local area, the powerhouse is a recent addition to the Crazy Mountain reservoir project. The power plant is located just downstream of the left embankment of the dam. A headrace channel leads to an intake structure with a single penstock passing flow to a conventional power turbine with an installed capacity of 80 megawatts (with an overload factor of 1.15) produces power for the local area. The plant efficiency is a constant 87% based on a constant tail water elevation of 640.8 ft. Station use is estimated at 2.3 cfs with a hydraulic loss of 1.5 ft.

Downstream Information:
Two additional rivers join the Ventura, below the project, before it empties into the Grand River. The Italian River confluence is located between the towns of Rockville and Greenfield. The Oak River joins the Ventura below Greenfield, but above River Pointe. A project to divert water from Rockville to the town of Bethesda (at the headwaters of the Oak River) has been discussed to aid in reducing flows at Greenfield.

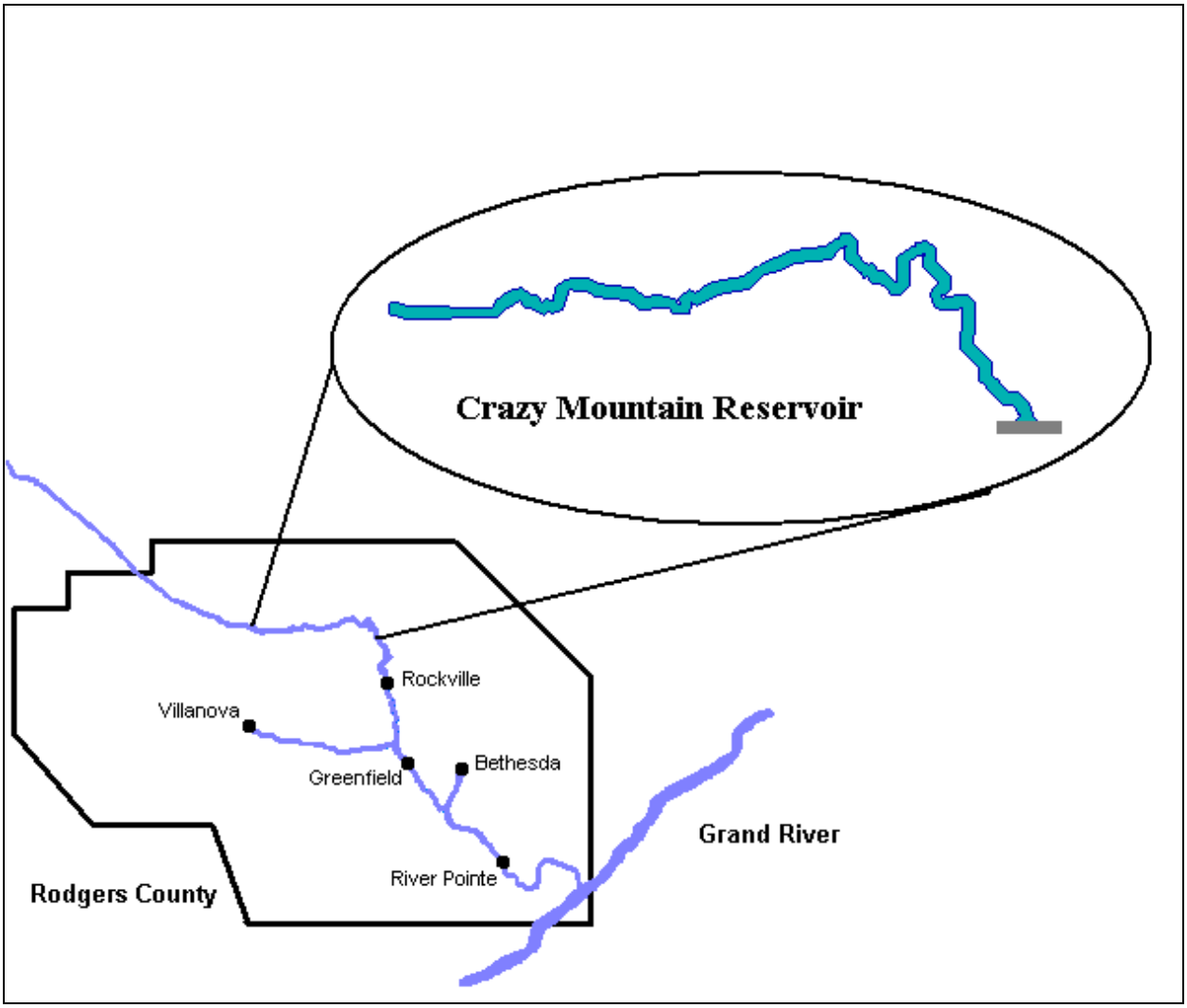


Figure 1-1. Crazy Mountain Reservoir Location Map

Section II

WATERSHED CHARACTERISTICS

General Characteristics:

The watershed above Crazy Mountain reservoir is largely undeveloped land with a total area of 3,115 square miles. The watershed surrounding the upper reach of the Ventura River is long and narrow in shape and generally flat. Types of cover vary from open fields and meadows to forest. These conditions tend to create slowly rising flood hydrographs with lower peaks and longer durations. However, there has been a lot of interest in development of the lands above the reservoir for both farming and residential uses. This development, should it occur, may change the characteristics of the typical storm hydrograph.

The average annual runoff of the Ventura River above the dam is about 1.4 million ac-ft. This is equivalent to approximately 7.8 inches from the drainage area. Watershed data has been collected over the past 95 years.

Climate:

The watershed experiences a wide temperature range with winters being cold and dry and spring and summer typically warm and wet. Information on the average precipitation and pan evaporation from a gage located near Rockville are provided in Tables 2-1 and 2-2.

Table 2-1.
Average Precipitation (inches)

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Rockville	1.15	1.11	2.17	3.08	4.23	4.70	3.97	3.81	3.92	2.40	1.78	1.19	33.96
Greenfield	1.02	1.01	2.15	3.40	3.77	4.34	4.22	4.05	3.61	2.33	2.05	1.46	33.87
River Pointe	1.05	1.02	2.30	3.56	4.09	4.48	4.77	3.94	3.44	2.60	2.26	1.45	35.22

Table 2-2.
Average Pan Evaporation (inches)

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rockville	--	--	--	4.13	5.64	6.83	7.27	6.19	4.63	3.31	1.50	--

Section III

WATER CONTROL PLAN

General Objectives:

Crazy Mountain reservoir was originally authorized for the purposes of flood control, hydropower, and water supply. Its uses were later expanded to include recreation and fish management. The primary purposes remain flood control and hydropower. Crazy Mountain reservoir is now operated for these purposes on the basis of the following objectives:

1. To restrict flows in the Ventura River to the controlling flow rates below the dam, at Greenfield, and at River Pointe (insofar as possible).
2. To provide the maximum practicable amount of conservation storage for irrigation, domestic, and municipal uses (without impairing the flood control functions of the reservoir).
3. To provide the maximum practicable amount of power generation (without impairing the flood control functions of the reservoir).
4. To provide sufficient releases to protect habitat for fish, particularly during spawning seasons.
5. To provide sufficient releases to supply water to the cities of Rockville and Greenfield.
6. To maintain a minimum pool level of at least 677 feet during periods of critical drought (insofar as possible, to not compromise releases for water supply or fish habitat protection).

Definition of Operating Zones:

Pool:		Top Elevation (ft):	Total Storage (ac-ft):
Major Flood Control		712	420,960
Normal Flood Control		707	309,146
Conservation			
Winter	01Jan	683	28,070
Winter	15Feb	683	28,070
Winter	20Mar	679	15,746
Spring	01May	679	15,746
Spring	20May	683	28,070
Summer	15Sep	683	28,070
Fall	01Oct	684	32,685
Fall	21Oct	685	37,300
Fall	15Nov	686	42,560
Fall	01Dec	686	42,560
Fall	15Dec	683	28,070
Winter	31Dec	683	28,070
Drought Contingency		677	11,798
Inactive		646	0

Flood Control:

The flood control pool has been subdivided into normal and major flood control zones.

Normal Flood Control:

The normal flood control pool is from the top of the seasonally varying conservation pool to 707 ft. This pool provides between 266,586 and 293,400 ac-ft of storage with the largest storage available during the spring storm season. Insofar as possible, the pool is operated to avoid exceeding downstream channel capacity at Greenfield, River Pointe, and below the dam. These locations are most susceptible to flooding along the river.

The maximum allowed flows at Greenfield are 12,000 cfs during the growing season and 18,000 cfs outside of it. These flows correspond to estimated failure stages of levees on (i) the east side of the river that protects agricultural areas and (ii) the west side of the river that protect the city of Greenville. Maximum allowed flows at River Pointe are 40,000 cfs during the growing season and 48,000 cfs outside of it. There is also a maximum release limitation at the dam of 6,000 cfs during the growing season and 10,000 cfs outside of it.

Max Flow @ Greenfield

Max Flow @ River Pointe

Max Release @ Dam

Additionally, releases should not increase by more than 1,000 cfs per hour, or decrease by more than 500 cfs per hour.

Flow Rate of Change

At no time should the release from the normal flood control pool be less than 700 cfs to maintain required flows for fish downstream of the reservoir.

Min Release @ Dam – Normal Cond.

Schedule A is for the normal flood control pool operation:

Schedule A
Normal Flood Control Pool Operation

Date/Condition	Dam Operation
All Dates	Guide curve up to max. flow at downstream control points. Do not release less than 700 cfs.
Non-Growing Season 15 Dec – 30 Apr	Do not release more than 10,000 cfs.
Non-Growing Season: to the extent possible, limit flows at downstream control points: Greenfield: 18,000 cfs River Pointe: 48,000 cfs	Operate for downstream capacities.
Growing Season 01 May – 14 Dec	Do not release more than 6,000 cfs.
Growing Season: to the extent possible, limit flows at downstream control points: Greenfield: 12,000 cfs River Pointe: 40,000 cfs	Operate for downstream capacities.

Section III (continued)

Major Flood Control:

The major flood control pool goes from 707 ft to 712 ft and provides an additional 111,814 ac-ft of flood storage. The pool is operated according to a release schedule to ensure the dam is not overtopped. Allowed releases are reduced during the summer growing season, from 1 May to 14 December, because large tracts of agricultural land located downstream of Greenfield are particularly prone to flooding.

(Sched. B) Max Release Function 0f Elev. - Rising Inflow Condition

The release schedule is defined by a maximum allowable release based on reservoir pool elevation. During the growing season, the allowable release increases linearly from 7,000 cfs at an elevation of 707 ft to 9,000 cfs at 711 ft. It increases linearly again between 711 ft and 712 ft to 20,000 cfs. During the non-growing season, the maximum allowable release is 10,000 cfs from elevations 707 ft up to 711 ft. At 711 ft, the maximum allowable release increases to 11,000 cfs. For elevations between 711 and 712 feet, maximum allowable release increases linearly up to 20,000 cfs at elevation 712 feet. At all times of the year and at pool elevations above 712 ft, gates must be kept fully open. The release schedule applies only when reservoir inflow is rising and inflow increases by more than 500 cfs over a 3-hour period of time.

Maintain Peak Release - Falling Inflow Condition

After inflow starts to fall, the maximum release made according to the release schedule can be maintained until the reservoir level drops below 707 feet.

Schedule B is for the major flood control pool operation:

Schedule B
Major Flood Control Pool Operation

Condition	Date/Dam Operation
Rising Inflow	
15 Dec – 30 Apr →	Non-Growing Season: Elev 707-711 – max release is 10,000 cfs 711 – max release is 11,000 and increases linearly to 712 – max release of 20,000 cfs
01 May – 14 Dec →	Growing Season: Elev 707 – max release is 7,000 cfs and increases linearly to 711 – max release is 9,000 and increases linearly to 712 – max release of 20,000 cfs Above elev 712 – gates fully open, all dates
Falling or Constant Inflow	Maintain peak release established while pool was rising until elevation returns to 707 feet. Resume schedule A releases.

Section III (continued)

Hydropower:

The power pool is defined as the drought contingency plus the conservation zone.

Hydropower is scheduled Monday through Friday from 0600-1000 hours to meet contractual requirements. Secondary power is produced outside the scheduled generation periods as a result of other project purpose release requirements. A monthly schedule of required hydropower has been developed for the operation of the plant. The requirements are listed in Table 3-1.

Hydropower Schedule (Monthly Req.)

Table 3-1.
Monthly Energy Requirements (MWH)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1250	1250	1250	2500	2500	2500	2500	1875	1875	1875	1250	1250

Water Supply:

The conservation pool has been subdivided into conservation and drought contingency zones.

Conservation Operations:

The Ventura River is used for water supply for the cities of Rockville and Greenfield, and the reservoir must maintain minimum flows for that purpose. During normal operations, flow at Rockville should be maintained at or above 2,500 cfs. If the reservoir pool drops below 680 ft NGVD the flow is allowed to decrease linearly with the elevation from 2,500 cfs at 680 ft to 500 cfs at 650 ft. Likewise, during normal operations, the flow at Greenfield should be maintained at or above 3,500 cfs. If the pool elevation drops below 680 ft the flow is allowed to decrease linearly with the elevation from 3,500 cfs at 680 ft to 700 cfs at 650 ft. **If the reservoir is below 650 ft no releases for water supply are made**.

Min Flow @ Rockville

Min Flow @ Greenfield

Table 3-2.
Required Flow at Rockville

Pool Elevation (ft)	Flow (cfs)
683	2,500
680	2,500
650	500
649.99	0

Table 3-3.
Required Flow at Greenfield

Pool Elevation (ft)	Flow (cfs)
683	3,500
680	3,500
650	700
649.99	0

Min Release @ Dam - Normal Cond.

At no time should the release from the conservation pool be less than 700 cfs to maintain required flows for fish downstream of the reservoir.

Max Release @ Dam

Max Flow @ Greenfield

Max Flow @ River Pointe

The same restrictions on maximum allowable release from the normal flood control pool also govern releases from the conservation pool. Maximum release from the dam must be less than 6,000 cfs during the growing season and 10,000 cfs during the non-growing season. The maximum allowable flows at Greenfield are 12,000 cfs during the growing season and 18,000 cfs for the non-growing season. At River Pointe, maximum allowable flows are 40,000 cfs during the growing season and 48,000 cfs for the non-growing season.

Specified Required Flow - Nutty Canal

Water is also diverted directly from the Crazy Mountain pool through the Nutty Canal for irrigation in fields located south of the reservoir; this water is only diverted when the reservoir level is above the drought contingency zone. The minimum required diversion varies monthly, with more water diverted during the early part of the growing season. The maximum channel capacity of the diversion is 2,000 cfs.

Table 3-4.
Required Flow through Nutty Canal (cfs)

Jan	Mar	Apr	May	Jul	Aug	Sep	Oct
10	100	500	1,000	800	500	100	10

Drought Contingency Operations:

Min Flow @ Rockville & Greenfield

During periods of extended drought, releases are decreased to maintain a minimum reservoir level. As mentioned above, the required flows at Rockville and Greenfield begin dropping at a reservoir elevation of 680 ft. These curves continue into the drought contingency pool down to an elevation of 650 ft.

Min Release @ Dam - Drought Condition

Releases for fish management can also be reduced during periods of extended drought when reservoir level drops into the drought contingency pool. During the spring spawning season, typically from 15 April to 30 April, releases can be lowered to 500 cfs. Outside of the spawning season the minimum fish release should be 300 cfs.

Table 3-5.
Required Release for Fish (cfs)

Condition	Release
Normal	700
Drought:	
15 Apr – 30 Apr → Spawning Season	500
01 Jan – 14 Apr & 01 May – 31 Dec → Non-Spawning Season	300

Appendix A - Physical Data

This Appendix contains physical data relevant to reservoir system analyses involving Crazy Mountain Reservoir.

Table A-1.
Reach Names and Routing Parameters

		Muskingum Routing Parameters		
REACH LOCATION	**REACH NAME**	**K**	**X**	**No. of Subreaches**
Along **Ventura River**, from **Crazy Mt. Outflow Junction** to **Rockville Junction**	VENT Crazy Mt. Outflow to Rockville	4	0.1	4
Along **Ventura River**, from **Rockville Junction** to **Italian River**	VENT Rockville to Italian River	8	0.1	8
Along **Ventura River**, from **Italian River** to **Greenfield Junction**	VENT Italian River to Greenfield	4	0.1	4
Along **Ventura River**, from **Greenfield Junction** to **Oak River**	VENT Greenfield to Oak River	8	0.1	8
Along **Ventura River**, from **Oak River** to **River Pointe**	VENT Oak River to River Pointe	8	0.1	8
Along **Italian River**, from **Villanova Junction** to **Ventura River**	ITAL Villanova to Ventura River	8	0.1	8
Along **Oak River**, from **Bethesda Junction** to **Ventura River**	OAK Bethesda to Ventura River	8	0.1	8

Table A-2.
Junction and Local Inflow Names

Junction	**Name of Local Inflow**	**Factor**
Crazy Mt. Inflow JCT	Crazy Mt. Local Inflow	1.0
Rockville	Rockville Local Inflow	1.0
Villanova	Villanova Local Inflow	1.0
Ventura + Italian		
Greenfield	Greenfield Local Inflow	1.0
Bethesda	Bethesda Local Inflow	1.0
Ventura + Oak		
River Pointe	River Pointe Local Inflow	1.0

Table A-3.
Elevation-Storage-Area Relationship

Crazy Mountain Pool		
Elevation (ft)	Storage (ac-ft)	Area (acres)
646	0	0
677	11798	1852
679	15746	2384
680	17720	2650
683	28070	4050
685	37300	4900
686	42560	5370
690	77030	8060
695	118800	11290
700	183710	14610
705	266790	18790
707	309146	20582
712	420960	25040
715	501670	27920
720	644470	30200

Table A-4.
Controlled Outlet Data

Controlled Outlet	
No. of Gates = 1	
Elevation (ft)	**Maximum Outlet Capacity (cfs)**
646	0
650	400
655	1200
660	2700
665	4700
670	6900
675	8700
680	10800
683	11800
686	12800
690	14200
695	15700
700	17000
705	18500
710	19600
712	20000
715	20600
720	21500

Table A-5.
Uncontrolled Outlet Data

Uncontrolled Outlet	Emergency Spillway
Length (ft)	500.0
Outlet Elevation (ft)	712.0
Elevation (ft)	**Outflow (cfs)**
712	0
713	1500
714	4500
715	8300
716	13100
717	18500
718	24700

Table A-6.
Power Intake - Penstock Data

Penstock	
No. of Gates = 1	
Elevation (ft)	**Maximum Outlet Capacity (cfs)**
646	0
650	400
655	1200
660	2700
665	4700
670	6900
675	8700
680	10800
683	11800
686	12800
690	14200
695	15700
700	17000
705	18500
710	19600
712	20000
715	20600
720	21500

Appendix B – Diversion and Diverted Outlet Data

Loopy Diversion:
The diversion between Rockville and Bethesda is installed as a flood bypass to help reduce flows at Greenfield. The flow through the diversion is defined as a function of the flow at Rockville. Table B-1 gives the relationship between the flows.

Table B-1. Loopy Diversion

Rockville Flow (cfs)	Diversion Flow (cfs)
100	0
1,000	100
5,000	500
10,000	3,000
20,000	8,000
25,000	13,000
35,000	13,000

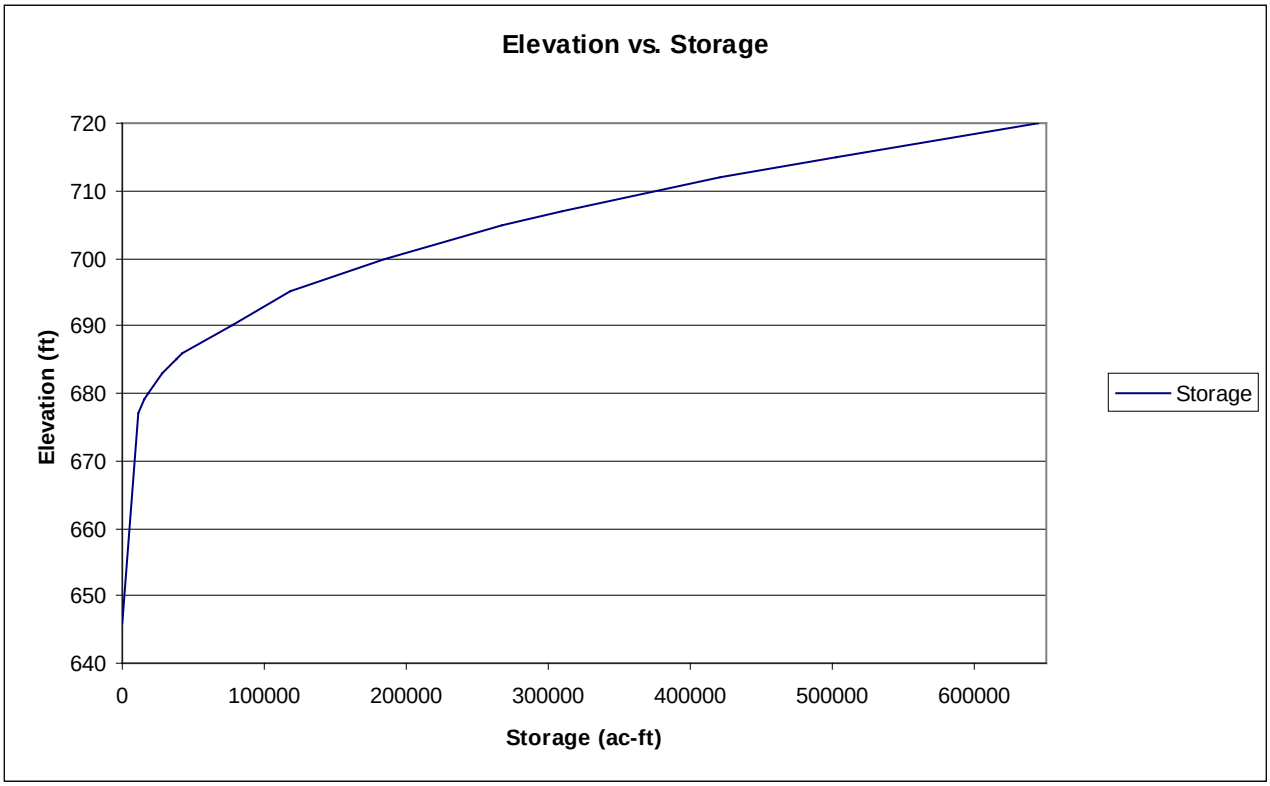
The diversion has Muskingum routing with a K of 10 hours, a Muskingum X of 0.1 and 10 subreaches. The losses are described as a return ratio of 0.95 (95% of the flow that enters at Rockville reaches Bethesda).

Nutty Canal Diverted Outlet:
Nutty Canal is a diverted outlet from the Crazy Mountain reservoir that is used to irrigate fields south of the reservoir. The canal does not connect back into the river system. The maximum capacity of the canal is defined in Table B-2.

Table B-2. Diverted Outlet Maximum Capacity Data

Elevation (ft)	Capacity (cfs)
646	0
650	1,800
655	2,290
660	2,580
665	2,820
670	3,040
675	3,230
680	3,400
685	3,550
690	3,680
695	3,790
700	3,880
705	3,950
710	4,000

Plate 1. Elevation - Storage - Area Curves
Crazy Mountain Reservoir



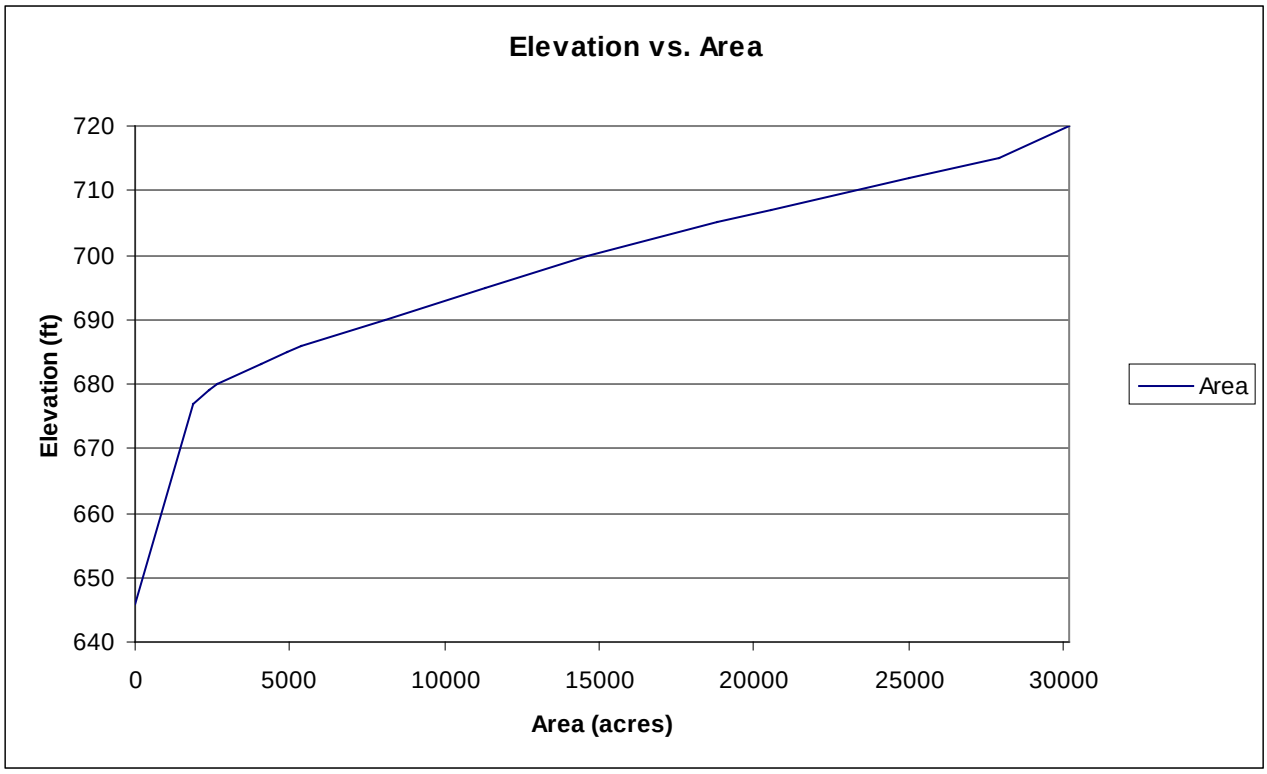
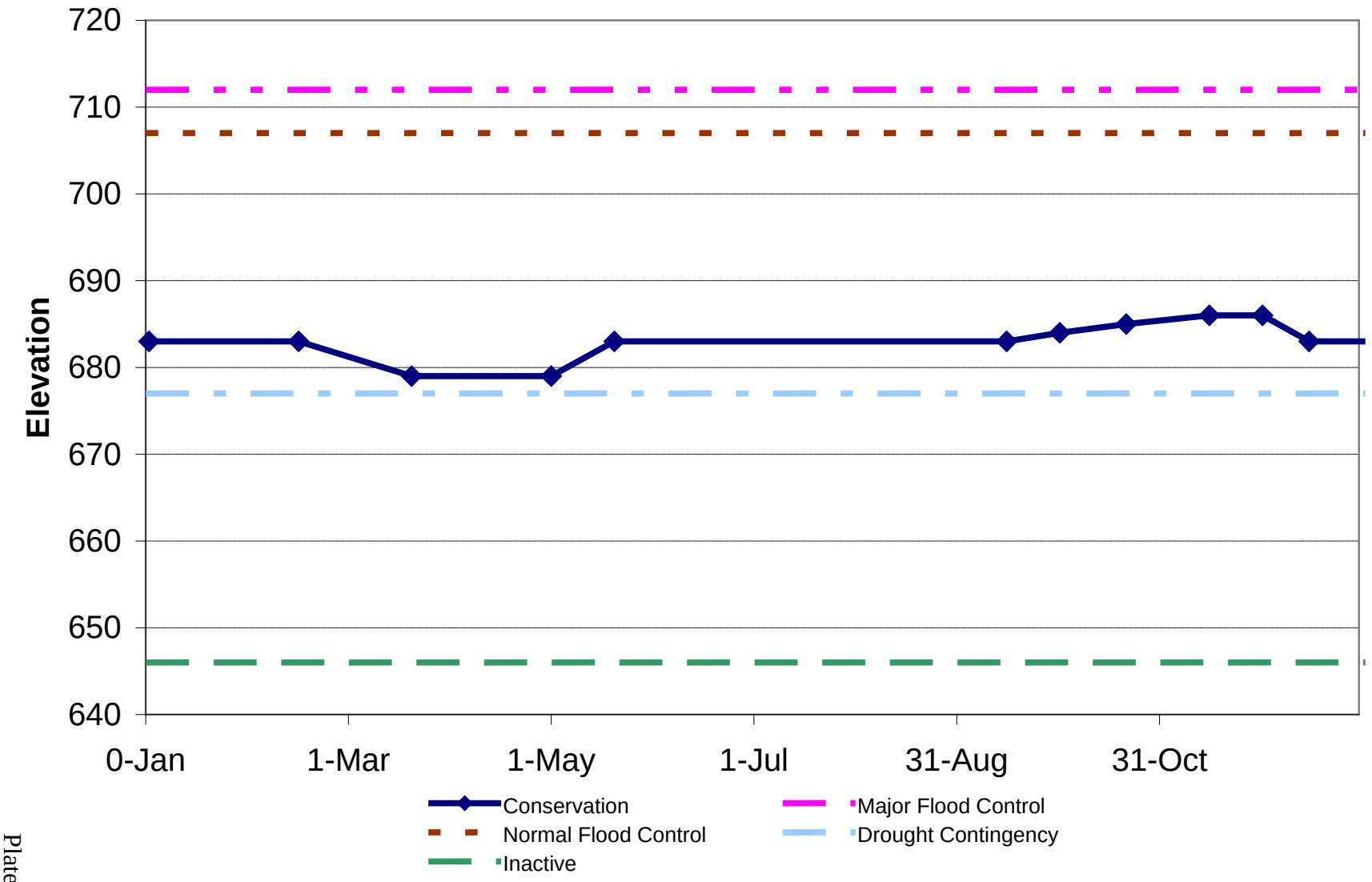


Plate 1


720
710
700
690
680
670
660
650
640
Elevation
0-Jan
1-Mar
1-May
1-Jul
31-Aug
31-Oct
Conservation
Major Flood Control
Normal Flood Control
Drought Contingency
Inactive

P-2

Plate 2