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Programmatic Environmental Impact Statement
Technical Appendix

Analysis of Impacts to Lacustrine and Riverine Fish Communities in the North Platte River

September, 2005

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Analysis of Impacts to Lacustrine and Riverine Fish Communities in the North Platte River

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Bureau of Reclamation
Platte River Office

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INTRODUCTION

This technical report presents an analysis of the impacts to lacustrine and riverine fish communities in the North Platte River resulting from the implementation of the Recovery Implementation Program (Program) for four threatened and endangered species in the Central Platte River Region. The Bureau of Reclamation (Reclamation) and the U.S. Fish and Wildlife Service (USFWS) are jointly preparing a programmatic environmental impact statement (EIS) for this Program. The EIS stems from the Cooperative Agreement signed by the States of Colorado, Wyoming, and Nebraska. The Cooperative Agreement's purpose is to set forth the plans by each of the three States to recover the interior least tern, piping plover, whooping crane, and pallid sturgeon.

Improving habitat for these threatened and endangered species by retiming or adding 130,000 to 150,000 acre-feet (ac-ft) of water per year is one of the main goals of the proposed Program. The Environmental Account in Nebraska, along with the Pathfinder Dam modification project in Wyoming and the Tamarack groundwater recharge project in Colorado, are expected to provide 70,000 to 80,000 ac-ft per year. The remaining water would come from other water supply projects or water conservation programs.

As of April, 2003, there were four proposed alternatives designed to restore habitat for the threatened and endangered species in the Central Platte—Wetland Restoration, Storage Emphasis, Channel Maintenance, Water Emphasis Emphasis, Governance Committee, and Water Conservation.

The primary impacts to the North Platte River result from proposed operational changes of the storage reservoirs along the North Platte River in Wyoming and Nebraska. The magnitude and timing of dam releases affect reservoir elevations and riverflows which in turn affect fish communities.

BACKGROUND

The North Platte River has been significantly altered by the construction and operation of a series of reservoirs in central Wyoming and in Nebraska (Figure 1). Sturgeon, goldeye, sauger, plains minnow, and sturgeon chub have disappeared since the 1900s. These species are adapted for turbid rivers. Dam construction has resulted in the conversion of a large, turbid river to a series of impoundments. The river below such impoundments is generally clear and is often greatly reduced in volume. While agricultural activities; pollution from urban and industrial activities; and the introduction of nonnative predatory fish such as walleye, smallmouth bass, northern pike, and rainbow trout may have played a

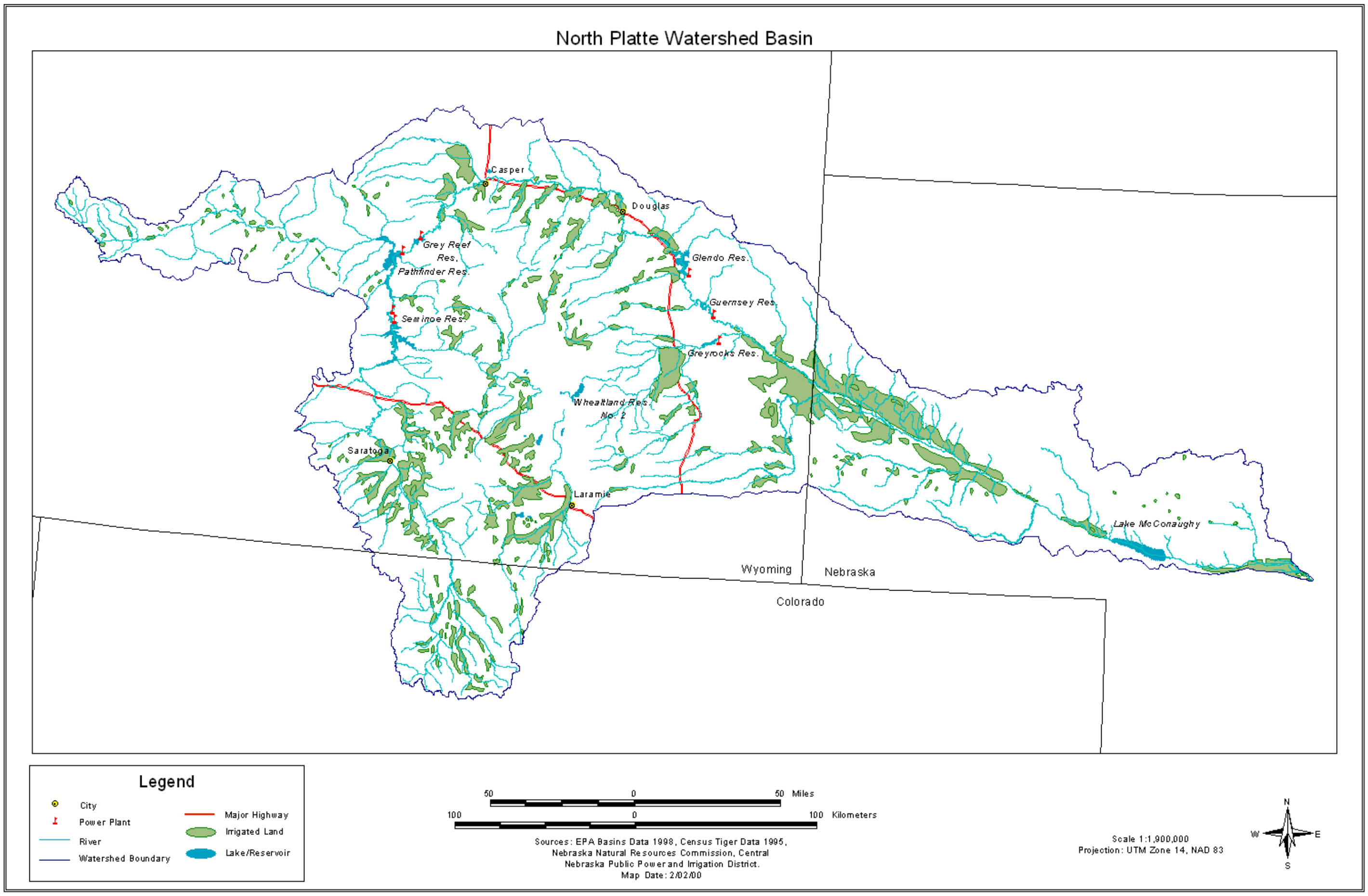

Figure 1. North Platte River Drainage with reservoirs in Wyoming and Nebraska.

role, Baxter and Stone (1995) considered the conversion of turbid, free-flowing North Platte River to a series of impoundments to be the major cause of the disappearance of these native fish. Significant recreational fisheries for nonnative gamefish such as rainbow trout, walleye, and channel catfish have been developed in most of the reservoirs and in many of the tailwaters.

Impacts of Reservoir Drawdowns on Lacustrine Fish Communities

Reservoir water level fluctuations greatly impact lacustrine (lake) fish communities. The timing, area, and duration of water level fluctuations are more important to biotic communities than the amount of vertical feet of fluctuation. Jenkins (1967) found a negative correlation between the total standing crop of fish and yearly vertical fluctuations in water levels in 70 reservoirs. Standing crops of fish were more variable in reservoirs with large seasonal changes in water levels (flood control or storage reservoirs) than in mainstream, run-of-river impoundments (Aggus and Lewis (1977).

Aquatic plants support bacteria, zooplankton, benthic invertebrates, and fish and can be affected directly and indirectly by water level fluctuations. Water level changes directly affect phytoplankton by physical entrainment and removal in reservoir outflows (Benson and Cowell 1967) and indirectly affect nutrient concentrations, turbidity (which affects light levels), temperature, and grazing pressure (Jones and Bachmann 1978a, 1978b, Guseva 1958, Markosyan 1969).

Exposure to air for several days can kill periphyton (organisms that live attached to underwater surfaces). Exposure of substrates for extended periods (178 days) followed by reflooding can significantly reduce periphytion biomass and productivity for nearly a year (Barman and Baarda 1978). Macrophytes provide spawning substrate and cover for many fish species. Drawdowns cause desiccation, freezing, and soil compaction which reduce the densities of many macrophyte species (Dunst et al. 1974).

As with phytoplankton, zooplankton can be entrained into reservoir outflows and removed. The highest zooplankton production occurs with high spring, summer, and fall reservoir levels followed by winter drawdown (Rodhe 1964), while large drawdowns during spring and summer resulted in low zooplankton production. Zooplankton productivity can be increased by flooding vegetated areas (Benson 1968).

Benthic invertebrates—a significant food source for many fish species—can be directly impacted by drawdowns or entrainment of planktonic stages in reservoir outflows. Reservoir fluctuations as little as 33 feet (ft) can destroy littoral benthos (Grimas 1964). As little as 20-ft fluctuations can reduce densities up to 50 percent (Grimas 1962).

Fish communities are impacted the most by water level fluctuations that are large, last several months, occur during the growing season, and inundate or eliminate productive areas of littoral or terrestrial vegetation (Ploskey 1986).

Water level fluctuations can alter predator-prey relations by reducing habitat complexity and the overall amount of habitat available. Prey such as small forage fish species and young game fish species are concentrated by large drawdowns that last at least 2 to 3 months at temperatures above 13 ^{o}C (Bennett 1962). These drawdowns force the small fish to abandon complex habitat in littoral areas serving as refugias, and increase their vulnerability to predation (Jenkins 1970). Piscivores such as walleye, white bass, and trout on the other hand often increase in weight by feeding heavily on the concentrated prey. Extended drawdowns that occur with a prolonged drought can cause the growth of predators to decrease as prey species are reduced in numbers and invertebrate production declines (Johnson 1974).

Fish species that spawn in littoral areas are adversely affected by water level fluctuations. Drawdowns cause habitat loss and mortality to eggs and young after exposure or suffocation by eroded sediments (Hassler 1970). Rapidly receding waters may also cause nest desertion, poor egg survival, and disrupted spawning for species such as centrarchids, yellow perch, northern pike, common carp, buffalofishes, and gizzard shad that spawn in shallow water. Low and variable spring water levels can adversely affect the spawning success of gizzard shad, emerald shiner, white bass, white crappie, and yellow perch (Walburg 1976).

Reproductive success of fish that spawn near shore in reservoirs—largemouth bass, northern pike, sauger, common carp, river carpsucker, smallmouth buffalo and bigmouth buffalo— is linked to post spawning survival (Ploskey 1986). Spawning success is adversely impacted by drawdowns which affect temperature, wind-caused turbidity and turbulence, predation, and food availability. Conversely, rising or high water levels during the spawning season and for several months afterward enhance post spawning survival by inundating shoreline vegetation that provides refugia and abundant food for young-of-year fish.

While seasonally fluctuating water levels reduce reservoir fish-carrying capacity, large changes that occur every 3 or 4 years can be beneficial. Productivity and carrying capacity can be significantly increased by large, prolonged changes in water levels that are infrequent enough to permit the growth of terrestrial vegetation in exposed areas.

Based on a consensus of available literature, Ploskey (1986) found that reservoir managers should attempt to (1) draw down water in late summer or fall, (2) establish herbaceous vegetation by natural colonization or seeding, (3) flood terrestrial vegetation in spring, and (4) maintain high water for as much of the growing season as possible. The Kansas Fish and Game Commission, for example, often limits the extent of drawdown to 10 to 20 percent of the original area, seeds vegetation extensively, and raises water levels slightly in fall to flood vegetation for waterfowl (Groen and Schroeder 1978). In most reservoirs, drawdowns are best scheduled for late summer or fall because water temperatures are above 13 ^{o}C, and warmwater piscivores such as walleye and pike are still feeding and growing. Earlier drawdowns may not be favorable to survival of young-of-year fishes, and drawdown in winter does not permit the establishment of terrestrial vegetation.

Impacts of Fluctuating Reservoir Outflows on Riverine Fish Communities

Reservoir operations for hydroelectric power generation or irrigation supply can cause extreme fluctuations in water levels and flow velocities. These dam operations result in unnatural rates of riverflow change of unnatural duration and unnatural frequency—few fish or invertebrate species can adapt themselves (Petts 1984). The rate of flow increase or decrease is the most important factor affecting riverine species (Petts 1984). Rapid increases in discharge can erode spawning gravels and wash away benthic invertebrates which provide a primary food source for many fish species. Mullan et al. (1976) found that extreme flow fluctuations result in depleted benthic invertebrate communities below dams such as Glen Canyon. Periphyton and macrophytes can be eliminated, while benthic invertebrate populations become dominated by those species that can actively move into the substrate interstices for protection against rapid increases in flow velocity. Scour releases from reservoirs can transport large quantities of fine sediment that can smother invertebrates or spawning substrate and incubating eggs. Rapid decreases in flows during spawning periods can desiccate incubating eggs and strand larval fish.

Reservoirs have also changed the physical and chemical regimes of many rivers, adversely affecting the reproductive ability of native fishes that require specific minimum temperatures and/or floods as triggering mechanisms for spawning or for the survival of eggs and young (Cadwallader 1978). Conversely, the reduced suspended sediment loads and regulated thermal regimes in some tailwaters immediately below dams often provide excellent fisheries. The "Miracle Mile" occurring below Kortes Dam is a prime example.

METHODS

Reclamation's North Platte River Environmental Impact Statement (NPREIS) hydrology model was used as the basic tool in this analysis to provide information about how each of the six alternatives would affect reservoir levels and riverflows throughout the North Platte River. Model data provide information on the monthly average reservoir elevations (ft) for dams located on the North Platte River in Wyoming and Nebraska, average depths, and monthly volume and timing of dam releases in cubic feet per second (cfs).

For the analysis of lacustrine fish community impacts, model data for Seminoe Reservoir, Pathfinder Reservoir, Alcova Reservoir, and Glendo Reservoir in Wyoming and Lake McConaughy in Nebraska were utilized. For the analysis of riverine fish community impacts, model data for outflows (dam releases) for Kortes Reservoir, Fremont Canyon Powerplant Bypass, Gray Reef, and Glendo Reservoir were selected. NPREIS uses a 48-year period of record which allows the comparison a wide range of water year types, encompassing below normal, normal, and above normal water years.

A spreadsheet analysis using Excel 2000 software was designed to compare flowing river sections of the North Platte River. Monthly average reservoir outflows (dam releases) in cfs for each alternative were compared with the Present Condition.

Based on discussions with the Wyoming Game and Fish Department (WGFD), additional resource indicators were identified to analyze impacts to the North Platte fisheries.

The WGFD requested that the Morphoedaphic Index (MEI) of fish production used by WGFD be used (Ryder 1965). The MEI is an empirically-derived formula for calculating potential fish yields from lakes. Higher MEI levels indicate higher projected fish standing crop. The formula is as follows:

$$\text{MEI} = \frac{\text{Total dissolved solids (TDS) (parts per million)}}{\text{Mean depth (feet)}}$$

$$\log(\text{yield (lbs./acre)}) = (0.7171)+(1.0151)\log(\text{MEI})$$

The MEI values were calculated for each alternative and compared to Present Conditions. Areal fish standing crops were also estimated using the formula above. In addition, areal fish standing crop was multiplied by the reservoir area to give a total standing crop for the reservoir.

Also, reservoir volume "flags" were identified by WGFD below which they believed that fishery impacts could be significant. The following "flags" were incorporated into the NPREIS model to highlight reservoir impacts for each alternative:

Pathfinder Reservoir - 200,000 ac-ft
Seminoe Reservoir - 200,000 ac-ft
Glendo Reservoir - 100,000 ac-ft
Alcova Reservoir - 150,000 ac-ft

In addition to these indicators of "significant drawdowns" to help highlight changes in the frequency of various reservoir elevations, the following second set of "flag" volumes were used to represent the occurrence of conditions critical to the survival of the fishery:

Pathfinder Reservoir - 50,000 ac-ft
Seminoe Reservoir - 50,000 ac-ft
Glendo Reservoir - 64,000 ac-ft

For river impacts, the WGFD suggested using stream flow "flags" to identify monthly reservoir outflows and instream flows below which fishery impacts could be significant. The following "flags" were incorporated into the NPREIS model to highlight river impacts for each alternative:

Fremont Canyon Powerplant Bypass - 75 cfs
Glendo Outflow - 25 cfs
Kortes Outflow - 500 cfs
Gray Reef Outflow - 500 cfs

In addition to the above flags, WGFD requested the analysis check for a stable or increasing storage from April 1 through June 30 in Glendo Reservoir.

Additional indicators included temperature modeling in Pathfinder Reservoir and the Pathfinder Reservoir ouflow in the North Platte River, temperature and dissolved oxygen impacts in Glendo Reservoir and downstream from Gray Reef Dam, and dissolved oxygen effects below Alcova Reservoir. Detailed methods for these analyses are available in the Water Quality Technical Appendix.

RESULTS

The following section describes the existing conditions and limiting factors for fish communities in each of the reservoirs and river reaches in this study, and presents an analysis of the impacts of each of the proposed alternatives. Summary tables appear for each alternative below. Appendix A contains the time series graphs resulting from the spreadsheet analyses for the North Platte River and are included as a reference. Additional details on water quality results, including statistics on MEI and standing crop values, are found in the report titled “MORPHOEDAPHIC INDEX FOR THE NORTH PLATTE BASIN RESERVOIRS AND A TEMPERATURE MODEL OF PATHFINDER RESERVOIR, WYOMING”.

Reservoir elevations, MEI levels, and total fish standing crop in Seminoe, Pathfinder, Alcova, Glendo, and Guernsey reservoirs are discussed relative to impacts to lacustrine fish communities in the North Platte River. Average monthly reservoir outflows in cfs at Kortes Reservoir, Fremont Canyon Powerplant Bypass, Gray Reef Reservoir, Glendo Reservoir, and Guernsey Reservoir are discussed to indicate impacts to riverine fish communities in the North Platte River.

Lacustrine Fish Communities

Seminoe Reservoir.—The following sections discuss the existing fish community and limiting factors, and analyze the impacts of each alternative.

Fish Community Existing Conditions and Limiting Factors.—Stocked rainbow trout are managed under a Basic Yield Concept in Seminoe Reservoir, with WGFD stocking 120,000 catchable rainbow trout annually. Wild populations of walleye and brown trout contribute to the fishery. Native fish species include white and longnose suckers; bigmouth and sand shiners; fathead minnows; and Iowa and johnny darters. Exotic species include walleye; rainbow, brown, cutthroat and lake trout; carp, and emerald shiners. Gizzard shad have been stocked in Seminoe Reservoir, but rarely overwinter successfully. Large annual reservoir elevation fluctuations averaging 37 vertical feet per year during the past 30 years limit productivity (Conder and Deromedi 1998). Extended periods of below average runoff exacerbate this situation. Turbidity—a result of high runoff and/or low carryover storage— is identified as a key factor influencing the declining trend in the Seminoe trout fishery (McMillan 1984).

Analysis of Reservoir Impacts –The following compares the four alternatives to Present Condition. The WGFD suggested a flag level of 200,000 ac-ft for Seminoe Reservoir. Table 1 summarizes reservoir elevations corresponding to this volume less than this flag (6,289 ft) for each alternative. All alternatives had more months out of all 48 water years with elevations less than the flag level compared to Present Conditions except Water Leasing. Table 2 summarizes total months below the minimum volume (50,000 ac-ft) for a viable fishery in Seminoe Reservoir for each alternative. Number of total months over the period of record when volumes would be less than this level ranged from 0 for Present Condition and Water Leasing to 10 for Wet Meadow. September for Wet Meadow was the only month that had an event with volumes less than this level more than once.

Generally, there was little difference in MEI levels among alternatives except Water Leasing (Table 3). Water Leasing was the only alternative with lower TDS, greater depth, and lower MEI levels than Present Condition. Wet Meadow had the highest MEI value among alternatives. Water Leasing had the highest total standing crop estimate among alternatives (Table 4) and it was the only alternative that had a higher total standing crop than Present Condition (Tables 4 and 5).

Table 1. Summary of elevations less than 6,289 ft (~200,000 ac-ft) in Seminoe Reservoir

Number of water years out of 48

Alternative	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Present Condition	3	3	3	4	5	6	4	2	0	0	1	3
Governance Committee	6	6	6	6	6	6	5	3	0	1	2	4
Water Emphasis	6	6	6	6	6	6	5	3	0	1	2	6
Wet Meadow	6	6	7	7	7	7	6	4	0	1	5	6
Water Leasing	1	1	1	2	2	3	3	0	0	0	0	1

Table 2. Summary of the total months below minimum elevation (6,250 ft (50,000 ac-ft)) for a viable fishery in Seminoe Reservoir

Number of water years out of 48

Alternative	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Present Condition	0	0	0	0	0	0	0	0	0	0	0	0
Governance Committee	1	1	1	1	1	1	1	0	0	0	0	0
Water Emphasis	1	1	1	1	1	1	1	0	0	0	0	0
Wet Meadow	1	1	1	1	1	1	1	0	0	0	1	2
Water Leasing	0	0	0	0	0	0	0	0	0	0	0	0

Table 3. Morphoedaphic Index for Seminoe Reservoir by Alternative

Alternative	Minimum	Average	Maximum
Present Conditions	4.46	6.13	8.52
Governance Committee	4.52	6.31	9.43
Water Emphasis	4.52	6.41	9.58
Water Leasing	4.40	5.90	7.92
Wet Meadow Emphasis	4.56	6.59	10.71

Table 4. Total Fish Standing Crop (tons) for Seminoe Reservoir by Alternative

Alternative	Minimum	Average	Maximum
Present Conditions	130	205	262
Governance Committee	109	204	264
Water Emphasis	108	201	263
Water Leasing	138	211	267
Wet Meadow Emphasis	90	197	264

Table 5. Percent Difference in Fish Standing Crop (tons) from Present Condition for Seminoe Reservoir by Alternative

Alternative	Minimum	Average	Maximum
Governance Committee	-16.2	-0.5	0.8
Water Emphasis	-16.9	-2.0	0.4
Water Leasing	6.2	2.9	1.9
Wet Meadow Emphasis	-30.8	-3.9	0.8

Pathfinder Reservoir.—The following sections discuss the existing fish community and limiting factors, and analyze the impacts of each alternative.

Fish Community Existing Conditions and Limiting Factors.— Pathfinder is managed under a Basic Yield Concept for rainbow trout with wild populations of walleye and brown trout contributing to the fishery. Native fish species include white and longnose suckers, bigmouth and sand shiners, fathead minnows, and Iowa and johnny darters. Exotic species include walleye; rainbow, brown, cutthroat, lake, spake, and Ohrid trout; lake chub; carp; and emerald and spottail shiners. Gizzard shad have been stocked in the reservoir but rarely overwinter successfully.

Large annual reservoir water level fluctuations limit productivity at Pathfinder Reservoir (Conder and Deromedi 1998). Rainbow trout populations declined during the low runoff period and associated low reservoir water levels beginning in 1988. A combination of increased predation and competition due to concentration of fish in the reduced reservoir pool—as well as turbidity from down cutting through fine sediments in the old river channel with the associated reduced productivity—were responsible for the decline in rainbow population. The trout population stabilized during the early 1990s, and the trout fishery improved. The above normal runoff of 1995 and associated increase in the reservoir surface area resulted in an increased trout growth rate with the increased storage (Conder and Deromedi 1998).

Analysis of Impacts - Reservoir Elevations.– The following compares the four alternatives to the Present Condition. The WGFD suggested a flag volume level for the analysis of 200,000 ac-ft for Pathfinder Reservoir. Table 6 summarizes reservoir elevations corresponding to this flag (5,787 ft) less than this elevation for each alternative. All alternatives, except Water Leasing, had more months out of all 48 water years with elevations less than 5,787 ft compared to Present Conditions. Table 7 summarizes total months below the minimum volume (50,000 ac-ft) for a viable fishery in Pathfinder Reservoir for each alternative. Number of months over the period of record when volumes would be less than this level ranged from 0 for Present Condition and Water Leasing to 11 for Wet Meadow. Most of these events occurred in December-March and August-September.

Generally, there was little difference in Pathfinder MEI levels among alternatives except Water Leasing (Table 8). Water Leasing was the only alternative with lower TDS, greater depth, and lower MEI levels than Present Condition. Wet Meadow had the highest MEI value among alternatives. Water Leasing had the highest total standing crop estimate among alternatives (Table 9) and it was the only alternative that had a higher total standing crop than Present Condition (Tables 9 and 10).

Appendix B compares temperature profiles for each alternative to Present Condition in Pathfinder Reservoir under various extremely dry summer scenarios (1961 and 1964). Results indicate that many times the 20ºC limit (Maximum Weekly Allowable Temperature) is exceeded under Present Condition and with each alternative near the surface. Rainbow trout experience significant mortality at prolonged exposure to water temperatures greater than 24ºC; and temperatures over 27ºC are lethal (WGFD 2004). The highest temperature among alternatives occurred in August 4, 1961 when Water Emphasis alternative reached 22ºC (Figure 2). All alternatives result in some thermal stress to the trout fishery during some days of critically dry summers compared to Present Condition. Results for 1961 and 1964 indicate that, for the Governance Committee Alternative, the main effect of the smaller pool was a deeper thermocline and a larger epilimnion in terms of elevation (Appendix B). The epilimnion should be cool enough to support trout.

Table 6. Summary of elevations less than 5,787 ft (~200,000 ac-ft) in Pathfinder Reservoir (Number of water years out of 48)

Alternative	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Present Condition	5	6	6	4	4	4	5	3	0	3	6	7
Governance Committee	6	6	6	6	6	6	6	4	1	4	8	11
Water Emphasis	7	7	6	6	6	6	7	5	1	5	8	12
Wet Meadow	10	9	8	7	7	8	8	5	2	5	12	12
Water Leasing	4	3	3	3	2	3	4	2	0	2	3	5

Table 7. Summary of the total months below minimum elevation (5,753 ft (50,000 ac-ft)) for a viable fishery in Pathfinder Reservoir
Number of water years out of 48

Alternative	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Present Condition	0	0	0	0	0	0	0	0	0	0	0	0
Governance Committee	0	0	1	1	1	1	0	0	0	0	2	2
Water Emphasis	0	0	1	1	1	2	0	0	0	0	2	2

Wet Meadow	1	1	1	1	1	1	0	0	0	0	2	3
Water Leasing	0	0	0	0	0	0	0	0	0	0	0	0

Table 8. Morphoedaphic Index for Pathfinder Reservoir by Alternative

Alternative	Minimum	Average	Maximum
Present Conditions	4.94	6.78	10.72
Governance Committee	4.73	7.01	11.64
Water Emphasis	4.74	7.11	11.52
Water Leasing	4.73	6.39	8.67
Wet Meadow Emphasis	4.85	7.38	14.13

Table 9. Total Fish Standing Crop (tons) for Pathfinder Reservoir by Alternative

Alternative	Minimum	Average	Maximum
Present Conditions	135	226	328
Governance Committee	133	221	330
Water Emphasis	133	217	327
Water Leasing	139	234	337
Wet Meadow Emphasis	134	215	321

Table 10. Percent Difference in Fish Standing Crop (tons) from Present Condition for Pathfinder Reservoir by Alternative

Alternative	Minimum	Average	Maximum
Governance Committee	-1.5	-2.2	0.6
Water Emphasis	-1.5	-4.0	-0.3
Water Leasing	3.0	3.5	2.7
Wet Meadow Emphasis	-0.7	-4.9	-2.1

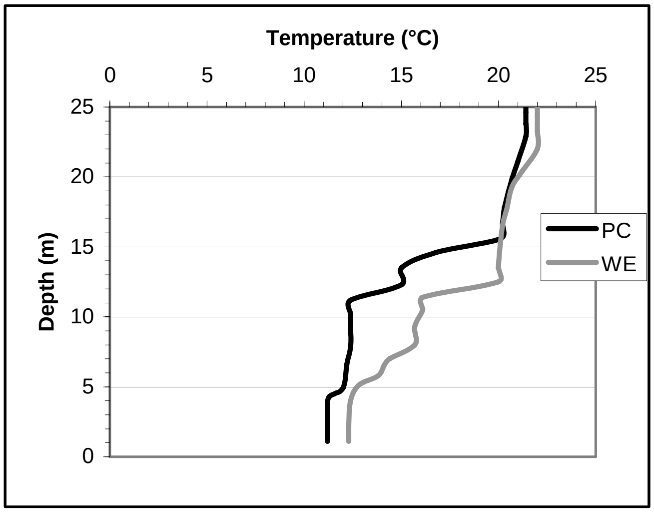

Figure 2. Temperature profile comparison between Present Condition (PC) and Water Emphasis alternatives in Pathfinder Reservoir, August 4, 1961.

Alcova Reservoir.—The following sections discuss the existing fish community and limiting factors, and analyze the impacts of each alternative.

Fish Community Existing Conditions and Limiting Factors.— Alcova Reservoir supports an excellent "basic yield" fishery for rainbow trout. The reservoir's trout population is based on the stocking of large numbers of subcatchable trout. The yield to the anglers is a stocked fish which has grown to a catchable size in the wild. Wild walleye and stocked brown trout are also available. Trout populations are entirely dependent upon stocking. With the growth of the walleye population, stocking of trout has shifted from fingerlings to trout averaging 9 inches. Major blue-green algae blooms do not commonly occur in this reservoir. Thus, zooplankton production generally remains high during summer months, supporting an excellent growth rate in trout (Conder and Deromedi 1998).

Native nongame species include fathead minnow, white and longnose suckers, bigmouth and sand shiners, and Iowa and johnny darters. Non-native species include lake chub, carp, emerald and spottail shiners. Largely because of trout fishing, Alcova ranks as one of the state's most important reservoir fisheries. It is commonly called "Casper's Playground", alluding to its popularity among Casper, Wyoming residents.

Analysis of Impacts - Reservoir Elevations.—The following compares the four alternatives to the Present Condition. Table 11 summarizes, on a monthly basis, the number of years out of 48 when reservoir elevations drop below 5,486 ft (150,000 ac-ft). Generally, there was little difference among alternatives. Reservoir elevations never drop below 5,486 ft for any alternative, including Present Condition (Table 11).

However, Water Emphasis Emphasis and Wet Meadow Restoration alternatives resulted in significantly higher MEI levels and corresponding fish standing crops than Present Conditions ($p < 0.05$) (Table 13). These alternatives also had the highest standing crop levels among alternatives (Table 12). Area-weighted MEI levels were slightly higher for all alternatives compared to Present Conditions (Table 14).

Alcova Reservoir is operated as a semi-fixed reservoir and there is no year-to-year variation in mean depth (Figure 3). There is a similar lack of variation in area. Thus, statistics for mean depth and area are not presented. The lack of variation in area and mean depth buffers any effect on MEI due to the alternatives.

Table 11. Summary of elevations less than 5,486 ft (~150,000 ac-ft) in Alcova Reservoir
Number of water years out of 48

Alternative	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Present Condition	0	0	0	0	0	0	0	0	0	0	0	0
Governance Committee	0	0	0	0	0	0	0	0	0	0	0	0
Water Emphasis	0	0	0	0	0	0	0	0	0	0	0	0
Wet Meadow	0	0	0	0	0	0	0	0	0	0	0	0
Water Leasing	0	0	0	0	0	0	0	0	0	0	0	0

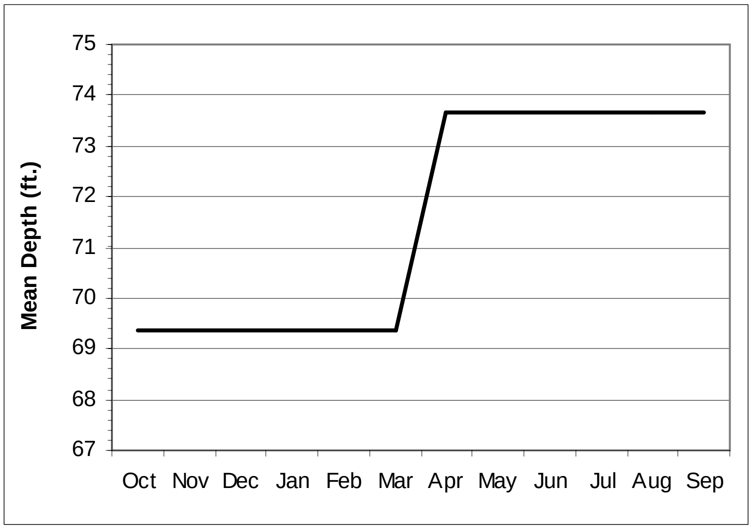

Figure 3. End-of-Month Mean Depth of Alcova Reservoir for all years and alternatives –

Table 12. Morphoedaphic Index for Alcova Reservoir by Alternative

Alternative	Minimum	Average	Maximum
Present Conditions	3.09	3.63	4.37
Governance Committee	3.05	3.61	4.37
Water Emphasis	3.06	3.62	4.30
Water Leasing	2.97	3.56	4.34
Wet Meadow Emphasis	3.13	3.66	4.36

Table 13. Total Fish Standing Crop (tons) for Alcova Reservoir by Alternative

Alternative	Minimum	Average	Maximum
Present Conditions	19.2	22.6	27.3
Governance Committee	19.0	22.5	27.3
Water Emphasis	19.0	22.6	26.9
Water Leasing	18.5	22.1	27.1
Wet Meadow Emphasis	19.5	22.8	27.3

Table 14. Percent Difference in Fish Standing Crop (tons) from Present Condition for Alcova Reservoir by Alternative

Alternative	Minimum	Average	Maximum
Governance Committee	-1.0	-0.4	0.0
Water Emphasis	-1.0	0.0	-1.5
Water Leasing	-3.6	-2.2	-0.7
Wet Meadow Emphasis	1.6	0.9	0.0

Glendo Reservoir.—The following sections discuss the existing fish community and limiting factors, and analyze the impacts of each alternative.

Fish Community Existing Conditions and Limiting Factors.— Glendo Reservoir is managed under a Wild Concept for walleye and yellow perch. Native species include channel catfish; shorthead redhorse; white and longnose sucker; quillback; fathead minnow; Iowa and johnny darter; river carpsucker; and red, bigmouth, and sand shiner. Exotic species include rainbow trout; walleye; yellow perch; black and white crappie; carp; gizzard shad; and emerald, golden, and spottail shiner. Channel catfish are stocked annually with gizzard shad stocked to bolster forage.

Conder and Deromedi (1998) have identified the severe reduction in available habitat due to annual reservoir drawdown of 87 percent as the major limiting factor for this reservoir. This late summer drawdown stimulates forage and game fish to emigrate downstream in the outflow.

Analysis of Impacts - Reservoir Elevations.—The following compares the four alternatives to the Present Condition. The WGFD suggested a flag elevation level of 4,580 ft (100,000 ac-ft) for Glendo Reservoir. Table 15 summarizes reservoir elevations less than this elevation for each alternative. All alternatives had more months out of all 48 water years with elevations less than 4,580 ft compared to Present Conditions. Table 16 summarizes total months below the minimum volume (64,000 ac-ft) for a viable fishery in Glendo Reservoir for each alternative. Number of months over the period of record when volumes would be less than this level ranged from 1 for Present Condition to 4 for all the other alternatives, all occurring in September.

Tables 17 - 19 summarize results of the MEI analysis for Glendo Reservoir. Generally, there was little difference among alternatives. Present Conditions had the lowest MEI and highest total fish standing crop levels compared to all alternatives (Tables 17 - 19).

Glendo Reservoir was the only reservoir with lower MEI levels for all alternatives compared to Present Condition.. The decrease in TDS and consequently in the MEI was due to the increased releases from Pathfinder through Alcova to Glendo. The increased releases provided greater dilution for saline inflows from tributaries between Alcova and the City of Casper. The saline inflows were primarily from Bates Creek, Poison Spring Creek, Poison Spider Creek, the Oregon Trail Drain, and Casper Creek; these tributaries do not carry large flows, but they do provide significant salt loads to the North Platte River. The increased dilution of the saline inflows shows up in Glendo as a decrease in TDS and its dependent MEI. This is also explained in the above referenced TDS/MEI report (Appendix B).

Tables 20 and 21 summarize month-to-month Glendo Reservoir elevation changes resulting from each alternative. In the April through June period, similar changes occurred among alternatives.

Table 15. Summary of elevations less than 4,580 ft (~100,000 ac-ft) in Glendo Reservoir
Number of water years out of 48

Alternative	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Present Condition	0	0	0	0	0	0	0	0	0	0	4	4
Governance Committee	3	0	0	0	0	0	0	0	0	0	5	10
Water Emphasis	6	0	0	0	0	0	0	0	0	2	8	24
Wet Meadow	6	0	0	0	0	0	0	0	0	1	8	22
Water Leasing	2	0	0	0	0	0	0	0	0	0	3	13

Table 16. Summary of the total months below minimum elevation (4,570 ft (64,000 ac-ft)) for a viable fishery in Glendo Reservoir
Number of water years out of 48

Alternative	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Present Condition	0	0	0	0	0	0	0	0	0	0	0	0
Governance Committee	0	0	0	0	0	0	0	0	0	0	0	0
Water Emphasis	0	0	0	0	0	0	0	0	0	0	0	0
Wet Meadow	0	0	0	0	0	0	0	0	0	0	0	0
Water Leasing	0	0	0	0	0	0	0	0	0	0	0	0

Table 17. Morphoedaphic Index for Glendo Reservoir by Alternative

Alternative	Minimum	Average	Maximum
Present Conditions	10.62	12.86	15.88
Governance Committee	10.81	13.21	17.44
Water Emphasis	10.77	13.30	17.74
Water Leasing	10.24	12.98	16.35
Wet Meadow Emphasis	10.76	13.39	17.54

Table 18. Total Fish Standing Crop (tons) for Glendo Reservoir by Alternative

Alternative	Minimum	Average	Maximum
Present Conditions	266	302	336
Governance Committee	258	294	343
Water Emphasis	256	294	336
Water Leasing	272	298	341
Wet Meadow Emphasis	254	293	332

Table 19. Percent Difference in Fish Standing Crop (tons) from Present Condition for Glendo Reservoir by Alternative

Alternative	Minimum	Average	Maximum
Governance Committee	-3.0	-2.6	2.1
Water Emphasis	-3.8	-2.6	0.0
Water Leasing	2.3	-1.3	1.5
Wet Meadow Emphasis	-4.5	-3.0	-1.2

Table 20. Month-to-month elevation decreases at Glendo Reservoir

Number of water years out of 48												
Alternative	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Governance Committee	0	0	0	0	0	0	16	14	23	39	48	47
Water Emphasis	0	0	0	0	0	0	16	13	21	39	48	43
Wet Meadow	0	0	0	0	0	0	15	15	23	41	48	42
Water Leasing	0	0	0	0	0	0	14	11	21	43	48	48

Table 21. Month-to-month elevation increases at Glendo Reservoir

Number of water years out of 48												
Alternative	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Governance Committee	47	48	48	48	48	48	32	34	25	9	0	1
Water Emphasis	47	48	48	48	48	48	32	34	27	8	0	5
Wet Meadow	47	48	48	48	48	48	33	32	25	6	0	6
Water Leasing	47	48	48	48	48	48	34	37	26	4	0	0

Temperature and Dissolved Oxygen

Figure 4 is a set of plots that show temperature and dissolved oxygen profiles in Glendo Reservoir in the month preceding drawdown to less than 64,000 acre-feet of storage and the 2 months following at 2 different sites. Site 1 (S1 on the plots) is located about 150 feet up the reservoir from the dam; site 2 (S2) is located approximately 2.8 miles up the reservoir from the dam.

At the end of August, when the reservoir pool level was till in excess of 100,000 acre-feet, the reservoir shows a significant deepening of the epilimnion. The temperature at site 1 was 19.5°C (67.1°F) in the upper mixed layer, which extended to a depth of about 50 feet. Coincidentally, the dissolved oxygen (DO) was at or above 6 mg/L. Conditions were similar at site 2, but the depth of the mixed layer was only about 30 feet. The conditions reflect instability with respect to thermal stratification and indicate that fall overturn was in its early stages.

The reservoir content at Glendo was 62,720 acre-feet of water at the time the measurements were made in September 1974. There were sharp gradients of both temperature and DO at the time. The temperature was suitable for salmonids throughout the reservoir, but adequate DO was only present in the upper 20 to 30 feet of water. The deeper layer of suitable DO was at site 2.

Ammonia gas (unionized ammonia) is highly toxic to fish. Ammonia gas forms in equilibrium with the ammonium ion, which becomes a more common nitrogen species as conditions become more chemically reducing. One indicator of reducing conditions is low DO. At the time the samples were collected in September 1974, ammonium concentrations at site 1 range from 0.13 mg/L at the surface to 0.29 mg/L at the bottom of the profile. Ammonium concentrations were lower at site 2. The ammonium concentration that would be in equilibrium with a toxic concentration of ammonia gas for salmonids at the pH of the reservoir at the time (8.3) is over 3 mg/L. Consequently, the most commonly occurring toxin that is associated with reducing condition s in water should not have been a problem in September 1974.

Temperature and DO profiles at the 2 sites in October and November 1974 are also shown in the plots. As is shown, the reservoir had increased to over 100,000 acre-feet by the time of the October sample. The reservoir continued to cool and was well oxygenated in all of the profiles in October and November. The conditions in October indicate that there was a relatively rapid recovery of water quality in the reservoir.

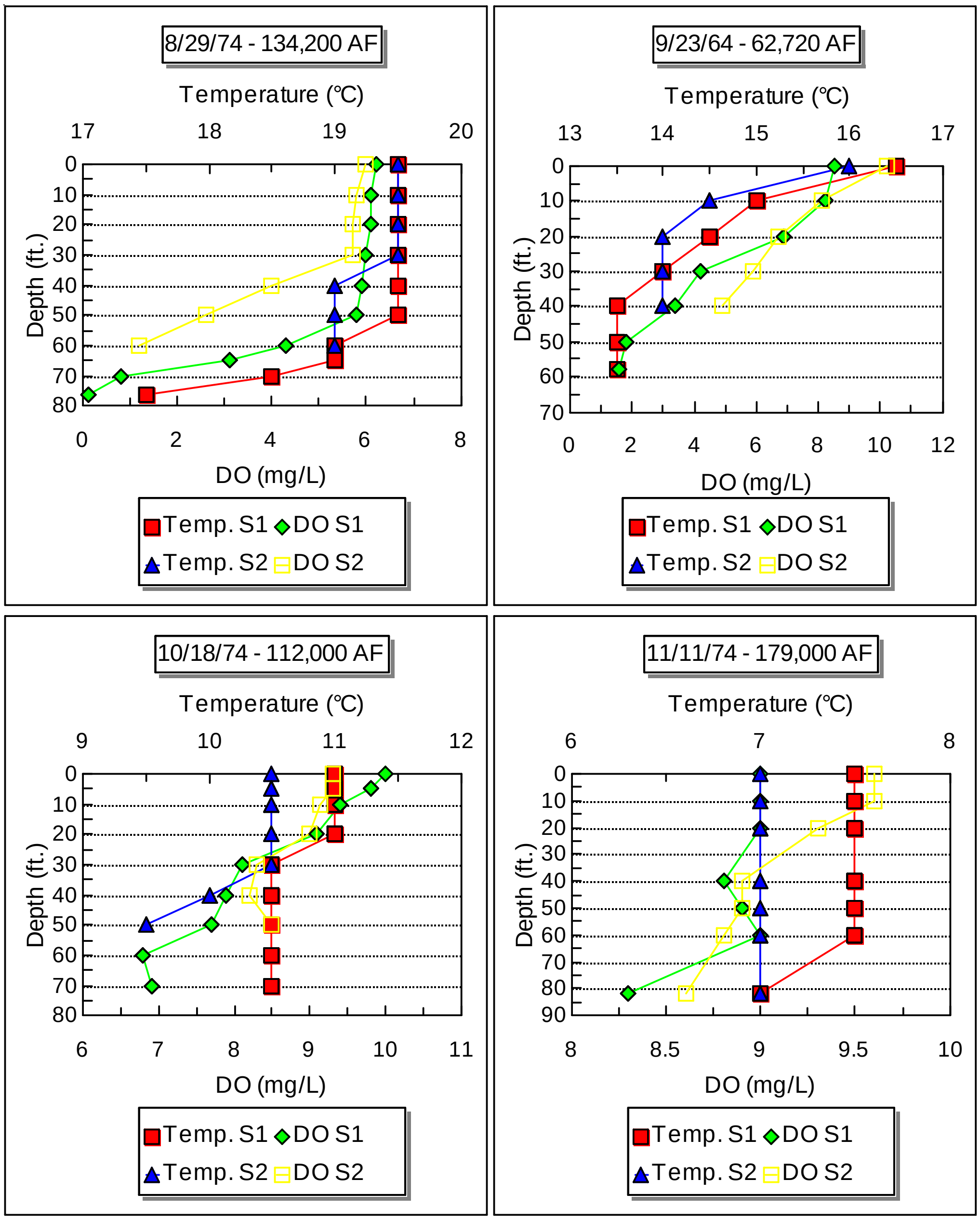

Figure 4. Temperature and dissolved oxygen profiles in Glendo Reservoir in the month preceding drawdown to less than 64,000 acre-feet of storage

Guernsey Reservoir.—Mean annual reservoir drawdown is 97 percent to accommodate the silt run, precluding the development of any fisheries in Guernsey Reservoir Conder and Deromedi (1998). For this reason, WGFD does not actively manage or stock the reservoir. Aquatic macroinvertebrates are greatly reduced during the silt run and recovery to pre-run conditions is slow following reduction in turbidity. A variance in state water quality standards was granted to allow the silt run to continue without citations (Conder and Deromedi 1998).

Analysis of Impacts - Reservoir Elevations.—– Tables 22 and 23 show number of months with net reservoir elevation changes compared to Present Condition for each alternative. Similar changes would occur among alternatives except Water Leasing which showed many more months (October-April and June) of elevations increases compared to the other alternatives. Largest reservoir increases with Water Leasing for any given month over the period of record ranged from 2 to 28 ft. This should result in improved conditions for developing a Guernsey Reservoir fisheries.

Table 22. Net elevation decreases at Guernsey Reservoir: Alternative minus Present Condition (number of water years out of 48)

Alternative	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept
Governance Committee	0	0	0	0	1	2	3	0	1	0	0	0
Water Emphasis	0	0	0	0	1	5	5	0	2	0	0	0
Wet Meadow	0	0	0	0	1	5	5	0	0	0	1	0
Water Leasing	0	0	0	0	0	3	1	2	1	0	0	0

Table 23. Net elevation increases at Guernsey Reservoir: Alternative minus Present Condition (number of water years out of 48)

Alternative	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept
Governance Committee	0	0	0	0	0	1	0	0	0	0	0	0
Water Emphasis	0	0	0	0	0	1	0	0	0	0	0	0
Wet Meadow	0	0	0	0	0	1	0	0	0	0	0	0
Water Leasing	6	6	6	6	6	3	1	0	2	0	0	0

Summary of Lacustrine Fishery Impacts

Table 24 summarizes North Platte Reservoir differences in standing crop compared to Present Condition. System-wide, Water Leasing alternative is the only alternative that would result in an average increase in fish standing crop over Present Condition.

Table 24. Difference in Fish Standing Crop (tons) from Present Condition for North Platte Reservoirs by Alternative

Reservoir	Alternative	Minimum	Average	Maximum
Seminoe	Governance Committee	-21.2	-1.8	9.1
	Water Emphasis	-22.2	-4.8	12.4
	Water Leasing	-7.6	5.4	21.1
	Wet Meadow Emphasis	-43.2	-8.3	11.8
Pathfinder	Governance Committee	-27.1	-4.6	13.0
	Water Emphasis	-46.1	-8.8	19.3
	Water Leasing	-16.3	7.8	31.0
	Wet Meadow Emphasis	-49.4	-11.2	18.3
Alcova	Governance Committee	-0.9	-0.1	0.6
	Water Emphasis	-1.0	0.0	0.7
	Water Leasing	-1.2	-0.4	0.0
	Wet Meadow Emphasis	-0.7	0.2	0.8
Glendo	Governance Committee	-22.7	-7.9	30.2
	Water Emphasis	-27.5	-8.1	17.3
	Water Leasing	-17.9	-3.6	9.9
	Wet Meadow Emphasis	-28.8	-8.8	19.1
System-	Governance Committee	-71.9	-14.3	52.9
wide	Water Emphasis	-96.7	-21.6	49.7
Change	Water Leasing	-43.0	9.2	62.0
	Wet Meadow Emphasis	-122.1	-28.0	50.0

Riverine Fish Communities

Kortes Reservoir Outflow.—The following sections discuss the existing fish community and limiting factors, and analyze the impacts of each alternative.

Fish Community Existing Conditions and Limiting Factors.— The Miracle Mile, from Kortes Dam to Pathfinder Reservoir, is a "blue ribbon" trout fishery (Class I; trout fishery of national importance) managed under a Trophy Concept for rainbow and brown trout. Rainbows sustain some natural recruitment and are also stocked annually. Brown trout are wild with no stocking. The construction of Seminoe Dam created a productive tailwater fishery, supplying clear, cold water. A minimum flow of 500 cfs was established in 1971 to protect this outstanding fishery. Native fish species include white and longnose suckers, longnose dace, fathead minnow, and bigmouth and sand shiners. Exotic species include rainbow, brown and cutthroat trout; walleye; carp; and emerald shiners. Fluctuations in daily flows can range from 500 to 2,900 cfs as a result of power generation. Such fluctuations can desiccate trout eggs, can strand and kill young trout and other small fish including benthic invertebrates, and can disrupt trout spawning.

Analysis of Impacts - Reservoir Outflows and/or River Flows (cfs).–The following compares the four alternatives to the Present Condition. All alternatives included the Pathfinder Modification and had the same goal of providing 130 to 150 kaf of water for T&E species in central Nebraska. Therefore, all alternatives were similar with small differences in formulation and results. With the exception of Water Leasing, there was little difference in flow impacts among alternatives. The Water Leasing alternative resulted in fewest flow decreases from October-February compared to Present Condition and the most flow increases during this period (Tables 25-26). All alternatives, except Water Leasing, had more months with flows less than 500 cfs compared to Present Condition (Table 27). One time in March (1965) flows dropped to 355 cfs for Governance Committee, Water Emphasis, and Wet Meadow alternatives, which could adversely affect rainbow trout spawning habitat. The one year (1965) where flows dropped to 449 and 329 cfs in October and November under the Wet Meadow Alternative and 442 cfs in November under the Water Emphasis Alternative may adversely affect brown trout spawning habitat.

The reason for periodic flows less than 500 cfs is that when there was no storage in Seminoe reservoir, the model passed the inflow to Seminoe to the river reach below Kortes dam. In the winter of 1965, storage was zero and inflow was less than 500 cfs. Flows never dropped below 500 cfs for Present Condition or Water Leasing (Table 27).

Table 25. Net flow decreases at Kortes Reservoir outflow: Alternative minus Present Condition (number of water years out of 48)

Alternative	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Governance Committee	18	20	21	22	24	8	13	13	16	19	28	6
Water Emphasis	22	25	24	27	27	10	13	6	15	22	32	6
Wet Meadow	22	26	27	26	30	10	15	7	15	22	23	7
Water Leasing	11	5	4	5	6	8	25	27	25	18	37	10

Table 26. Net flow increases at Kortes Reservoir outflow: Alternative minus Present Condition (number of water years out of 48)

Alternative	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Governance Committee	12	16	18	19	17	29	27	25	23	11	15	20
Water Emphasis	13	14	15	14	15	24	31	35	26	12	10	31
Wet Meadow	13	13	15	13	12	27	30	35	26	13	21	34
Water Leasing	21	33	35	36	35	34	17	12	14	12	7	15

Table 27. Flows less than 500 cfs for North Platte River at Kortes Reservoir outflow (number of water years out of 48)

Alternative	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Present Condition	0	0	0	0	0	0	0	0	0	0	0	0
Governance Committee	0	0	1	1	1	1	0	0	0	0	0	0
Water Emphasis	0	1	1	1	1	1	0	0	0	0	0	0
Wet Meadow	1	1	1	1	1	1	0	0	0	0	0	0
Water Leasing	0	0	0	0	0	0	0	0	0	0	0	0

Fremont Canyon Powerplant Bypass.—The following sections discuss the existing fish community and limiting factors, and analyze the impacts of each alternative.

Fish Community Existing Conditions and Limiting Factors.—For approximately 6.5 miles below Pathfinder Dam, the North Platte River flows through Fremont Canyon. Currently, dewatering severely limits the use of this river segment by fish. This reach occasionally contains game fish from Pathfinder Reservoir that become trapped in the deep pools when flows are shut off. During the brief and infrequent water release or spill events from Pathfinder, a fishery can be maintained within this reach. A cooperative effort among the Service, Reclamation, NRCS, WGFD, Natrona County, Wyoming Flycasters, and local land owners and sportsmens groups has developed a year round 75 cfs flow and public access in this reach. This will provide an excellent fishery resource of regional importance. Reclamation implemented this minimum flow in August, 2002 (Duane Stroup, personal communication) and it is call the “Cardwell” fishery “. This is primarily a rainbow trout fishery.

Analysis of Impacts - Reservoir Outflows and/or River Flows (cfs).–The following compares the four alternatives to the Present Condition. No alternatives showed net flow decreases from September-April (Table 28). Similar flow decreases occurred among alternatives the other months compared to Present Condition. Flow increases only occurred April through September and were also similar among alternatives (Table 29). Generally, there was little difference in flow impacts among alternatives and no alternative, including Present Condition, resulted in flows less than 75 cfs during any months (Table 30).

Table 28. Net flow decreases Fremont Canyon (Pathfinder) turbine bypass: Alternative minus Present Condition (number of water years out of 48)

Alternative	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Governance Committee	0	0	0	0	0	0	0	6	17	19	10	0
Water Emphasis	0	0	0	0	0	0	0	6	17	30	10	0
Wet Meadow	0	0	0	0	0	0	0	5	12	23	7	0
Water Leasing	0	0	0	0	0	0	0	5	9	31	10	0

Table 29. Net flow increases Fremont Canyon (Pathfinder) turbine bypass: Alternative minus Present Condition (number of water years out of 48)

Alternative	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Governance Committee	0	0	0	0	0	0	0	3	5	17	1	1
Water Emphasis	0	0	0	0	0	0	1	4	5	11	2	4
Wet Meadow	0	0	0	0	0	0	1	6	11	16	7	3
Water Leasing	0	0	0	0	0	0	0	6	10	7	1	1

Table 30. Flows less than 75 cfs for North Platte River in Fremont Canyon (Pathfinder) turbine bypass (number of water years out of 48)

Alternative	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Present Condition	0	0	0	0	0	0	0	0	0	0	0	0
Governance Committee	0	0	0	0	0	0	0	0	0	0	0	0
Water Emphasis	0	0	0	0	0	0	0	0	0	0	0	0
Wet Meadow	0	0	0	0	0	0	0	0	0	0	0	0
Water Leasing	0	0	0	0	0	0	0	0	0	0	0	0

Figures 5 to 13 compare Pathfinder Reservoir outlet temperatures to the Cardwell fishery for each alternative to Present Condition. Analysis of the graphs does not indicate that water temperatures would be adversely affected by any alternative. Maximum release temperatures remain below 20°C (68°F), which should support a trout fishery from the perspective of temperature.

Governance Committee Alternative and the Present Condition

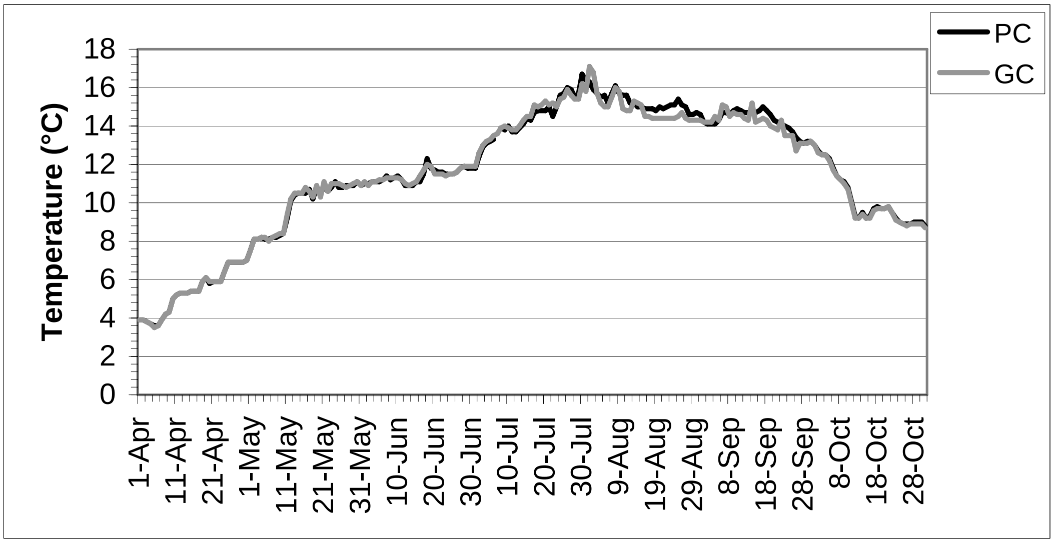

Figure 5. Temperature of Fremont Canyon Powerplant Bypass - 1977

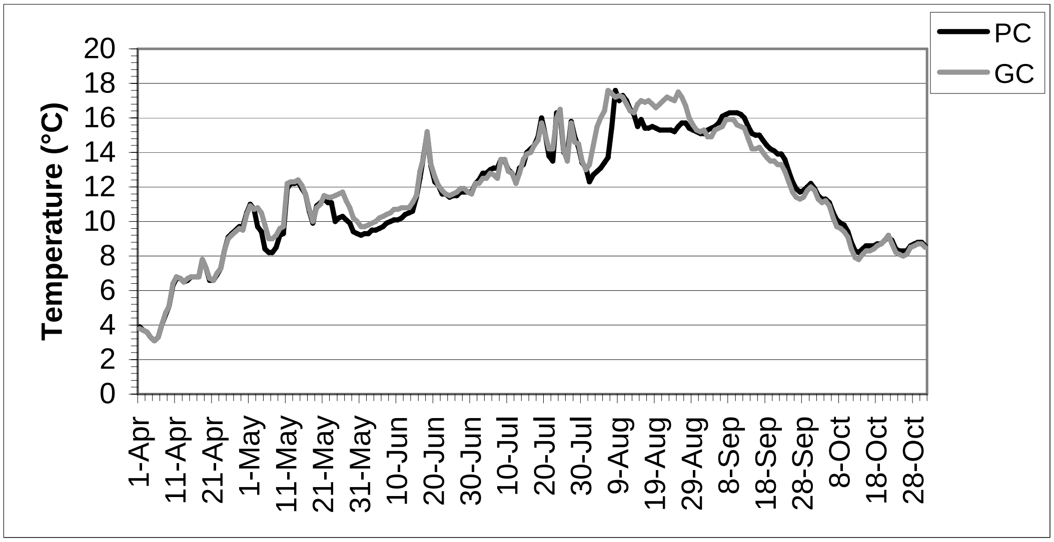

Figure 6. Temperature of Fremont Canyon Powerplant Bypass – 1961

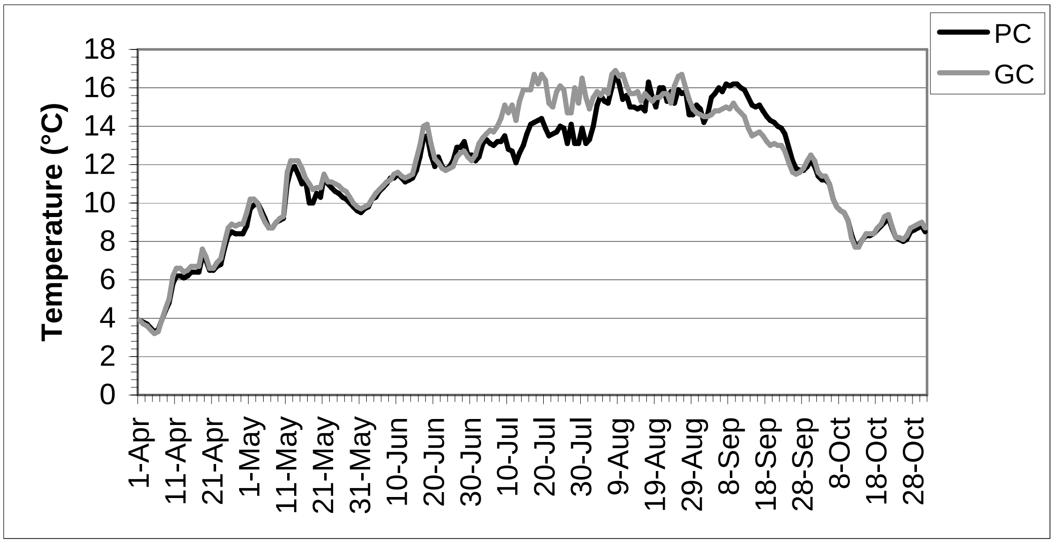

Figure 7. Temperature of Fremont Canyon Powerplant Bypass – 1964

Water Emphasis Alternative and the Present Condition

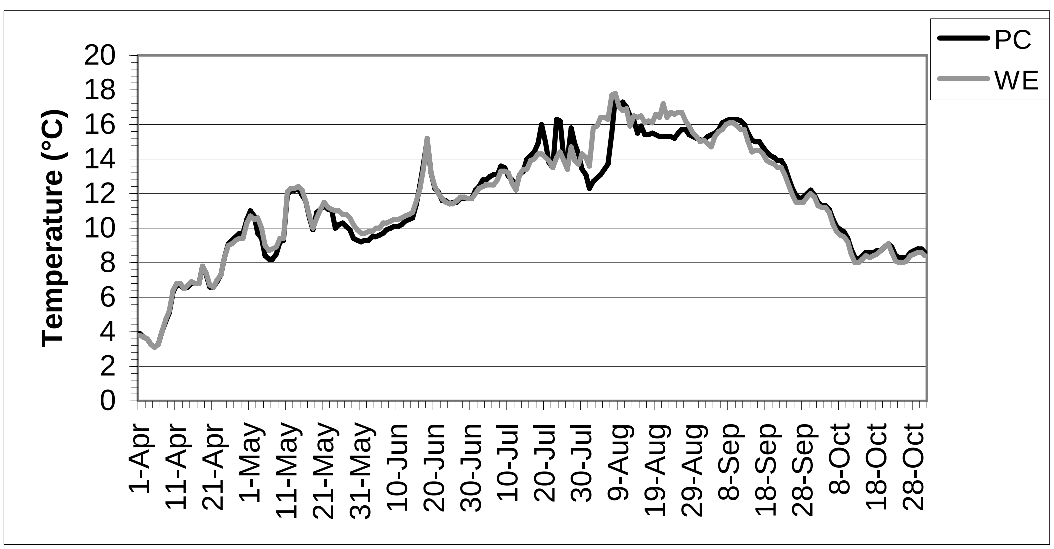

Figure 8. Temperature of Fremont Canyon Powerplant Bypass – 1961

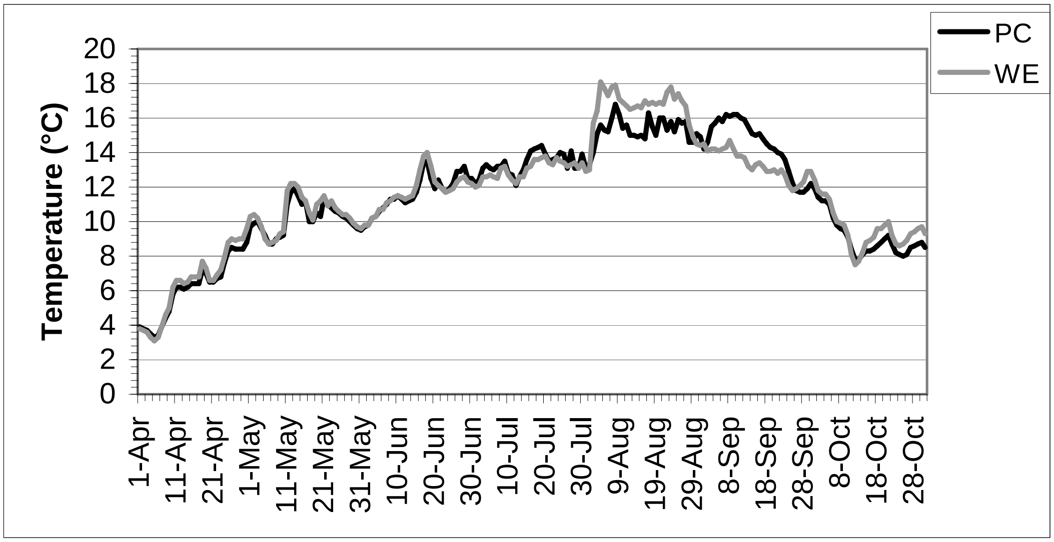

Figure 9. Temperature of Fremont Canyon Powerplant Bypass – 1964

Full Water Leasing Alternative and the Present Condition

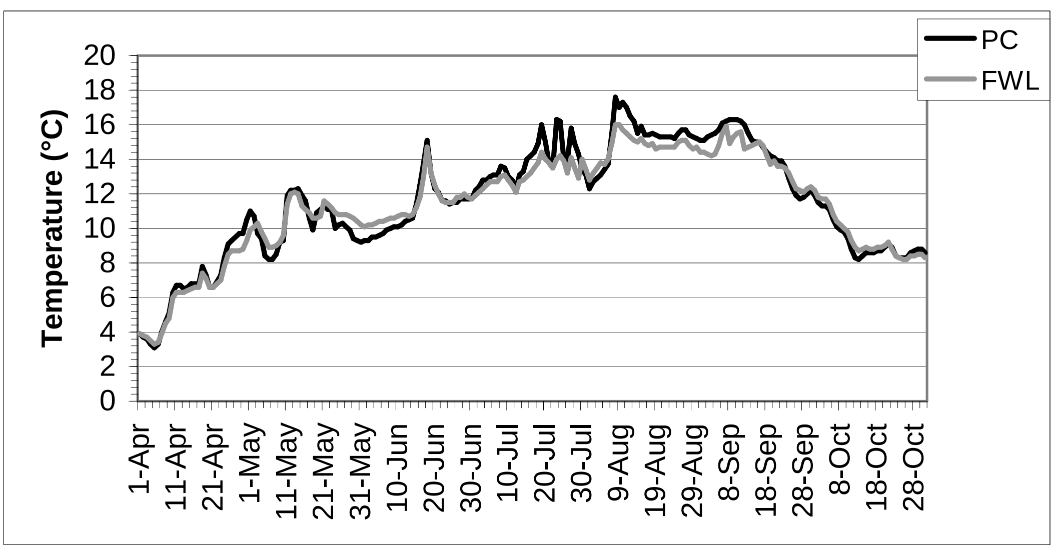

Figure 10. Temperature of Fremont Canyon Powerplant Bypass – 1961

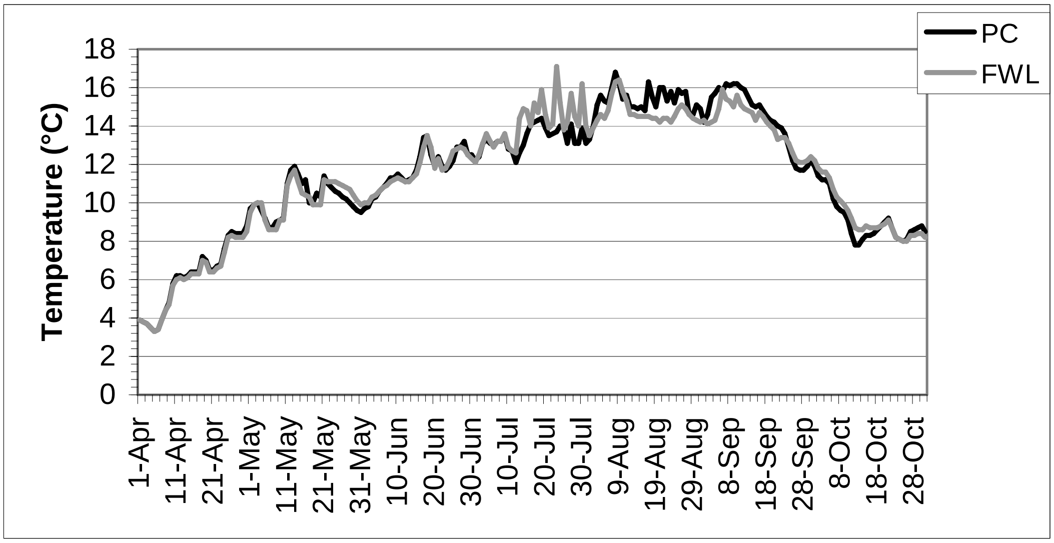

Figure 11. Temperature of Fremont Canyon Powerplant Bypass – 1964

Wet Meadow Emphasis Alternative and the Present Condition

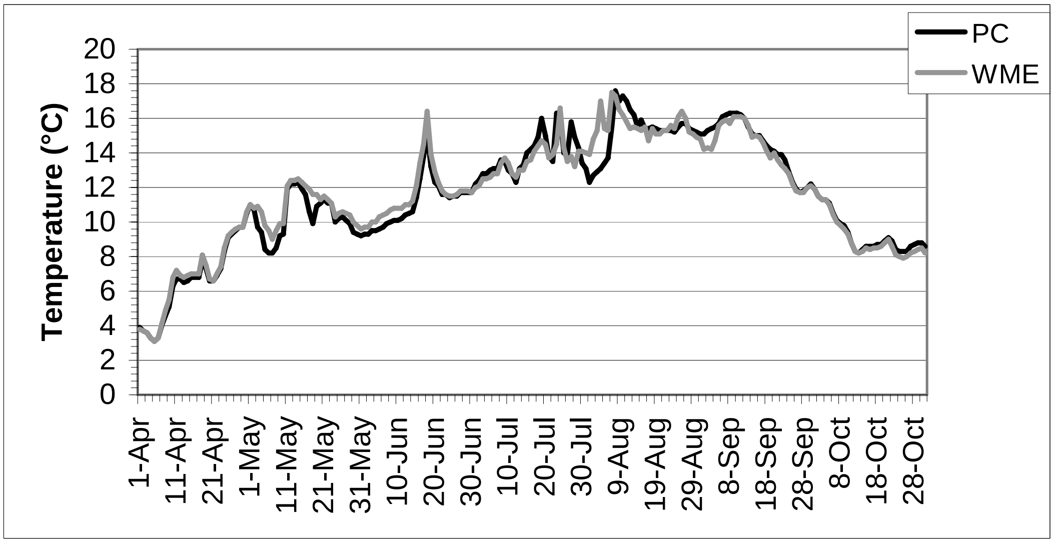

Figure 12. Temperature of Fremont Canyon Powerplant Bypass – 1961

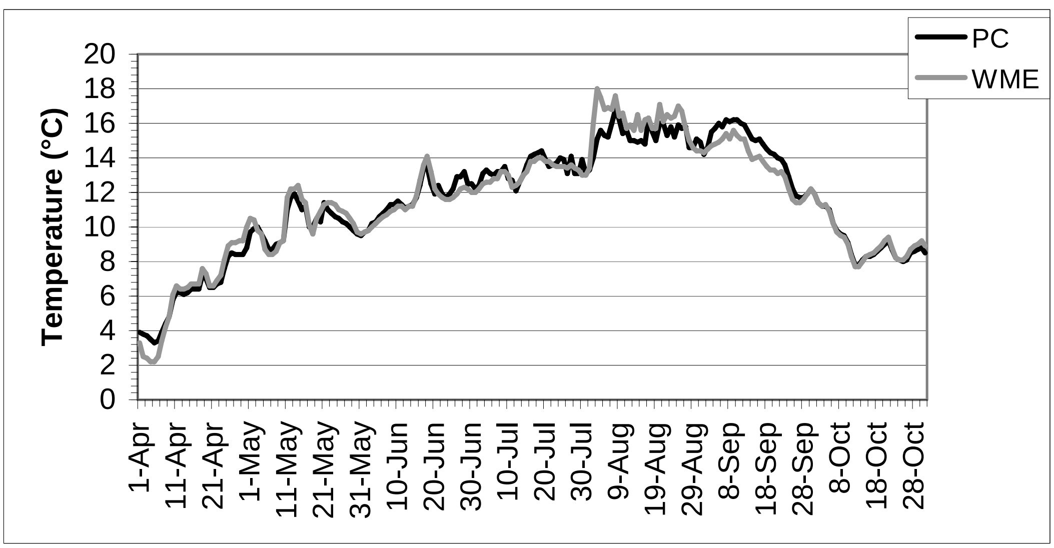

Figure 13. Temperature of Fremont Canyon Powerplant Bypass – 1964

Alcova Reservoir Outflow. - Figure 14 indicates that there is some degree of aeration between Alcova and Gray Reef dams. The data also indicate that there is little D.O. depletion in the Alcova release. The powerplant intake is near the surface of the reservoir – about 10 feet deep in the winter when the reservoir is drawn down, and about 20 feet deep in the summer when the reservoir is full. Since the reservoir content (operation) will not be affected by any alternative, D.O. depletion below Alcova reservoir should not be a problem.

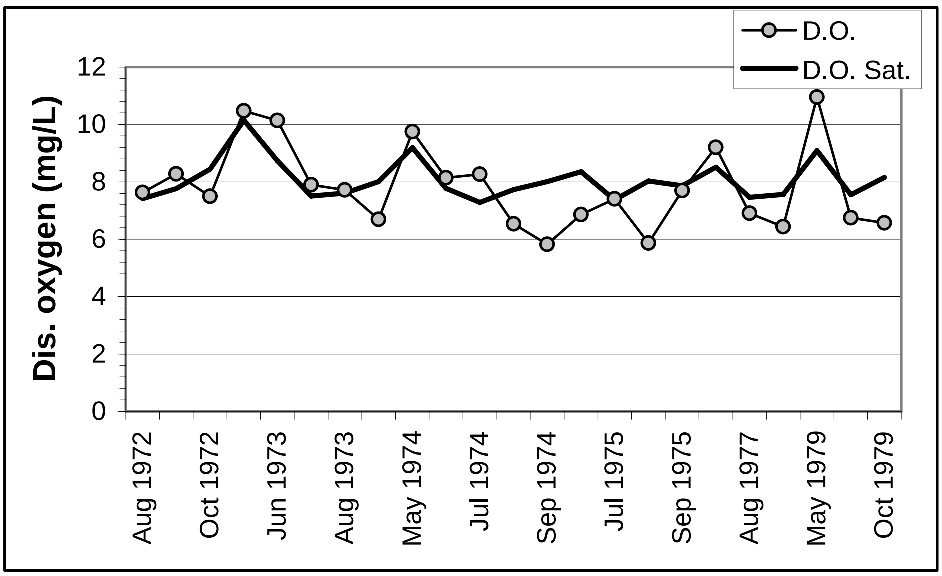

Figure 14. Dissolved oxygen in the releases from Alcova Dam. Note – generally at or slightly below saturation

Gray Reef Outflow.—The following sections discuss the existing fish community and limiting factors, and analyze the impacts of each alternative.

Fish Community Existing Conditions and Limiting Factors.—The 32-mile reach of the North Platte River from Gray Reef Dam to Goose Egg (Bessemmer Bend) has been designated Class I (trout fishery of national importance) or "blue ribbon" fishery by WGFD. This fishery has the highest standing crop of rainbow trout, brown trout, and cutthroat trout in Wyoming. Walleye are also found in this reach. This fishery is managed under the trophy concept including a one-trout limit, use of artificial flies and lures only, and the release of all trout less than 20 inches.

From Bessemmer Bend downstream to the Mills Bridge in Casper, the North Platte River becomes a Class II trout fishery (trout fishery of statewide importance) largely from input of fine sediments from Bates Creek. These two reaches received a total of 16,993 angler days/year in 1995 and 1996 (Mavrakis and Yule 1998).

The 100-mile reach of river from Mills Bridge in Casper to Glendo Reservoir is managed under a Basic Yield Concept for rainbow trout, brown trout, and channel catfish. Native fish species include white and longnose sucker; bigmouth, red, common, and sand shiner; creek, flathead, and lake chub; plains killifish; central stoneroller; quillback; shorthead redhorse; green sunfish; stonecat; black bullhead; johnny and Iowa darter; river carpsucker; channel catfish; and fathead and brassy minnow. Exotic species include brown and rainbow trout, walleye, flathead catfish, yellow perch, gizzard shad, and carp.

Reclamation conducted an extensive fish survey of the North Platte River from Casper to the Nebraska State line in March 1999 to supplement Wyoming Game and Fish Department's information on fish communities (Broderick 2000). Some sites were sampled by backpack electrofishing while others were sampled by raft-mounted electrofishing. Electrofishing samples were combined into five reaches. The Casper to Douglas Reach (upstream of Orin) is characterized by 62 percent native fish and 38 percent exotic species, while the next reach from Douglas to the Glendo Reservoir Inlet (which encompasses Orin) is characterized as 40 percent native fish and 60 percent exotic species, principally walleye. The Casper to Douglas Reach has 58 percent turbidity tolerant species in the catch with 32 percent intolerant; and the Douglas to Glendo Inlet Reach is characterized as 56 percent of the catch as tolerant, with no intolerant species captured.

Conder and Deromedi (1998) indicate that sediment accumulation has degraded trout habitat, adversely impacting trout spawning areas, juvenile rearing areas and aquatic macroinvertebrates. Elevated water temperatures of as much as 30 ^{o}C limit trout production downstream of the Natrona/Converse county line.

Analysis of Impacts - Reservoir Outflows and/or River Flows (cfs).–The following compares the four alternatives to the Present Condition. With the exception of Water Leasing, there was little difference in flow impacts among alternatives. The Water Leasing alternative resulted in fewest flow decreases from October-March compared to Present Condition and the most flow increases during this period (Tables 31-32). Water Leasing flows were always greater than 500 cfs (Table 33). Governance Committee, Water Emphasis, and Wet Meadow alternatives had some months with flows less than 500 cfs (Table 33). One time in March (1965) flows dropped below 400 cfs for these alternatives, which would result in a significant reduction in rainbow trout spawning habitat (Dey and Annear 1993). Flows in March of

1965 were 366, 363, and 359 cfs for Governance Committee, Water Emphasis, and Wet Meadow, respectively. Present Condition flows were always above 500 cfs.

Table 31. Flow decreases at Gray Reef Reservoir outflow: Alternative minus Present Condition (number of water years out of 48)

Alternative	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Governance Committee	6	4	6	4	5	6	7	9	9	11	21	3
Water Emphasis	11	11	13	12	12	10	8	13	21	28	33	3
Wet Meadow	11	14	16	14	14	10	10	10	16	23	20	5
Water Leasing	0	0	2	0	0	5	7	15	14	30	40	0

Table 32. Flow increases at Gray Reef Reservoir outflow: Alternative minus Present Condition (number of water years out of 48)

Alternative	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Governance Committee	1	5	7	5	14	32	24	37	35	37	26	44
Water Emphasis	2	5	7	5	14	34	29	34	23	20	15	45
Wet Meadow	3	6	8	6	14	34	27	30	23	16	28	43
Water Leasing	12	14	16	14	13	32	22	27	32	18	8	48

Table 33. Flows less than 500 cfs for North Platte River at Gray Reef Reservoir outflow (number of water years out of 48)

Alternative	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Present Condition	0	0	0	0	0	0	0	0	0	0	0	0
Governance Committee	0	0	0	0	1	1	0	0	0	0	0	0
Water Emphasis	0	0	0	1	1	1	0	0	0	0	0	0
Wet Meadow	0	1	1	1	1	1	0	0	0	0	0	1
Water Leasing	0	0	0	0	0	0	0	0	0	0	0	0

Dissolved oxygen depletion below Gray Reef dam should not be a problem because oxygen is generally at or above saturation during summer months (Figure 15). Also, increased summer temperatures should not be a problem. With one exception, summer temperatures downstream from Gray Reef dam have always been less than 20°C (68°F) (Figure 16).

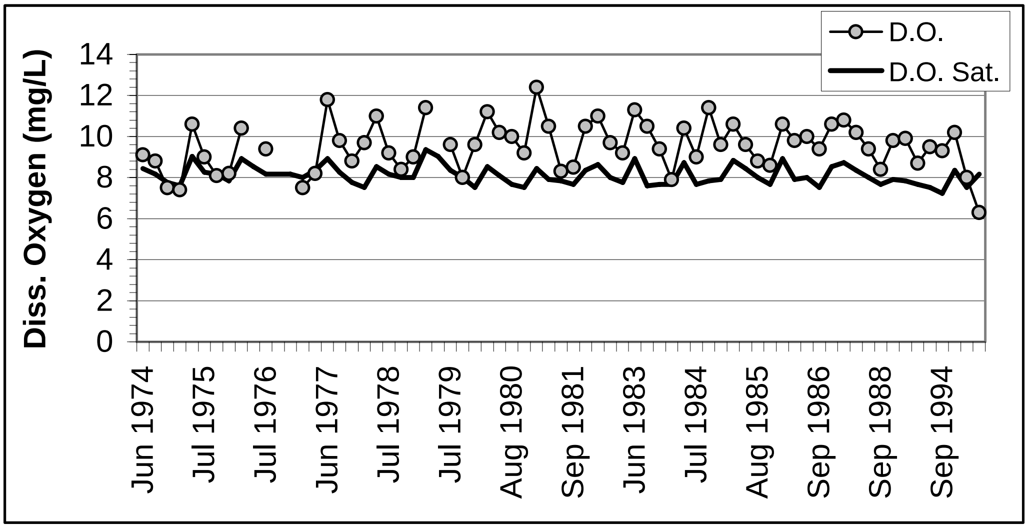

Figure 15. Summer dissolved oxygen downstream (0.8 mile) from Gray Reef Dam.

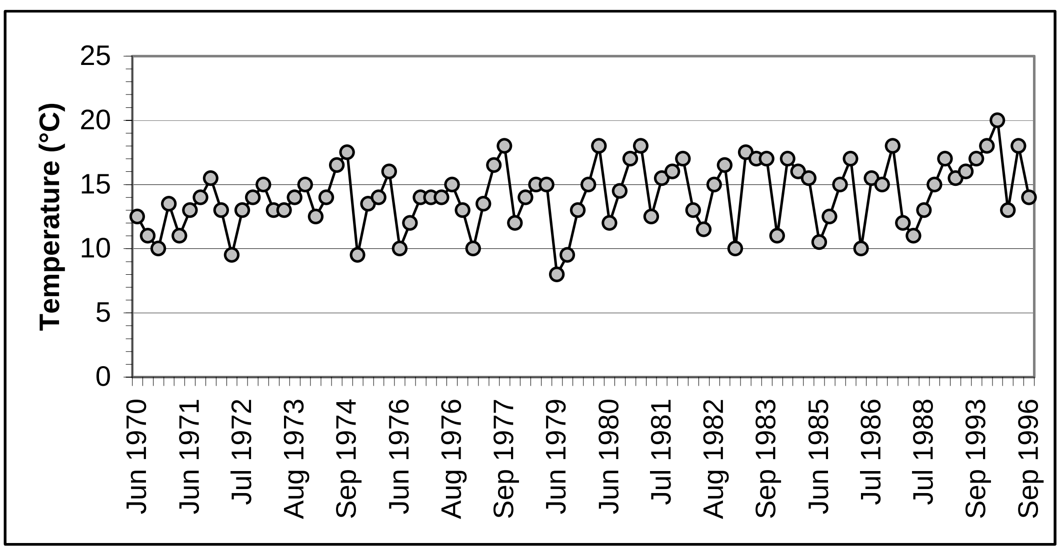

Figure 16. Summer temperatures downstream (0.8 mile) from Gray Reef Dam

Glendo Reservoir Outflow.— The following sections discuss the existing fish community and limiting factors, and analyze the impacts of each alternative.

Fish Community Existing Conditions and Limiting Factors.— The 22-mile Class III river reach from Glendo Dam to Guernsey Reservoir is managed under a Basic Yield Concept for rainbow trout, with wild brown trout also contributing to the fishery. Fingerling rainbow trout are stocked annually to augment natural recruitment. Native species include channel catfish, longnose dace, quillback, fathead minnow, and white and longnose suckers. Exotic species include rainbow, brown, and cutthroat trout; carp; walleye; yellow perch; black crappie; gizzard shad; and emerald and spottail shiner.

Broderick (2000) found that in the samples sites immediately below Glendo Dam, 80 percent of the fish sampled were native species and 20 percent were exotics; and 75 percent of the species were turbidity intolerant with 25 percent tolerant.

The North Platte River below Glendo Reservoir provides a popular local fishery for rainbow and brown trout. The sport fishery is limited by fluctuating waterflows. Non-irrigation season flows in this reach are 25 cfs which suppress trout populations during the critical wintering period and high flows during the larval and juvenile life stages (Conder and Deromedi 1998). The non-irrigation season flow of 25 cfs occurs in the river immediately below Glendo Dam via the Glendo Dam Low Flow Outlet works. The Glendo Dam Low Flow Outlet works provides a year round flow of 25 cfs between Glendo Dam and Glendo Powerplant outlet works.

Analysis of Impacts - Reservoir Outflows and/or River Flows (cfs).–The following compares the four alternatives to the Present Condition. Among alternatives, the Governance Committee had fewest number of months with flows less than Present Conditions and most months with flows greater than Present Conditions, particularly during the spring months (Tables 34 and 35). No alternative or Present Condition had any months with flows less than 25 cfs (Table 36).

Table 34. Flow decreases at Glendo Reservoir outflow: Alternative minus Present Condition (number of water years out of 48)

Alternative	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Governance Committee	0	0	0	0	1	5	12	33	38	31	41	1
Water Emphasis	0	0	0	0	1	5	11	39	42	45	47	1
Wet Meadow	0	0	0	0	1	5	11	34	35	25	16	5
Water Leasing	9	0	0	0	0	4	15	34	31	43	47	4

Table 35. Flow increases at Glendo Reservoir outflow: Alternative minus Present Condition (number of water years out of 48)

Alternative	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Governance Committee	0	0	0	0	0	0	1	12	6	13	5	47
Water Emphasis	0	0	0	0	0	0	1	2	4	3	1	47
Wet Meadow	0	0	0	0	0	0	1	3	3	5	3	43
Water Leasing	0	0	0	0	2	2	4	5	12	4	1	44

Table 36. Flows less than 25 cfs for North Platte River at Glendo Reservoir outflow (number of water years out of 48)

Alternative	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Present Condition	0	0	0	0	0	0	0	0	0	0	0	0
Governance Committee	0	0	0	0	0	0	0	0	0	0	0	0
Water Emphasis	0	0	0	0	0	0	0	0	0	0	0	0
Wet Meadow	0	0	0	0	0	0	0	0	0	0	0	0
Water Leasing	0	0	0	0	0	0	0	0	0	0	0	0

Guernsey Reservoir Outflow— The North Platte River below Guernsey Reservoir to the Wyoming-Nebraska border is considered a Class V trout fishery, meaning it is incapable of maintaining a trout fishery (WGFD 1987). Modifications of an outlet structure, deep pools below the Highway 85 bridge, plus augmentation of flow from the Laramie River, provide minimal habitat for gamefish in the river at Torrington. Catchable sized rainbow trout and fingerling channel catfish are stocked in better habitat areas in the fall. Trout provide a put and take fishery during fall, winter, and spring. Trout are lost in the summer due to high water temperatures and downstream drift with high irrigation flows. Success of the channel catfish stock has not been determined. During the non-irrigation season, when Inland Lakes water is not being moved from the mainstem, no releases are made from Guernsey Reservoir. Any flow occurring below the dam at that time is associated with seepage from the dam. Conder and Deromedi (1998) indicated that a minimum flow of 300 cfs during the non-irrigation season would greatly benefit the fish community in this reach.

Broderick (2000) found that the reach immediately below Guernsey Dam to the Laramie River confluence had the highest proportion of native fish (97 percent) of all the sample sites; 86 percent of which were turbidity intolerant. Below the confluence of the Laramie River, the species composition shifted, with 77 percent of the catch categorized as native fish species. The proportion of turbidity intolerant species dropped to 25 percent.

The annual "silt-run" below Guernsey Dam severely degrades the riverine habitat. The silt run delivers fine sediment for 10-14 days each summer. A side effect of the silt run is excessive turbidity in the North Platte River from Guernsey Dam to Whalen Diversion. This is very detrimental to aquatic life in the river. Conder and Deromedi (1998) indicate that the existing flow releases from Guernsey Reservoir limit the fishery in the North Platte River below the dam to the Laramie River confluence to deep pools where fish can overwinter. Extremely reduced flows also occur below the Laramie River confluence in April, May, and June further reducing fish habitat availability and impairing overwinter survival. Conder and Deromedi (1998) state that efforts to stock trout and channel catfish in this reach have failed in part because of dewatering conditions, high summer irrigation flows causing downstream drift, and entrainment into irrigation canals.

Analysis of Impacts - Reservoir Outflows and/or River Flows (cfs).–The existing fishery downstream from Guernsey Reservoir to the Wyoming-Nebraska state line is marginal and there is not any official established maintenance flow. We assumed any impacts were related to flow releases from the reservoir with higher flows than Present Conditions resulting in better conditions for fish. Tables 37 and 38 show net flow decreases and increases, respectively, at the Guernsey Reservoir outflow for each alternative compared to Present Condition. Water Emphasis had the most months with flow decreases compared to Present Condition and Governance Committee alternative had the most months with flow increases among alternatives.

Table 37. Net flow decreases at Guernsey Reservoir outflow: Alternative minus Present Condition (number of water years out of 48)

Alternative	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept
Governance Committee	0	0	0	0	0	4	9	35	38	31	41	1
Water Emphasis	0	0	0	0	0	4	8	40	42	45	47	1
Wet Meadow	0	0	0	0	0	4	8	35	32	23	15	5
Water Leasing	10	0	0	0	0	2	15	35	33	44	47	4

Table 38. Net flow increases at Guernsey Reservoir outflow: Alternative minus Present Condition (number of water years out of 48)

Alternative	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept
Governance Committee	0	0	0	0	0	0	0	13	7	12	5	47
Water Emphasis	0	0	0	0	0	0	0	1	6	3	1	47
Wet Meadow	0	0	0	0	0	0	0	1	3	5	5	43
Water Leasing	0	0	0	0	1	3	4	6	13	4	1	44

Panhandle Streams - Several streams in the Scottsbluff area draining out of the Sandhills, such as Nine Mile Creek, Spotted Tail Creek, Dry Sheep Creek, and Sheep Creek, contain brown and rainbow trout populations. These streams are likely fed mostly by groundwater. However, most of them cross Interstate 80 or the Highline Canal. Thus, most of them probably do receive some seepage water from the canals, and runoff from irrigated lands. The Full Water Leasing alternative leases 32% of the water supply from these canals. A rough analysis showed that some reduction in flow in these streams could result from leasing (Water Quality Appendix), in spite of state laws requiring that the state engineer will ensure maintenance of the return flow regime even when waters are leased. This impact on flows could result in reduced habitat for the trout populations. In addition to potentially reduced flows, summer water temperatures in these streams may increase with the Water Leasing Alternative. If trout in the drains are remnants of the Lake McConaughy population, the high temperature is probably not a problem. The Lake McConaughy strain of rainbow has been planted all over the Intermountain West because of their tolerance to high temperatures, at least high for trout. Even so, where the native ground water enters the stream, there should be cool water refugia for some of the fish.

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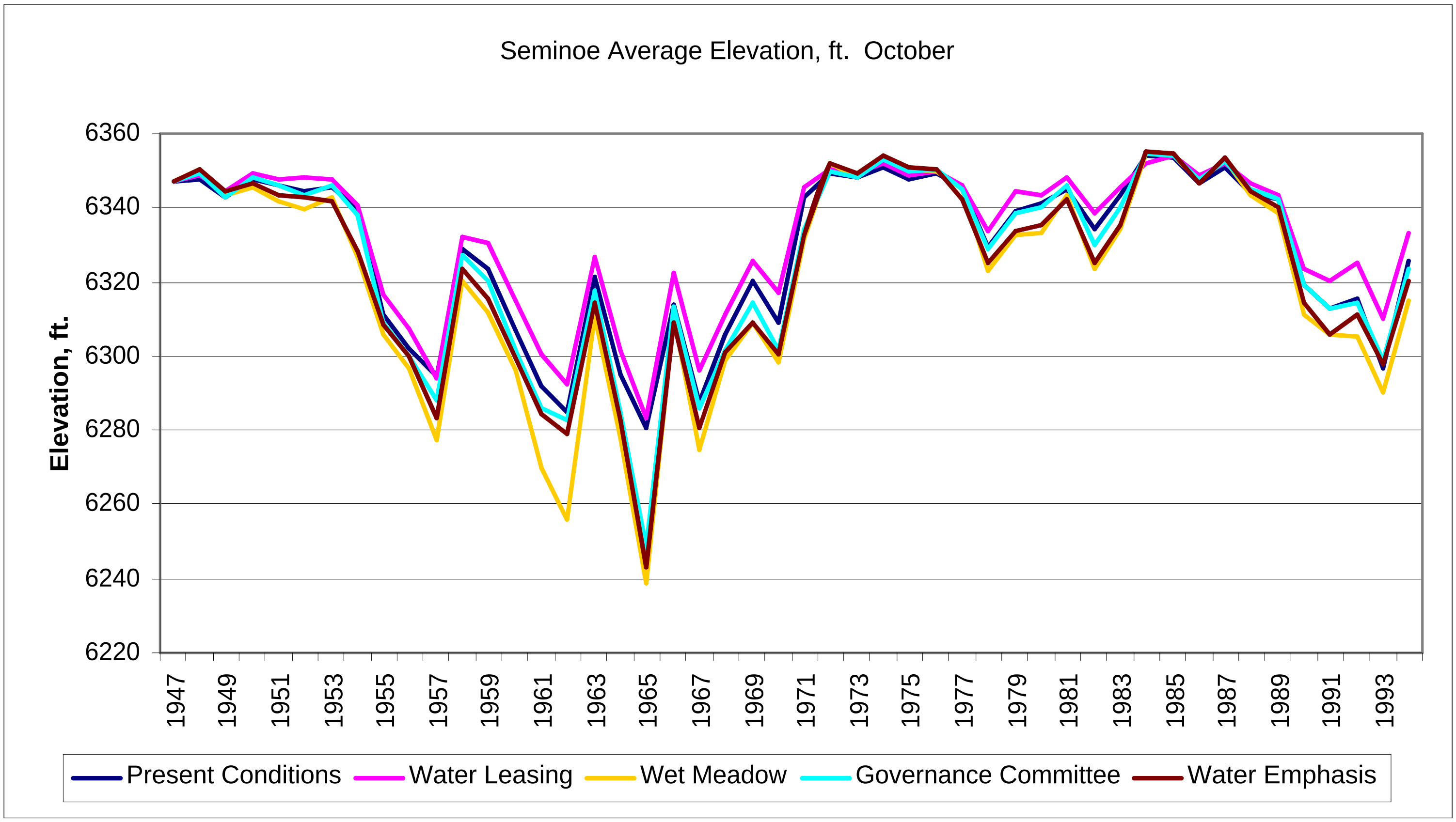
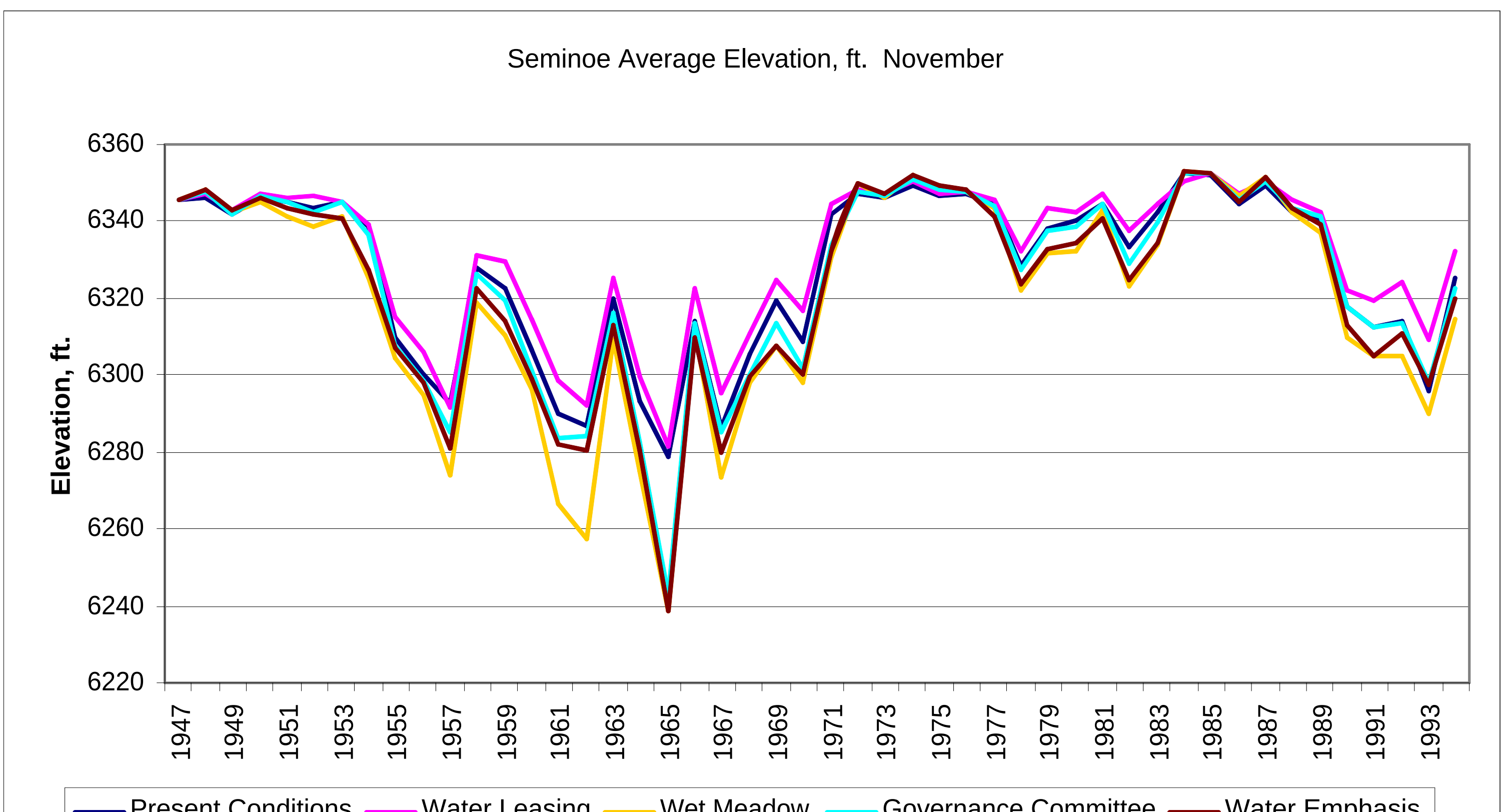
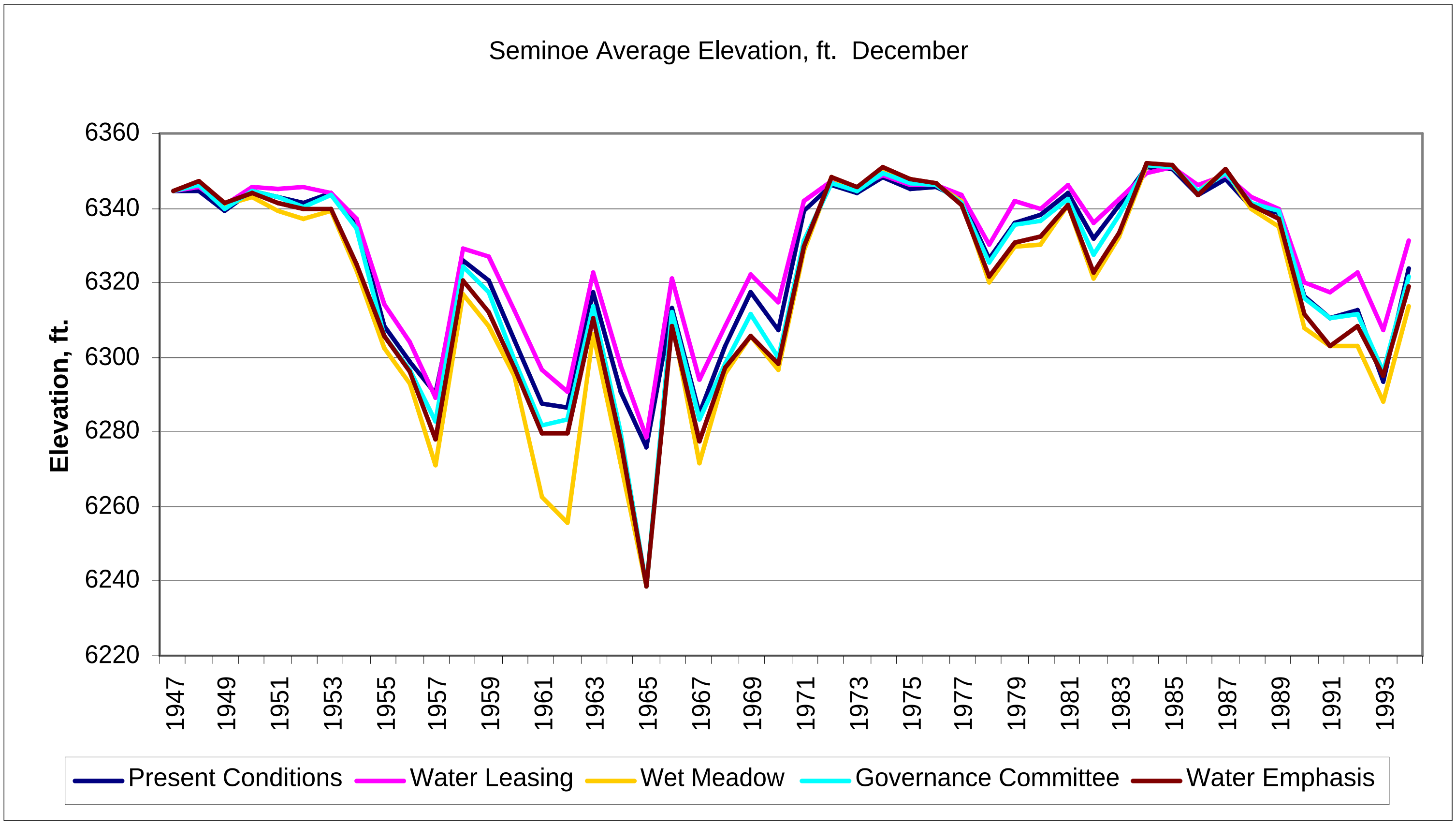
Appendix A Reservoir Elevation and Outflow Time Series

Seminole Reservoir Elevations



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Elevation, ft.
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6340
6320
6300
6280
6260
6240
6220
1947
1949
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1953
1955
1957
1959
1961
1963
1965
1967
1969
1971
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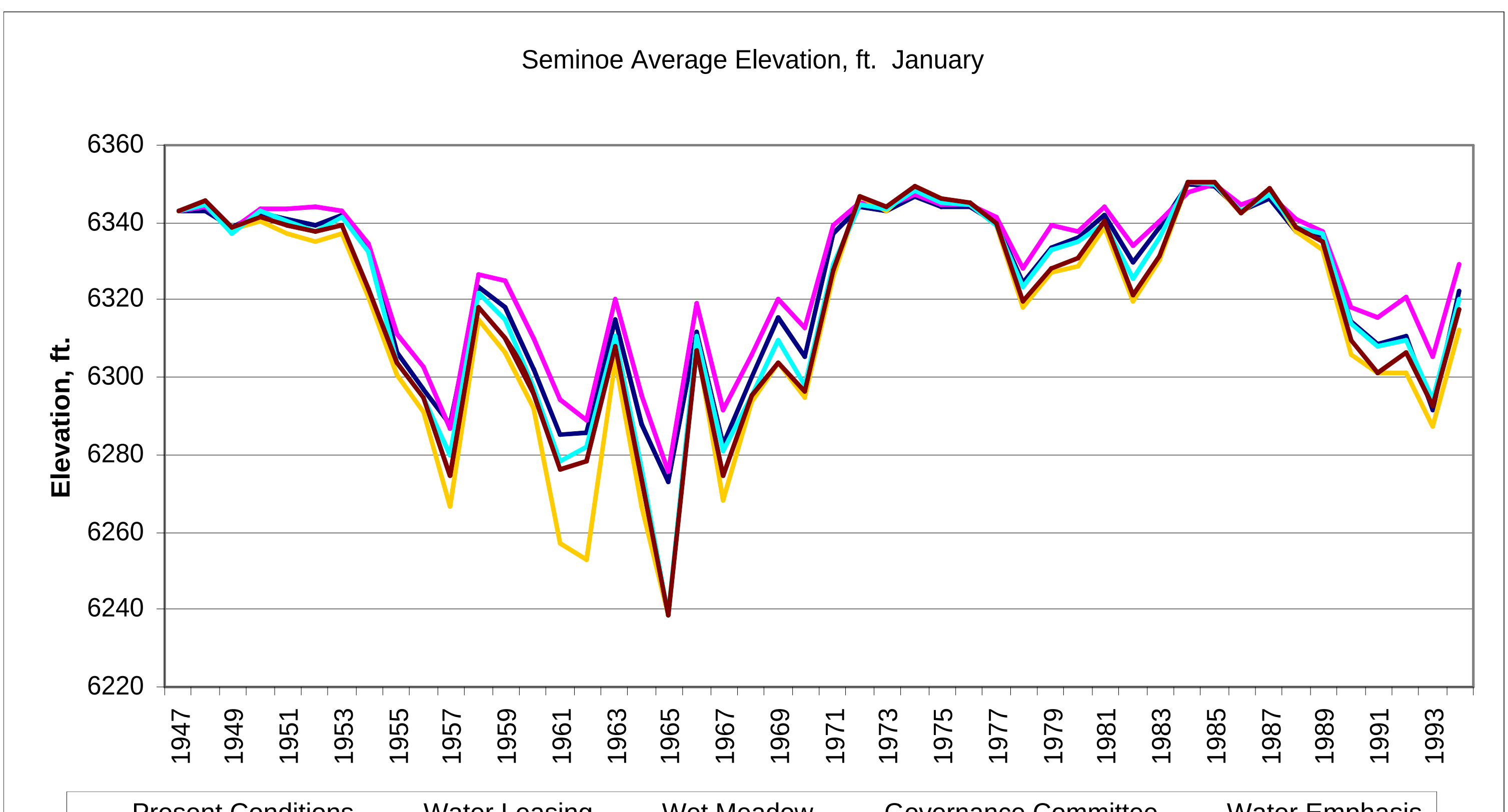
1987
1989
1991
1993
Present Conditions
Water Leasing
Wet Meadow
Governance Committee
Water Emphasis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6300
6280
6260
6240
6220
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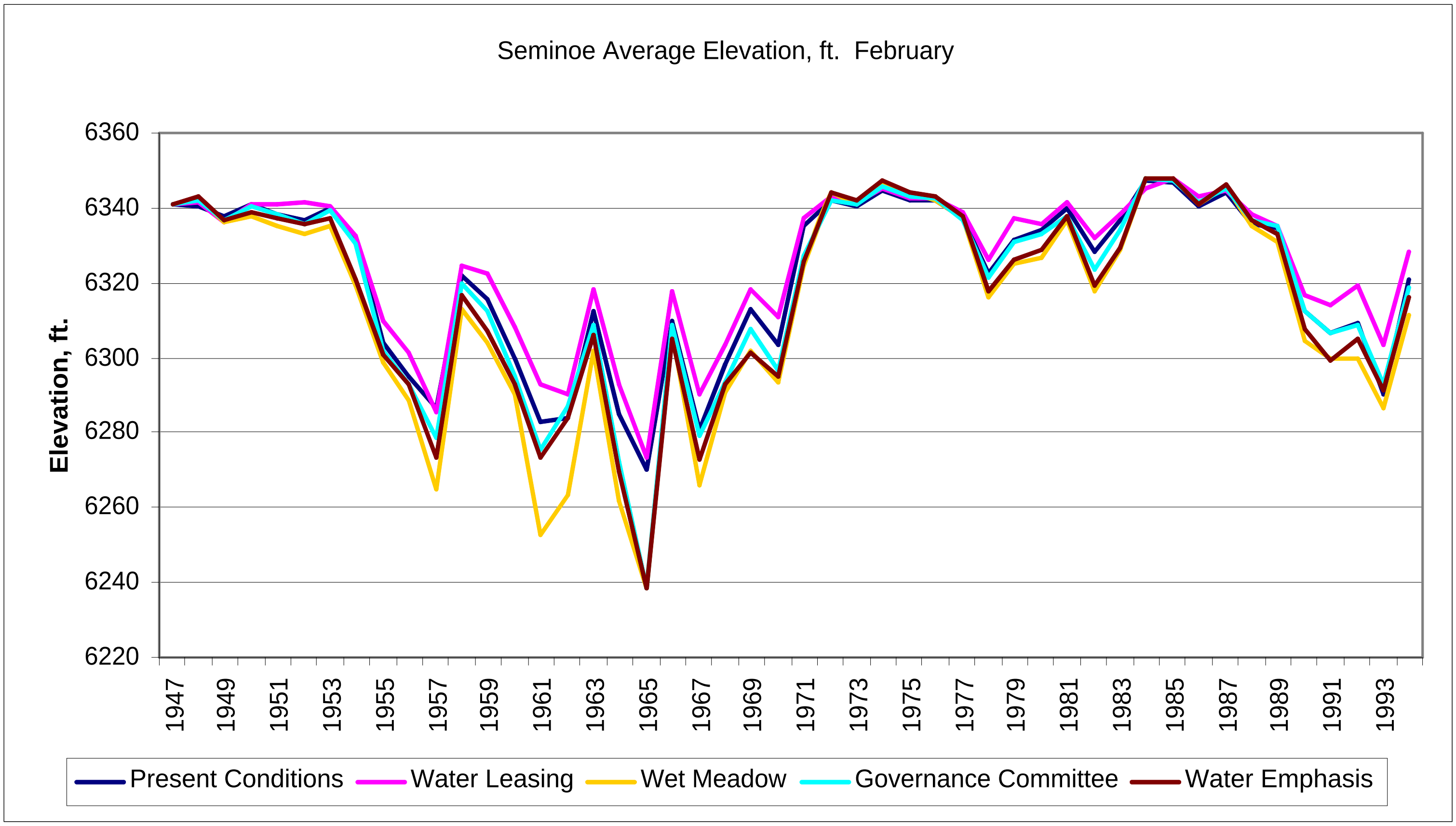
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Elevation, ft.
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6320
6300
6280
6260
6240
6220
1947
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1955
1957
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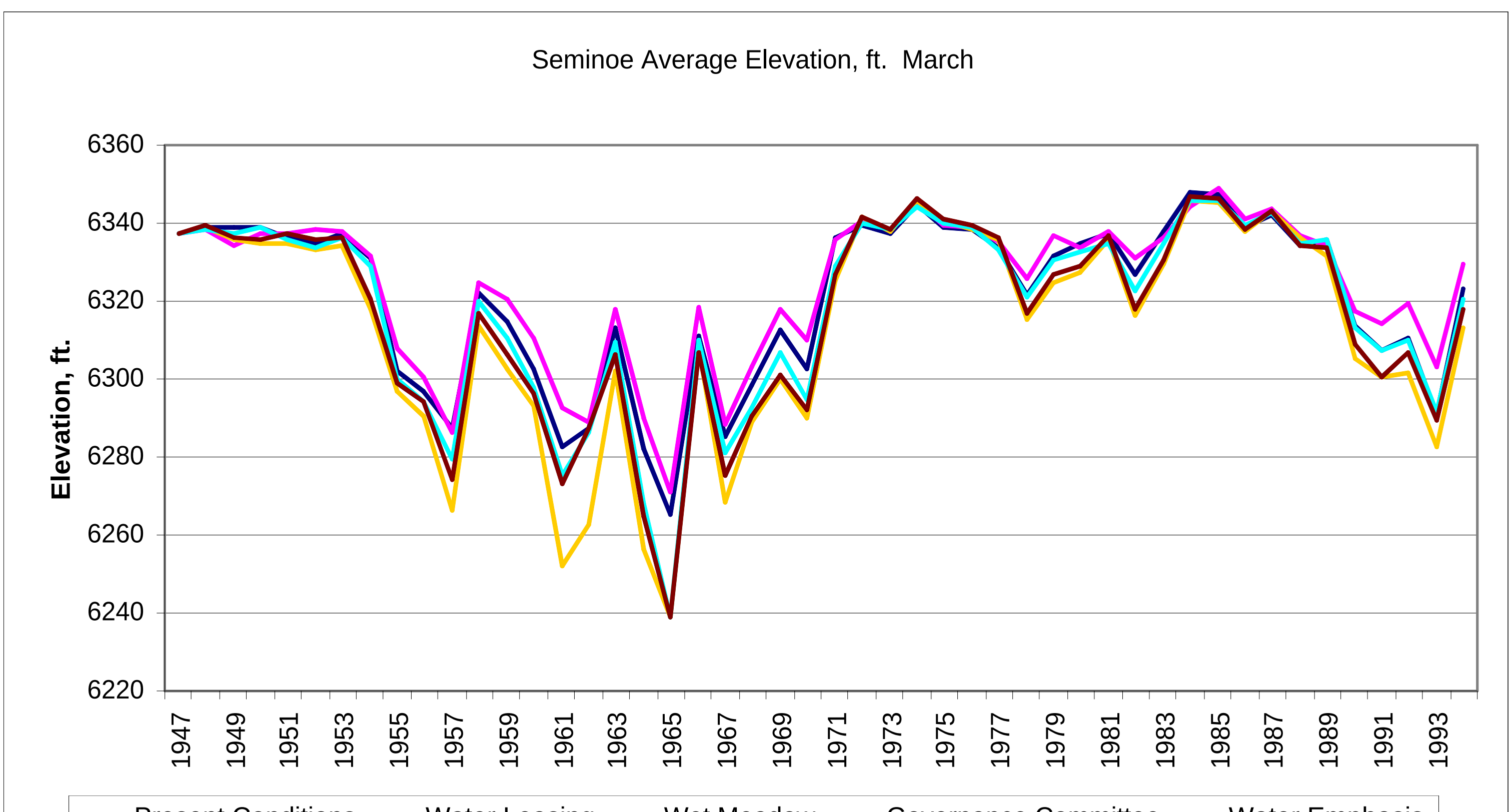
Present Conditions
Water Leasing
Wet Meadow
Governance Committee
Water Emphasis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Elevation, ft.
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6340
6320
6300
6280
6260
6240
6220
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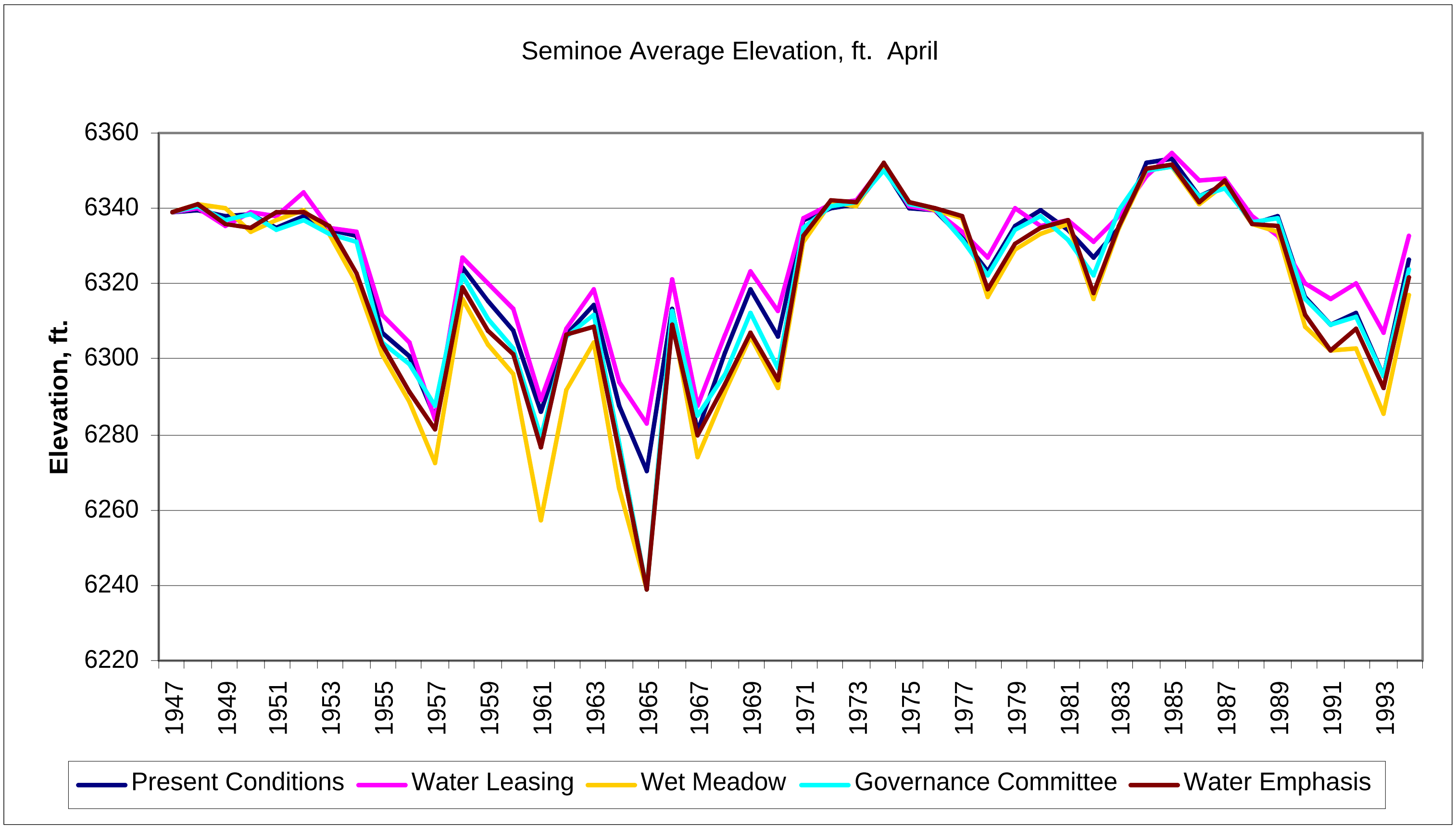

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Elevation, ft.
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6300
6280
6260
6240
6220
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1955
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1965
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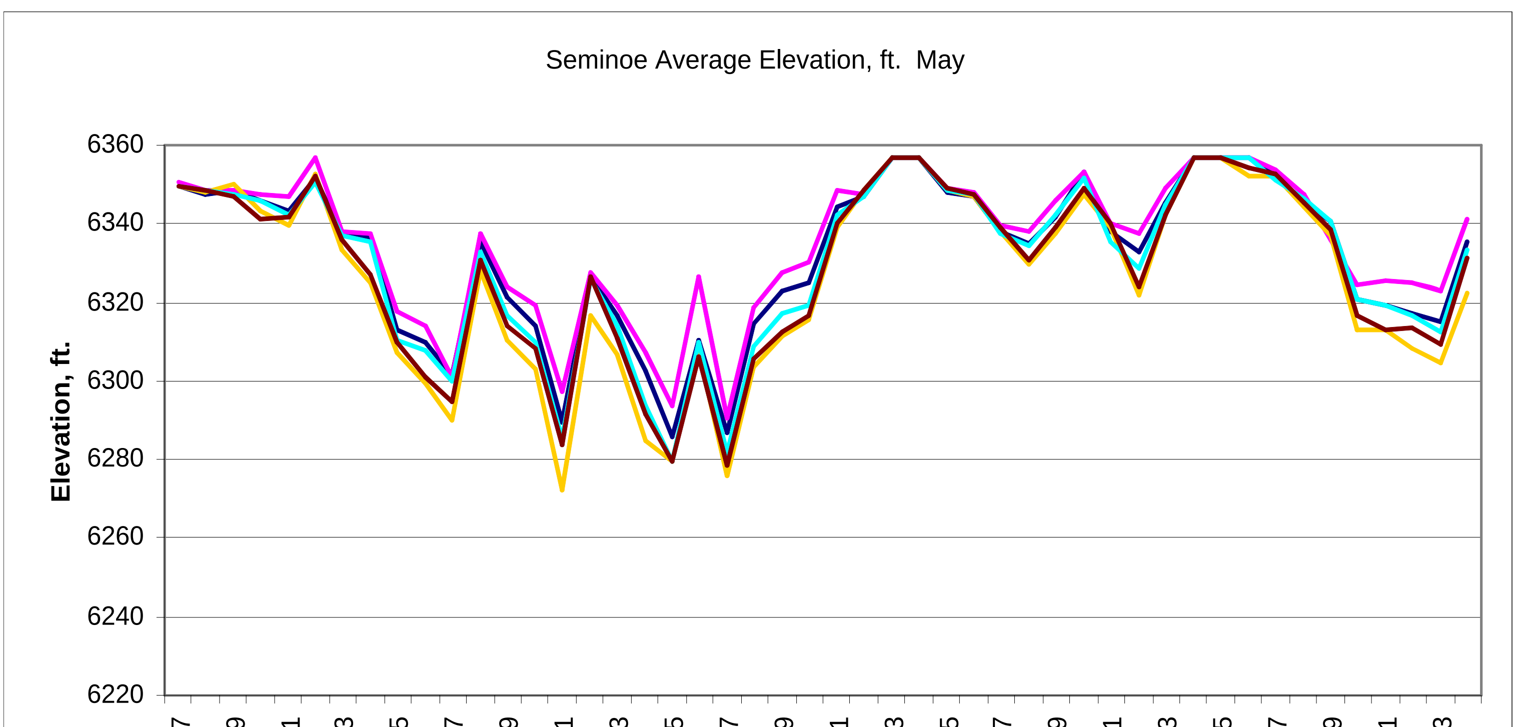
1993
Present Conditions
Water Leasing
Wet Meadow
Governance Committee
Water Emphasis



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Elevation, ft.
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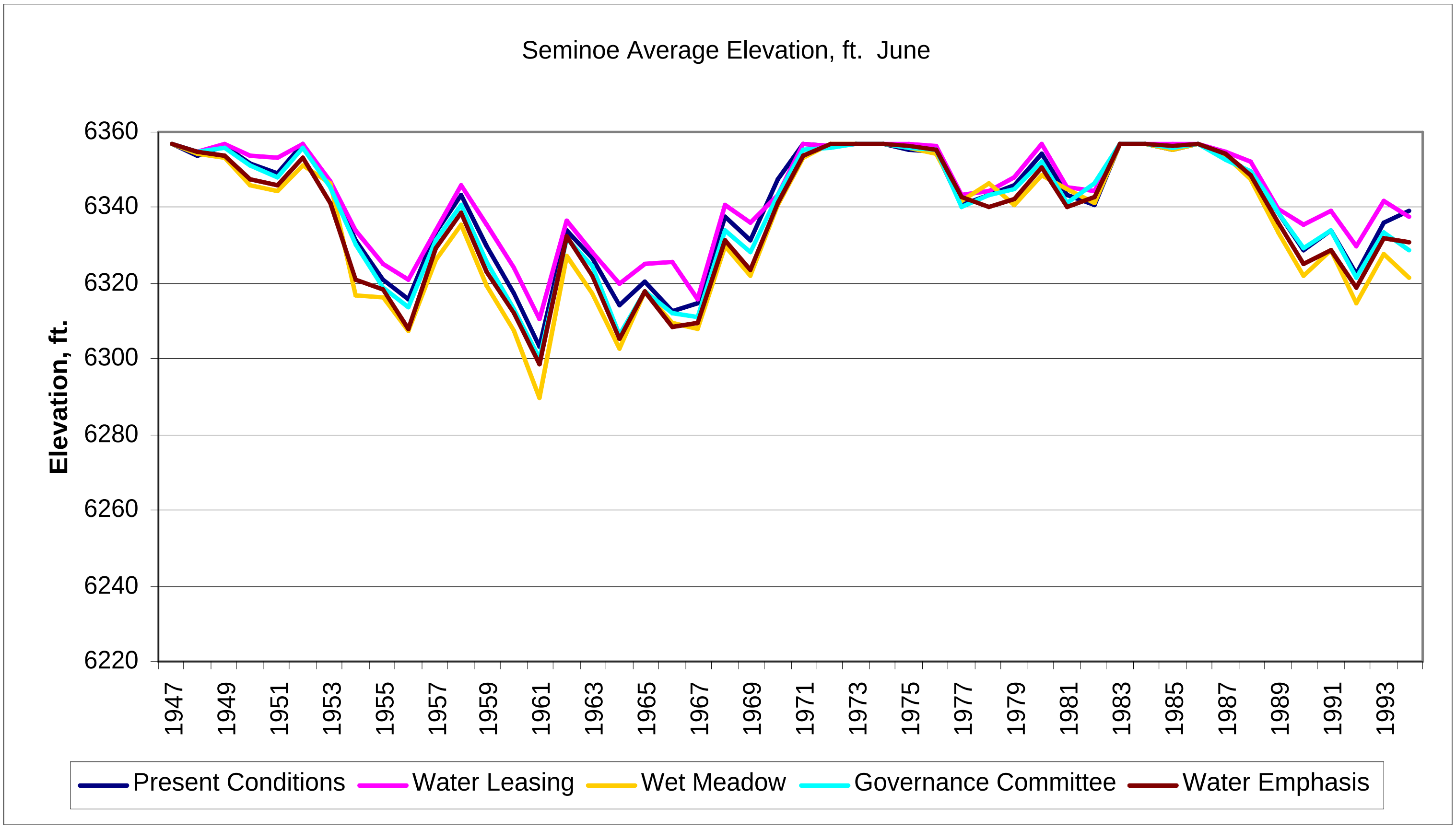
6320
6300
6280
6260
6240
6220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6280
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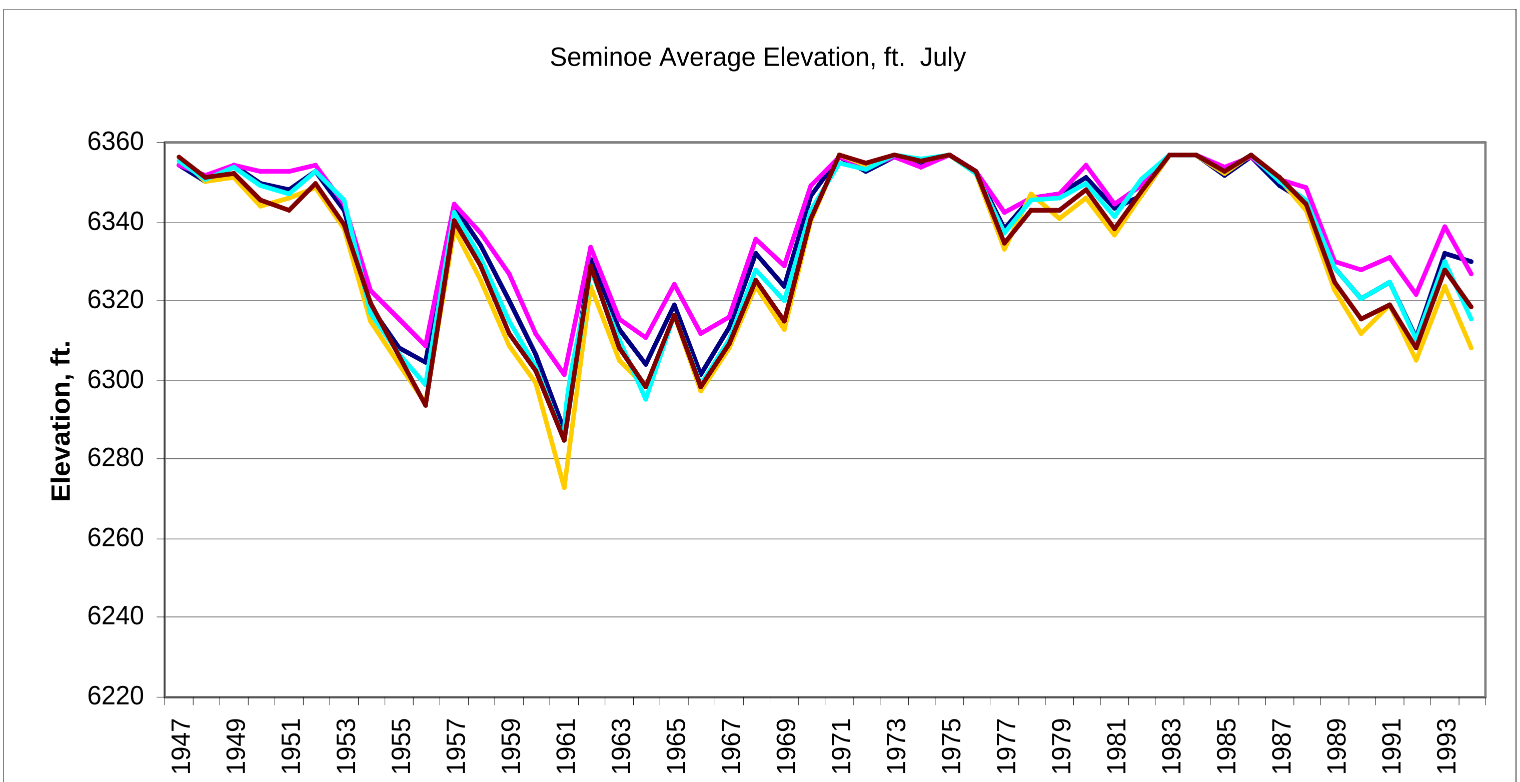
Present Conditions
Water Leasing
Wet Meadow
Governance Committee
Water Emphasis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6240
6220
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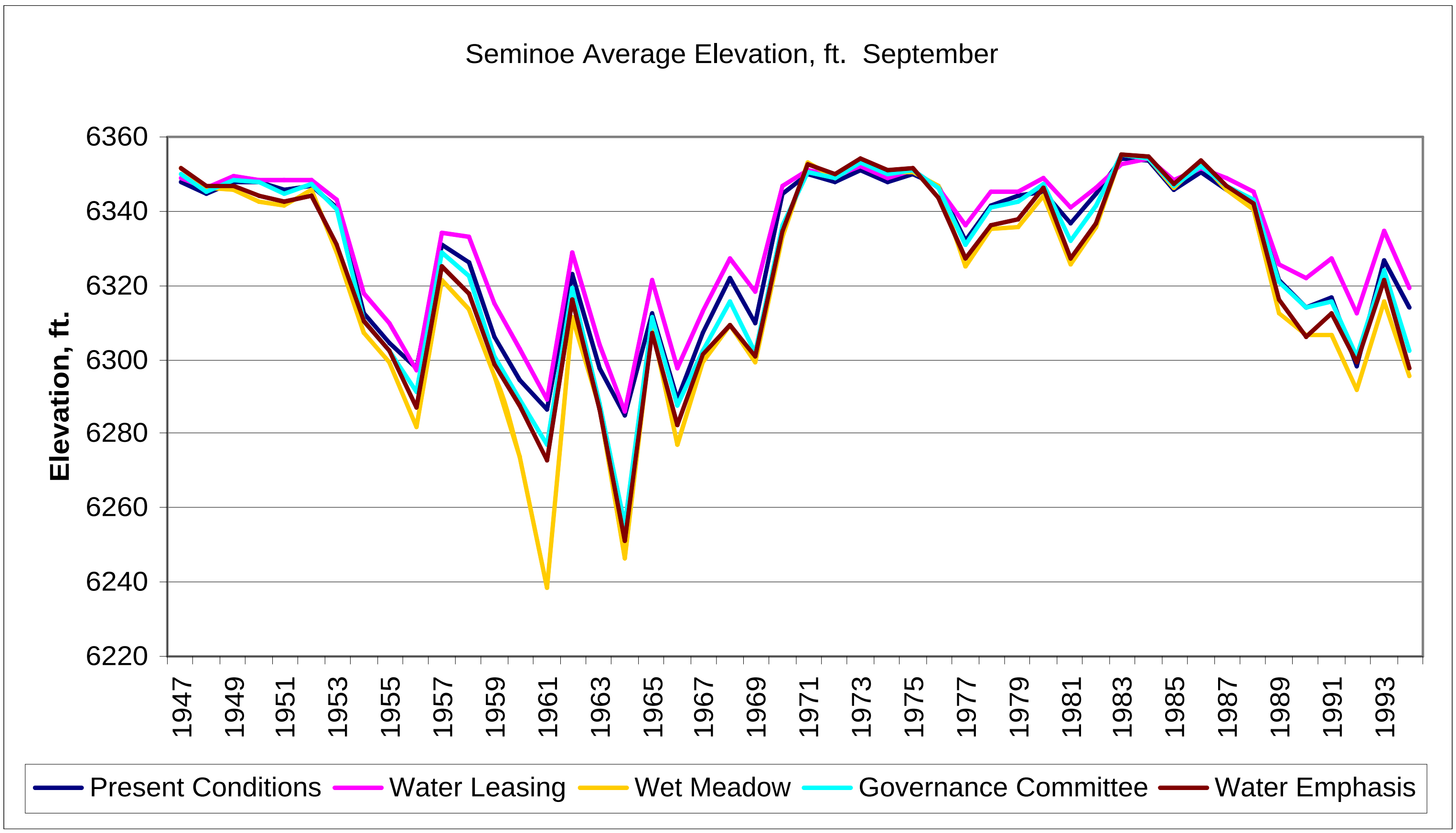

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Elevation, ft.
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6280
6260
6240
6220
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1953
1955
1957
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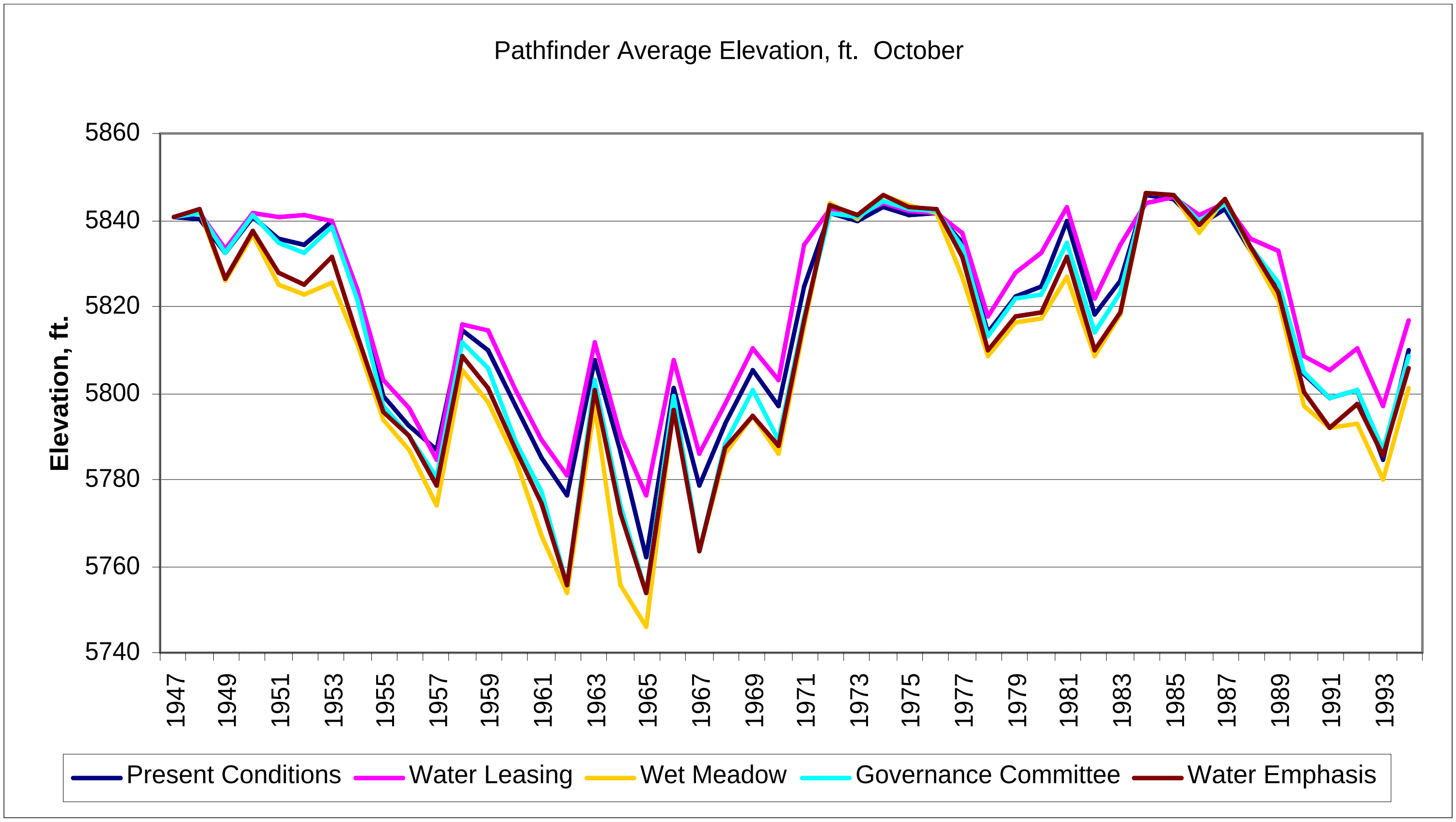
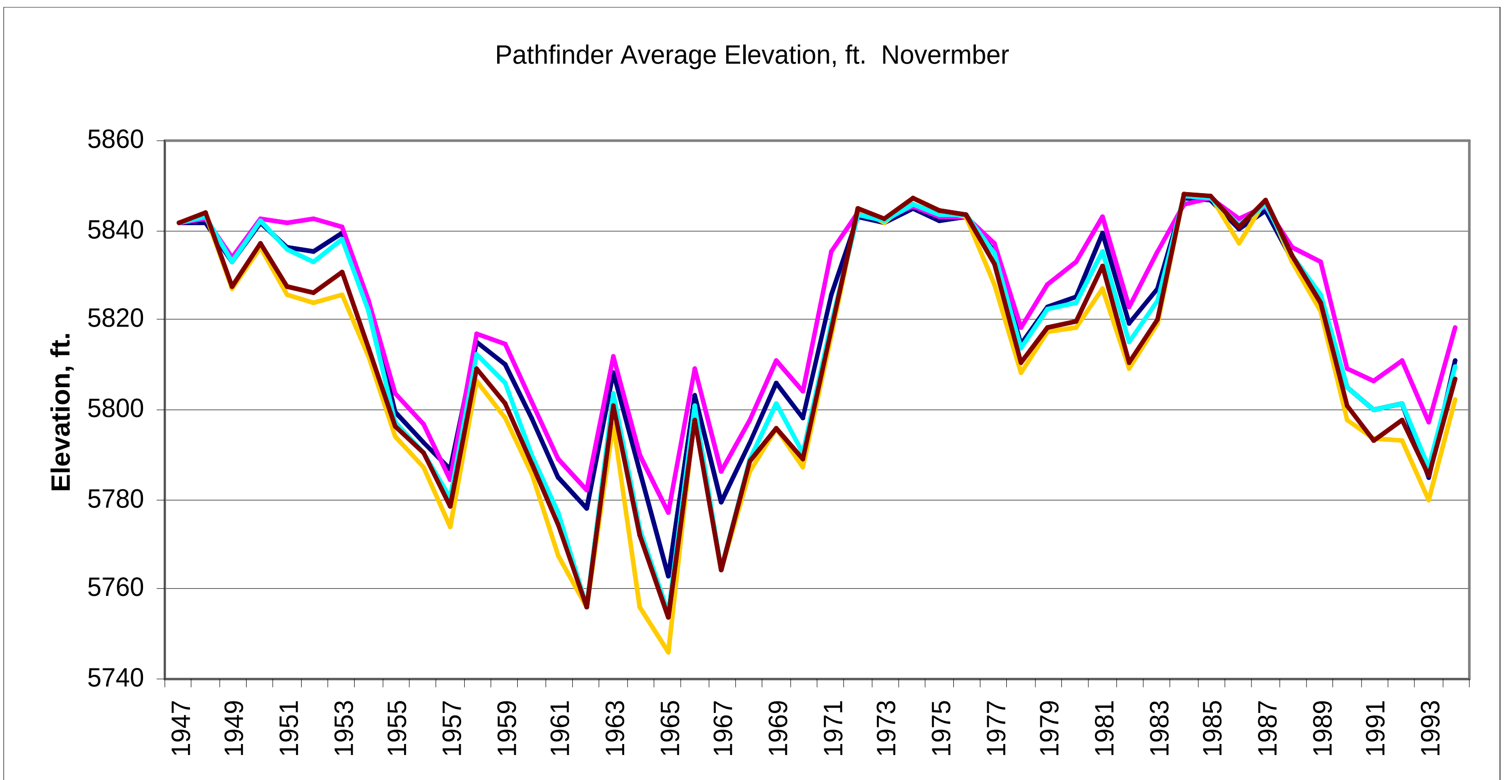
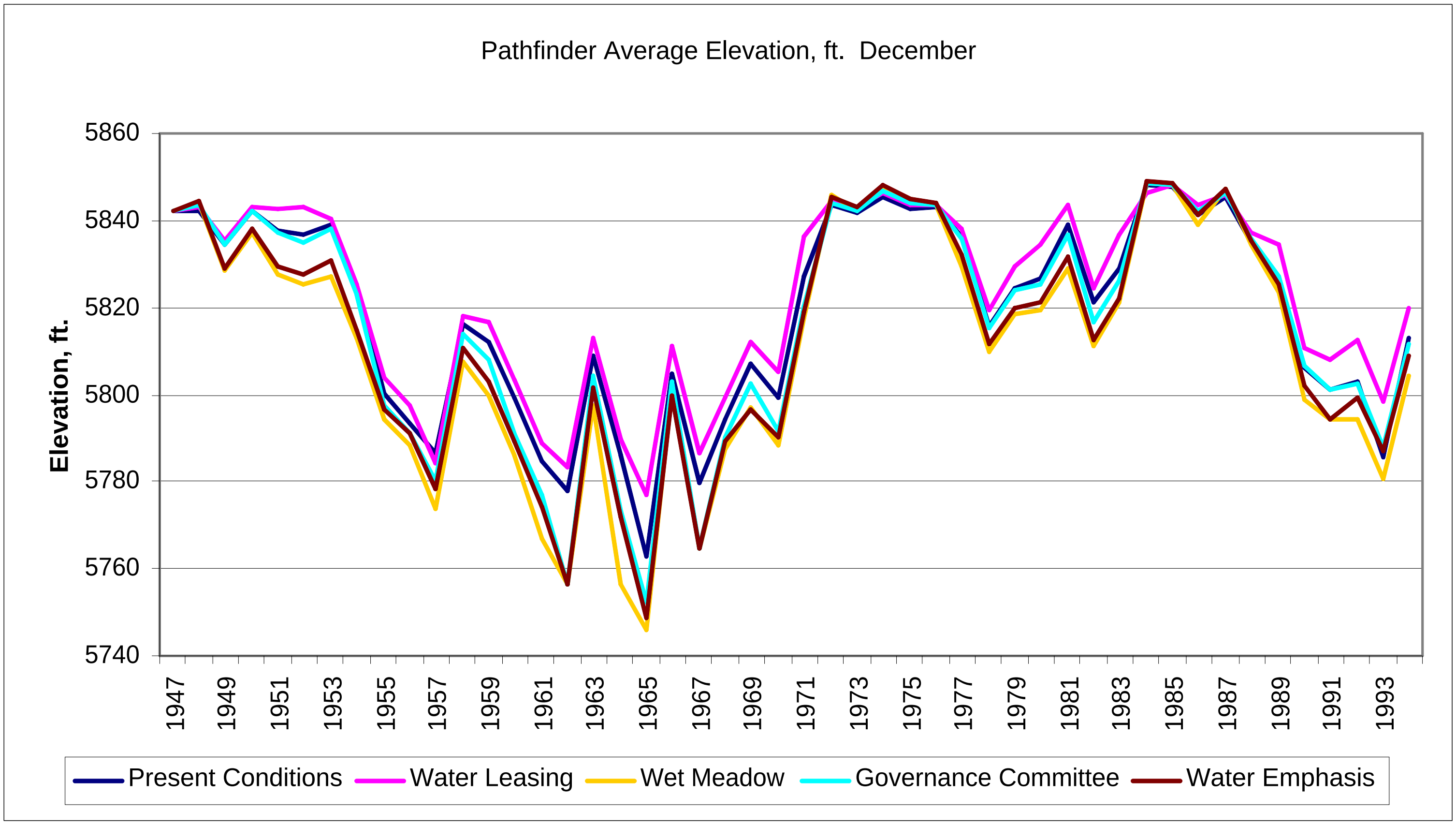
1993
Present Conditions
Water Leasing
Wet Meadow
Governance Committee
Water Emphasis

Pathfinder Reservoir Elevations







Pathfinder Average Elevation, ft. December
5860
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5740
Elevation, ft.
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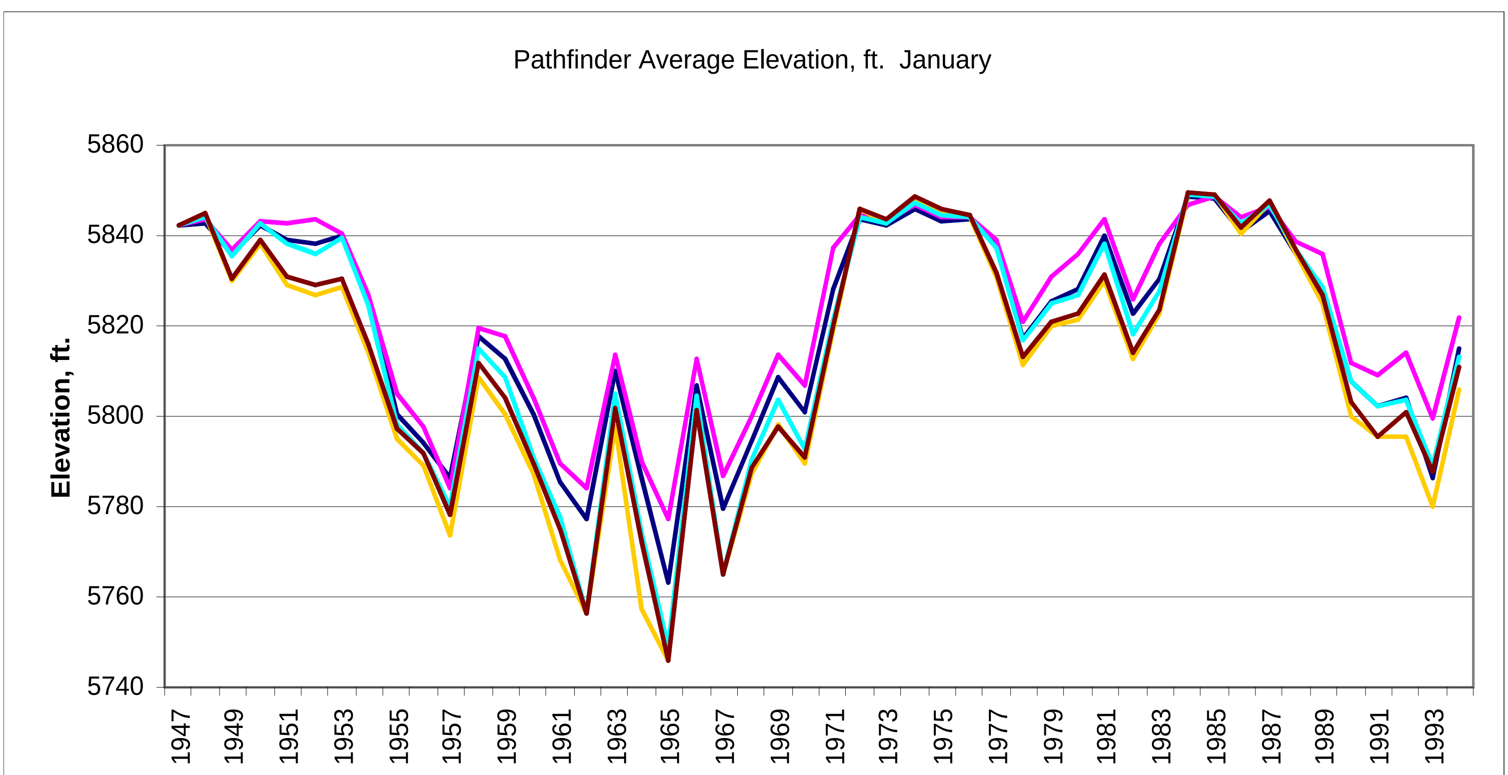
Present Conditions
Water Leasing
Wet Meadow
Governance Committee
Water Emphasis



Pathfinder Average Elevation, ft. January
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5760
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Elevation, ft.
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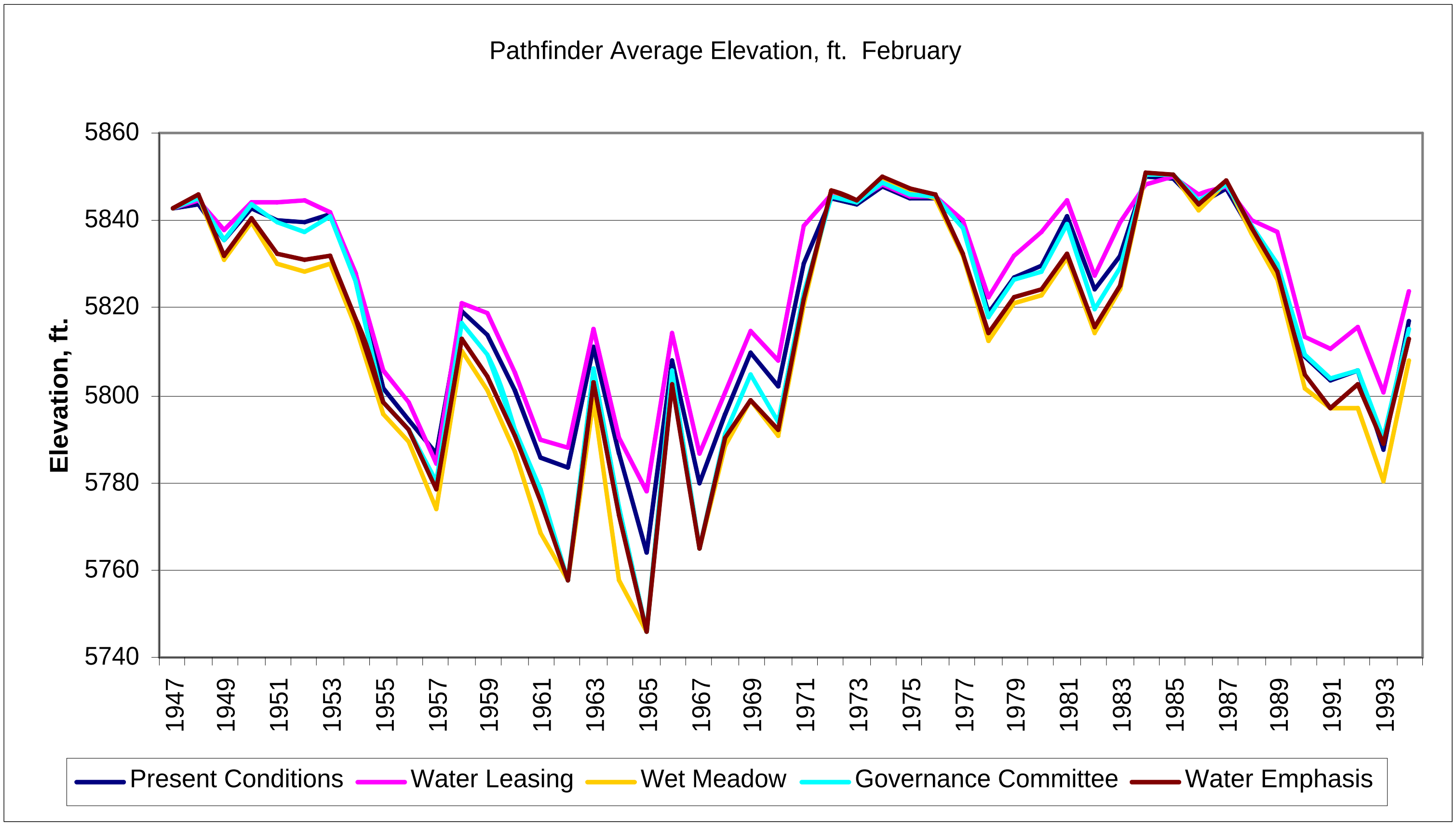
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Elevation, ft.
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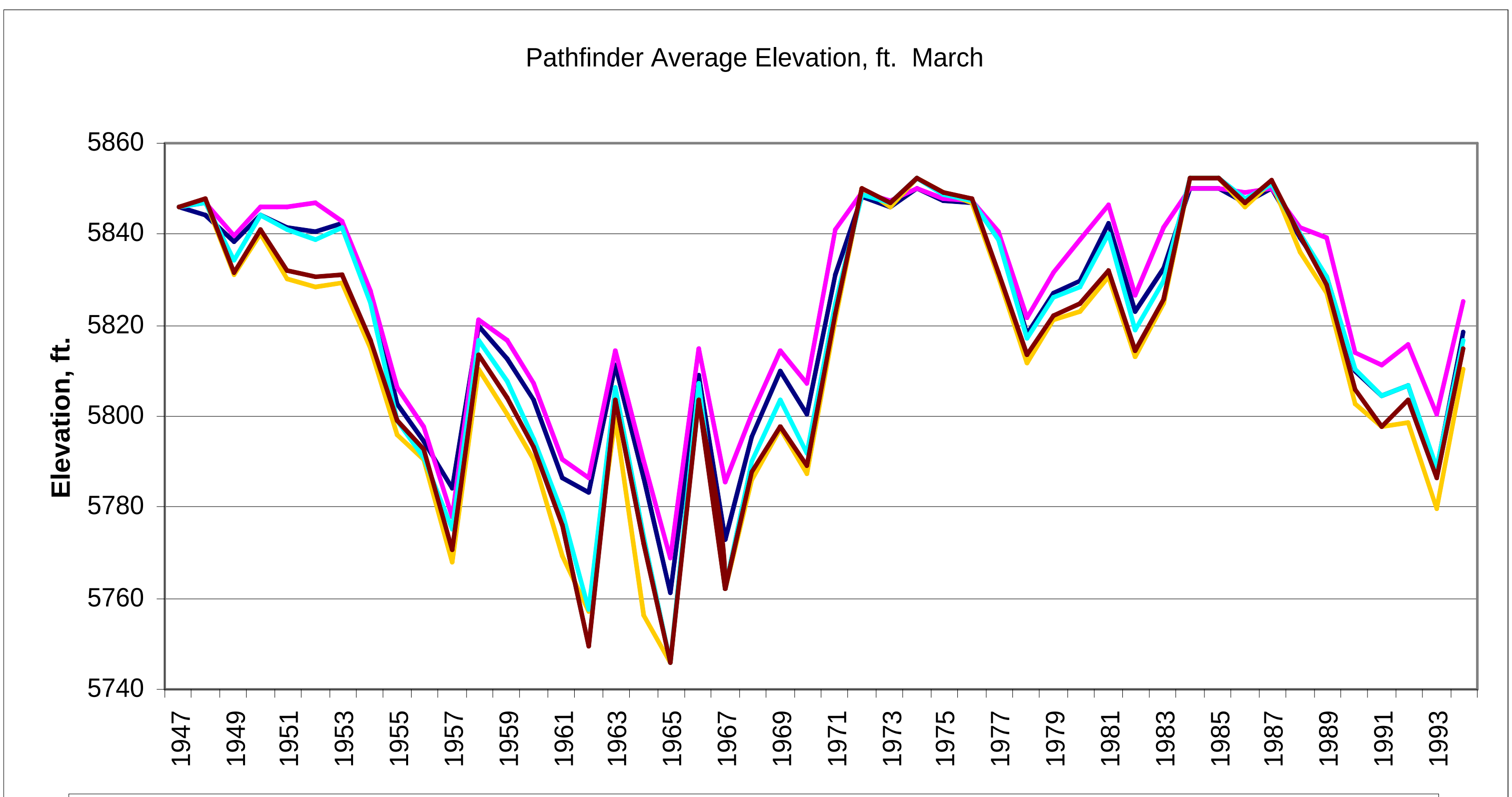
Present Conditions
Water Leasing
Wet Meadow
Governance Committee
Water Emphasis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Elevation, ft.
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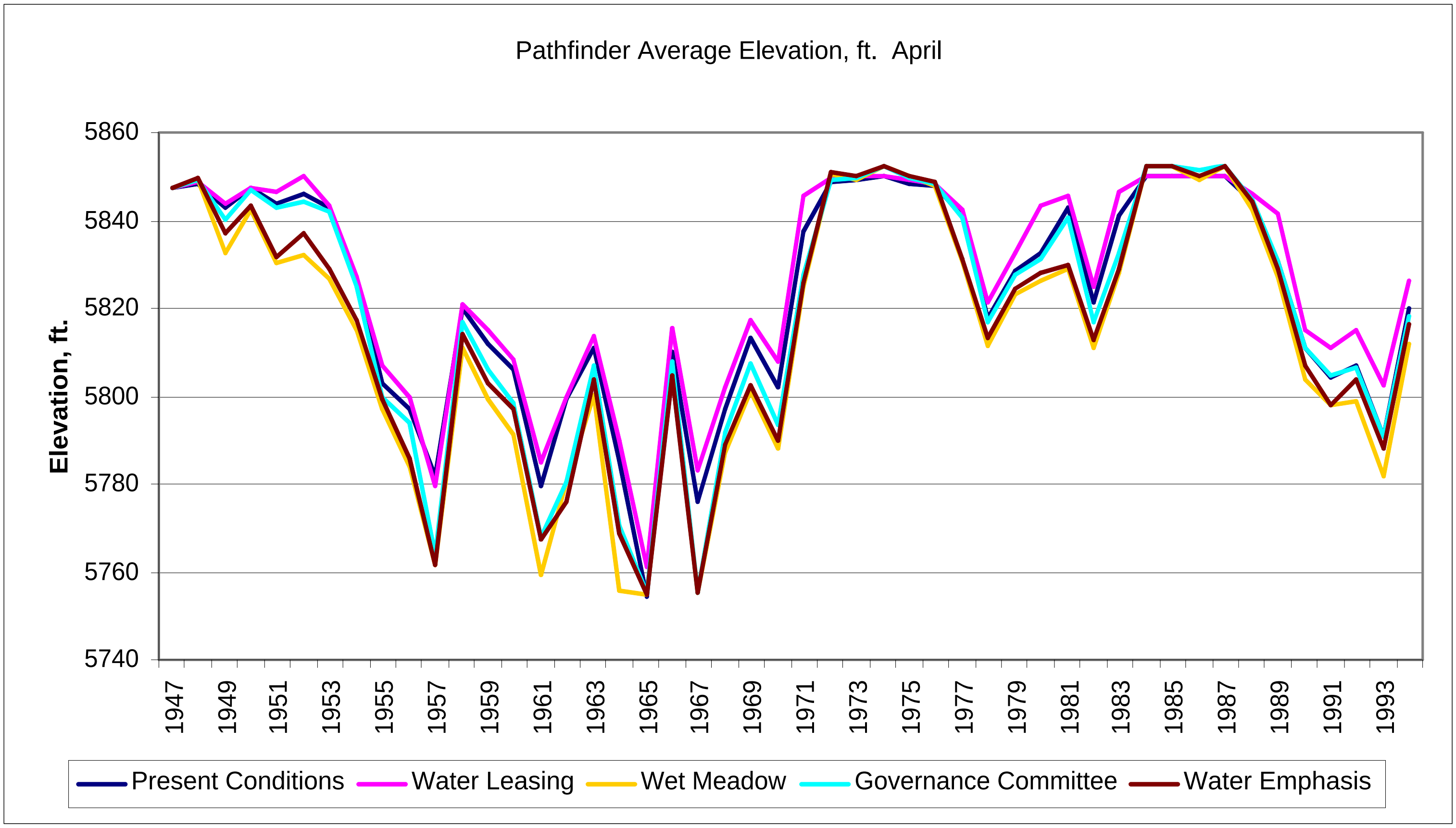

Pathfinder Average Elevation, ft. April
Elevation, ft.
5860
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5800
5780
5760
5740
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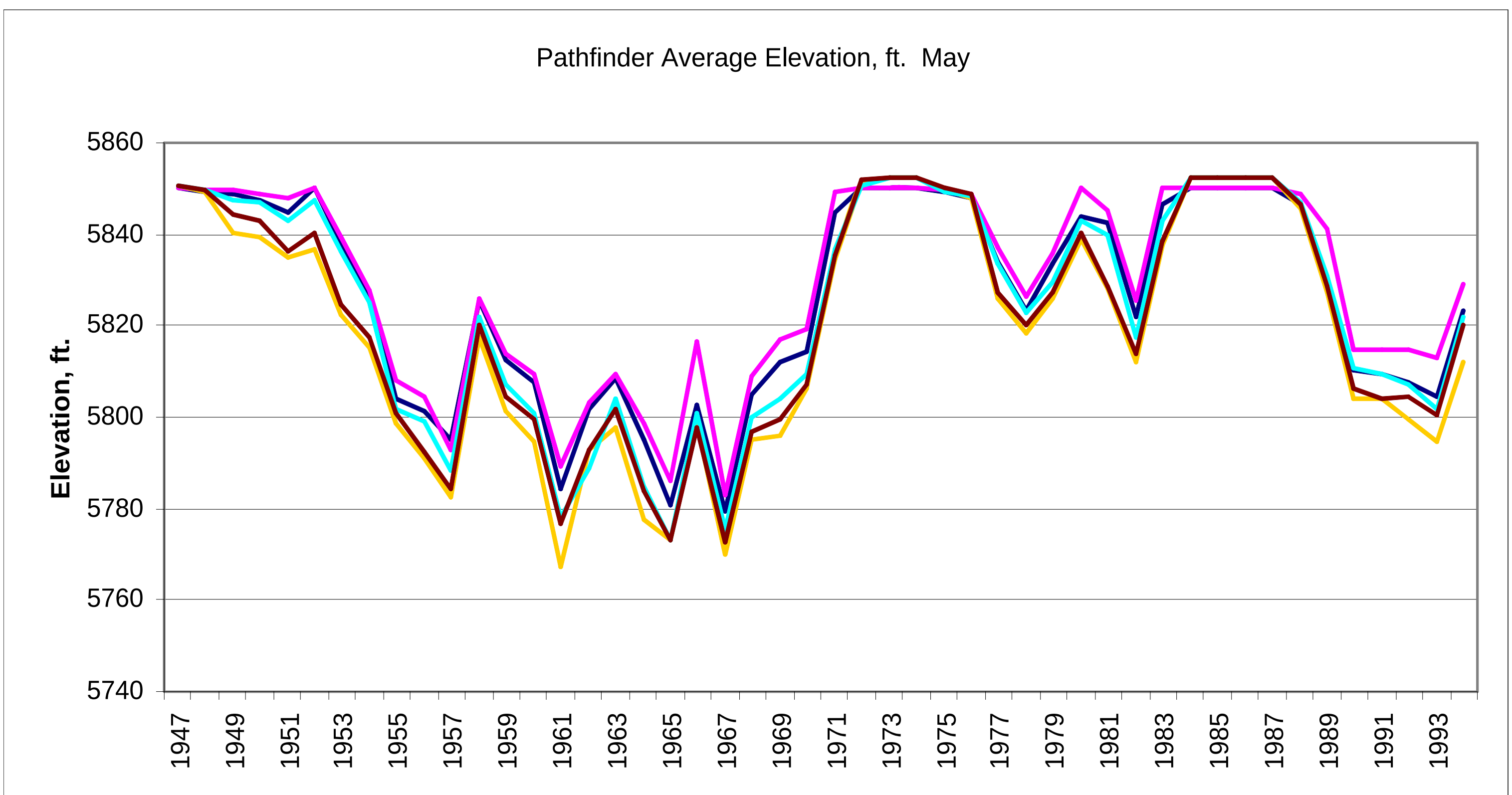
Present Conditions
Water Leasing
Wet Meadow
Governance Committee
Water Emphasis



Pathfinder Average Elevation, ft. May
Elevation, ft.
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5760
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1947
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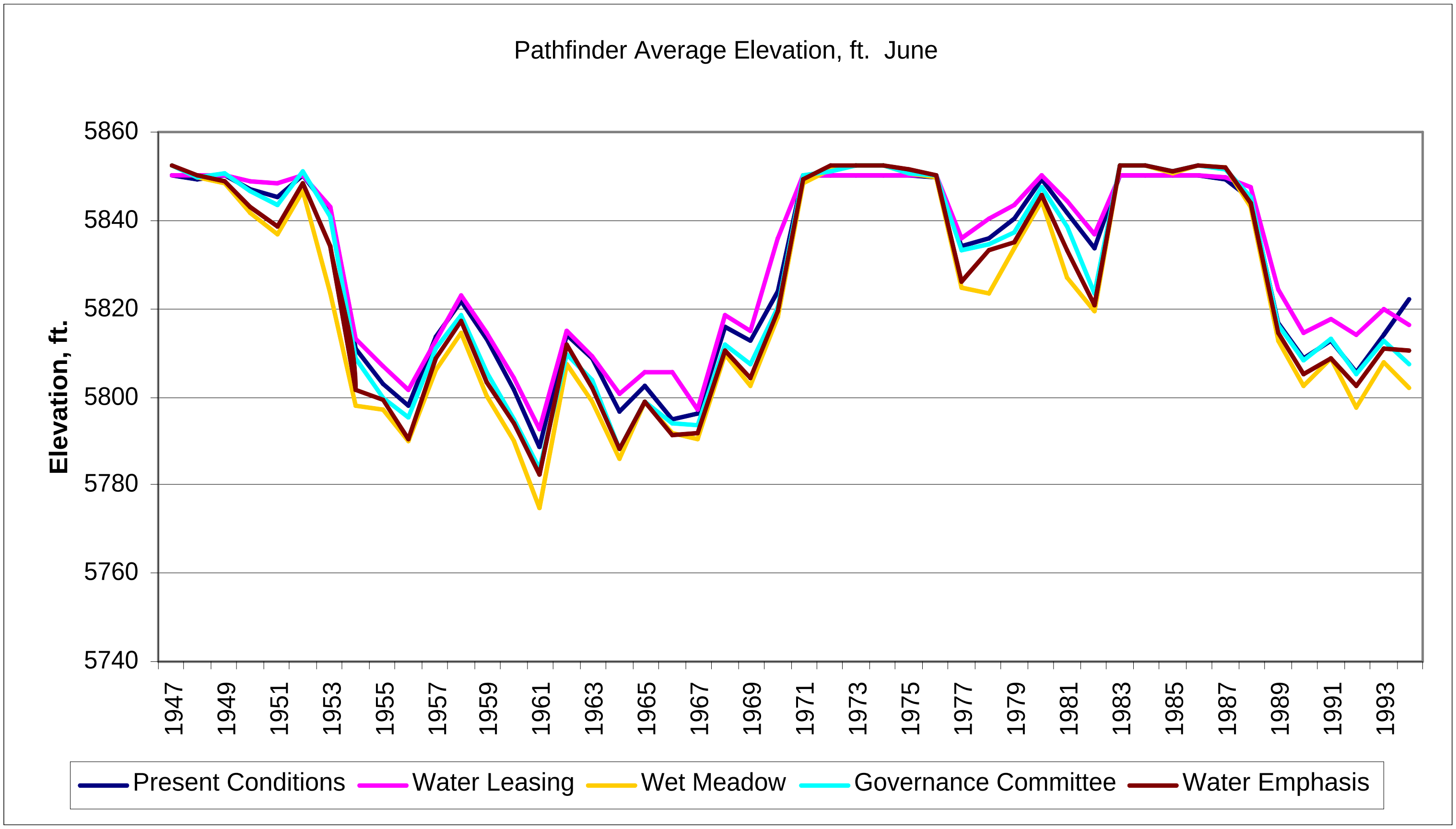
Pathfinder Average Elevation, ft. June
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5760
5740
Elevation, ft.
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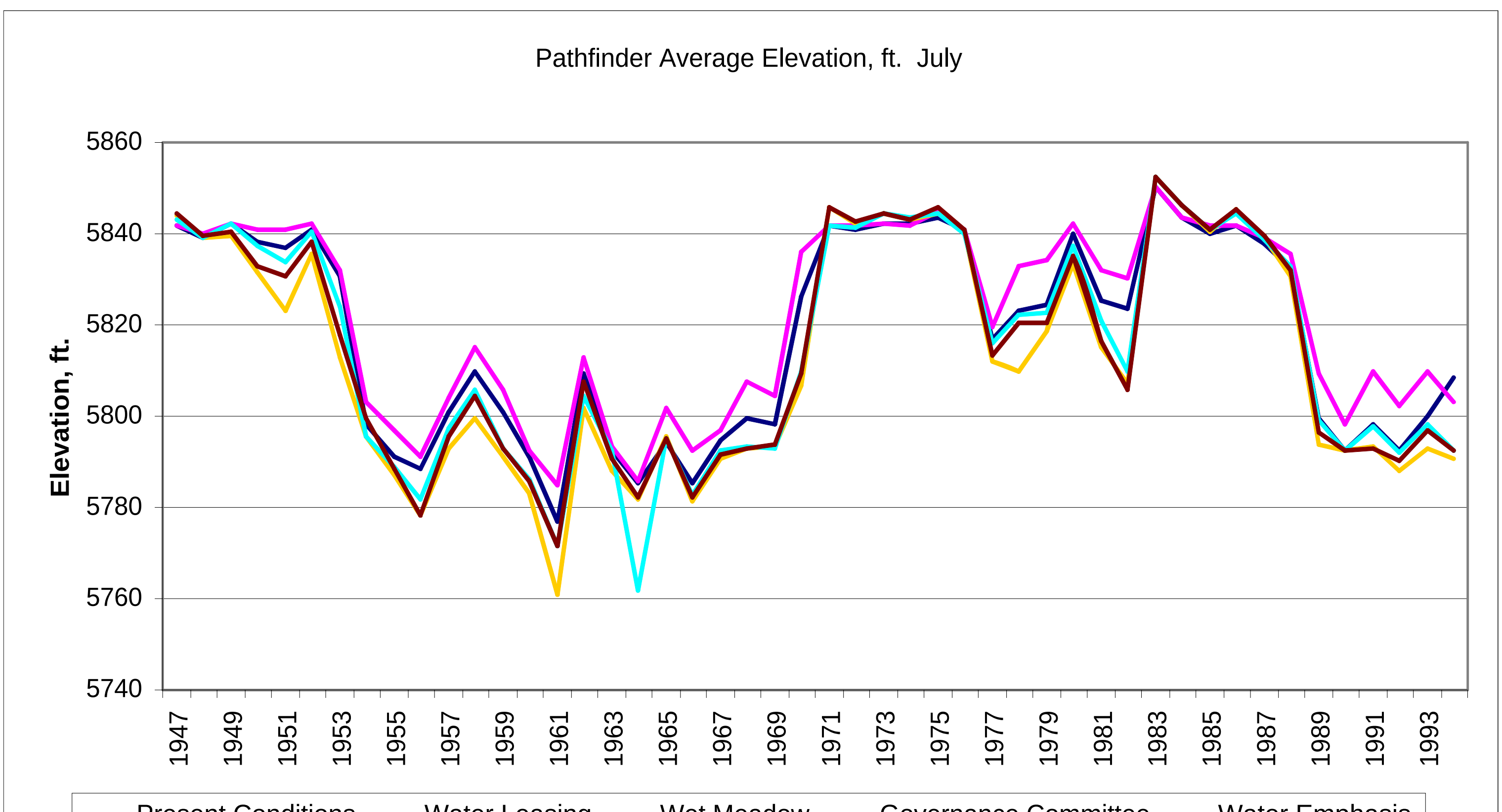
Present Conditions
Water Leasing
Wet Meadow
Governance Committee
Water Emphasis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5740
Elevation, ft.
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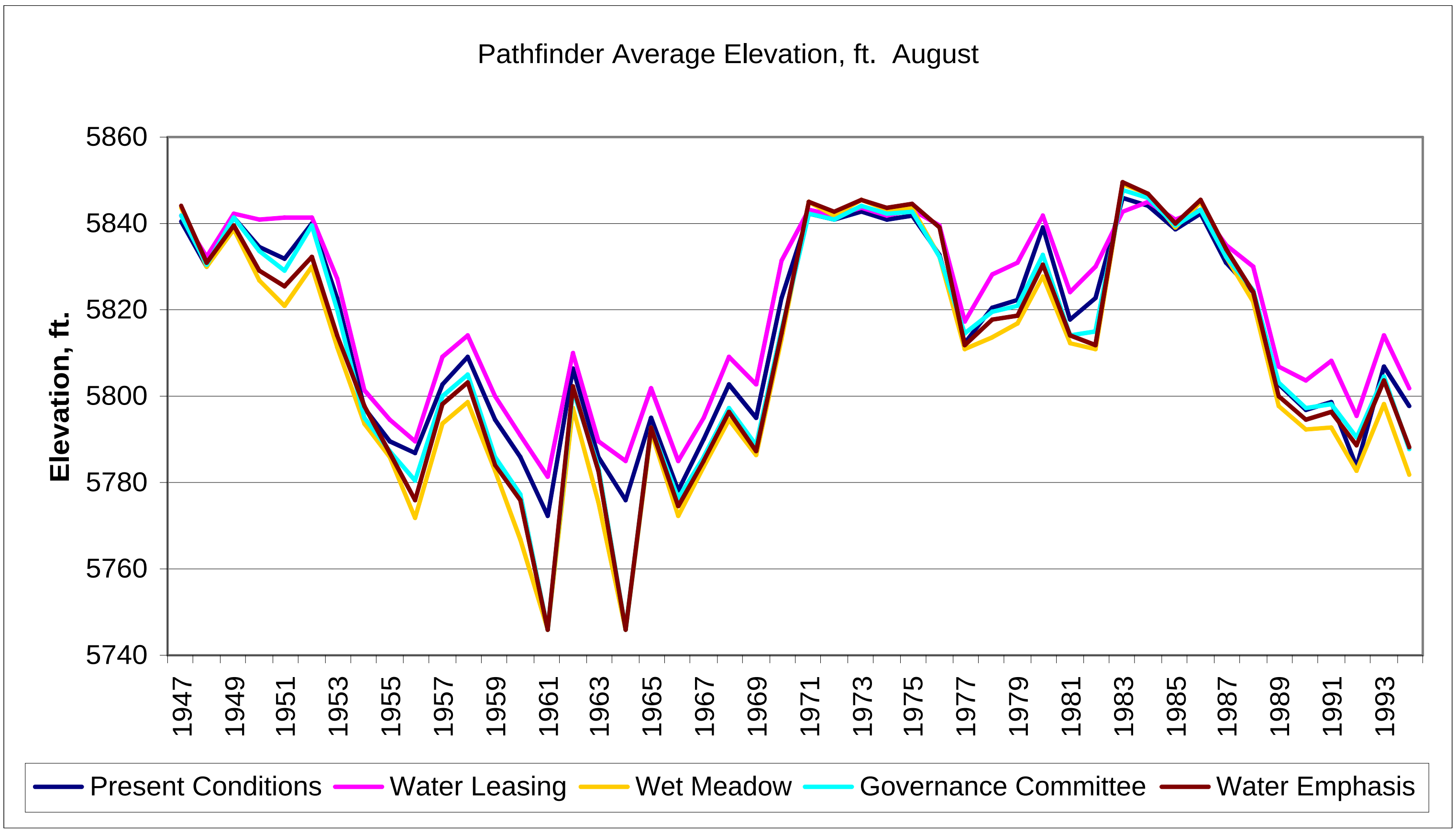
Pathfinder Average Elevation, ft. August
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5760
5740
Elevation, ft.
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1949
1951
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1957
1959
1961
1963
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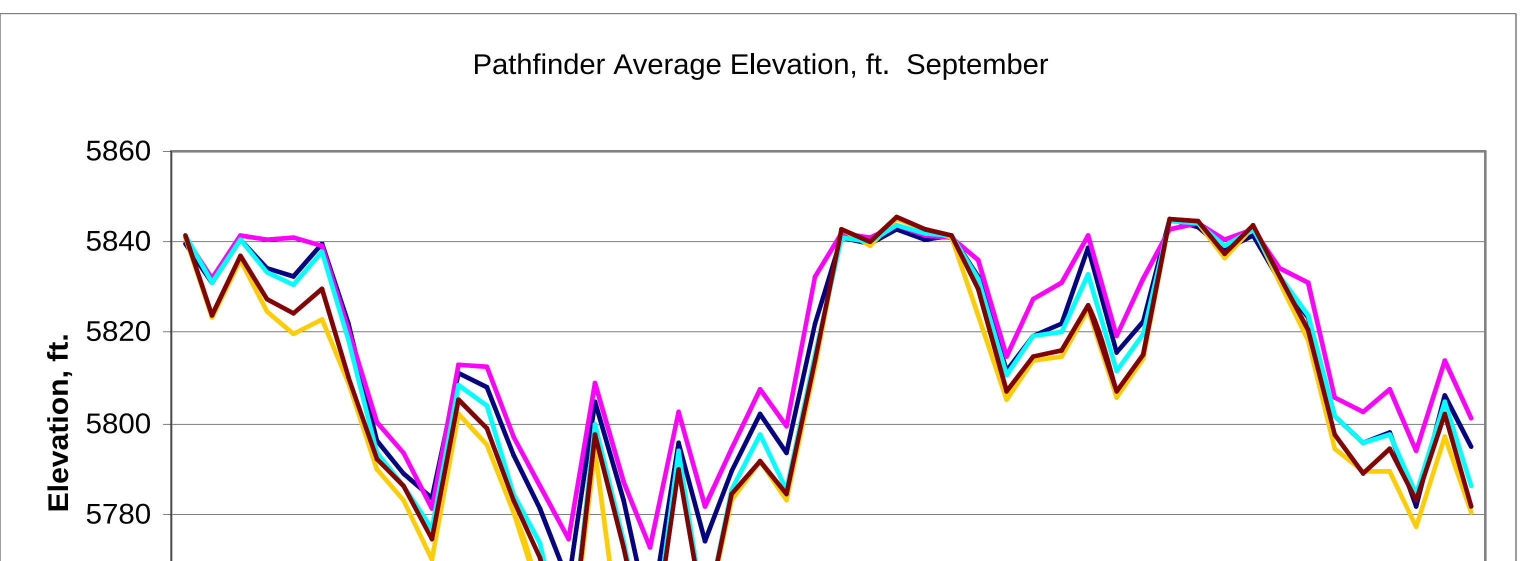
Present Conditions
Water Leasing
Wet Meadow
Governance Committee
Water Emphasis


Pathfinder Average Elevation, ft. September
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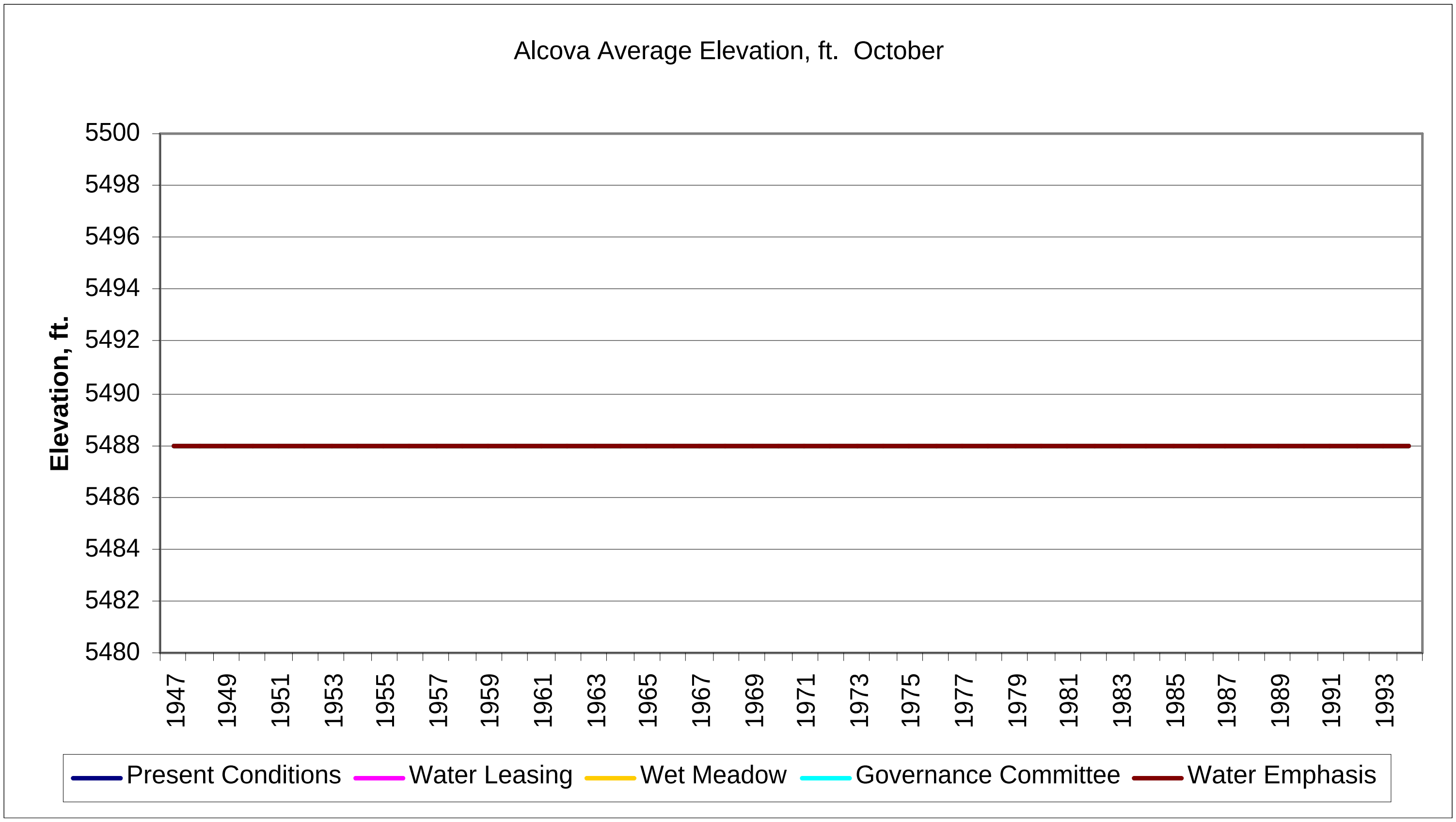
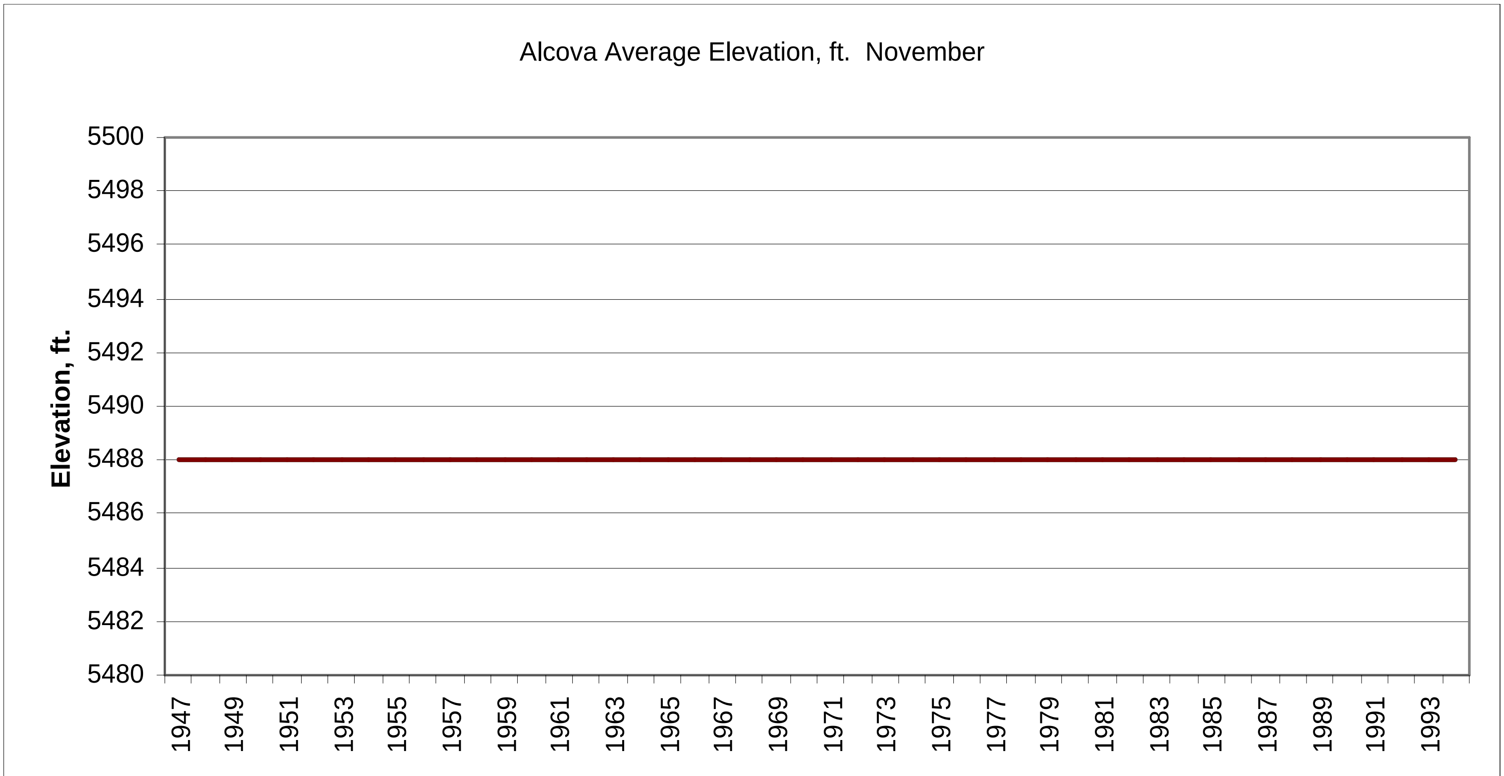
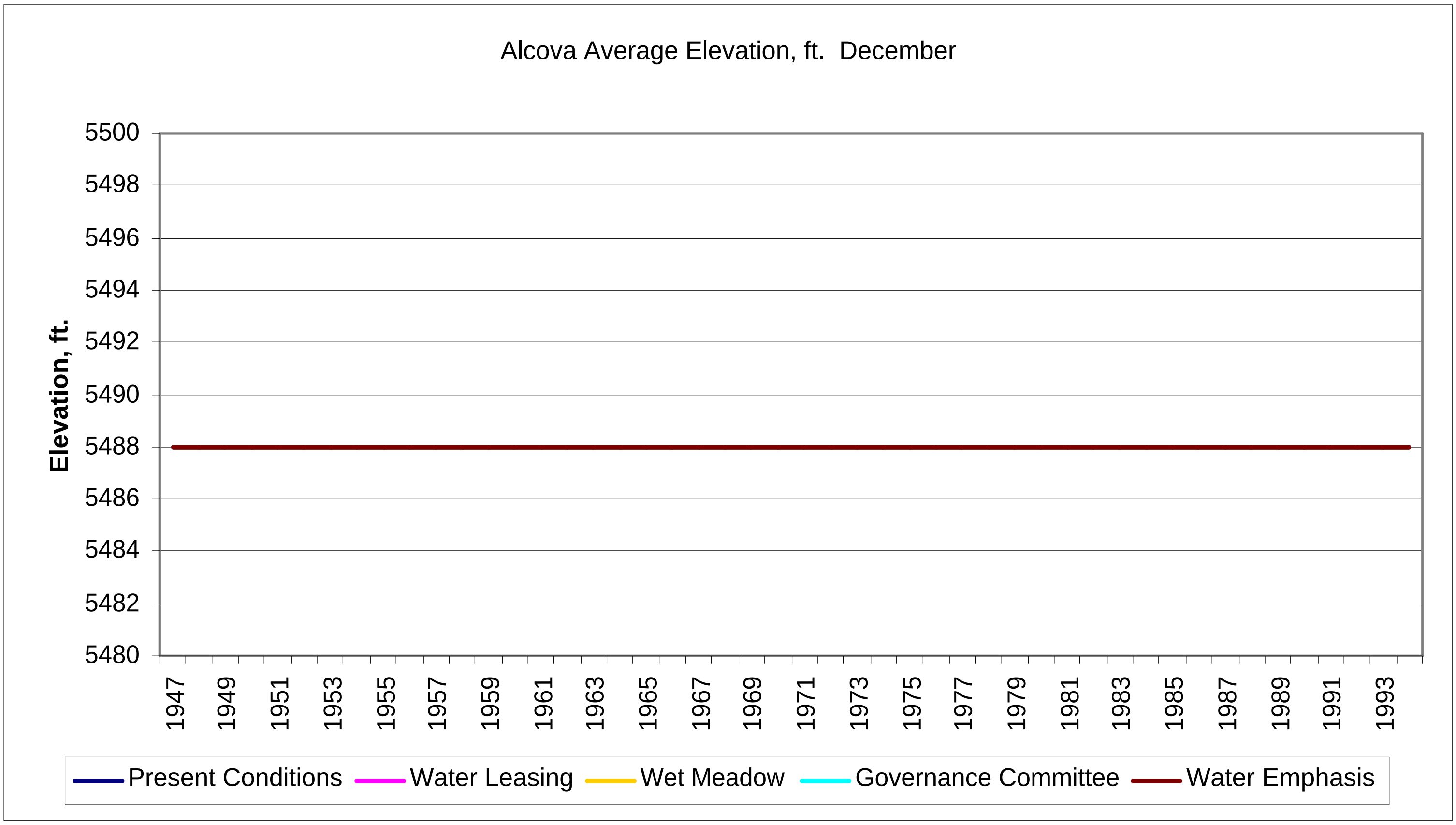
5780
Elevation, ft.

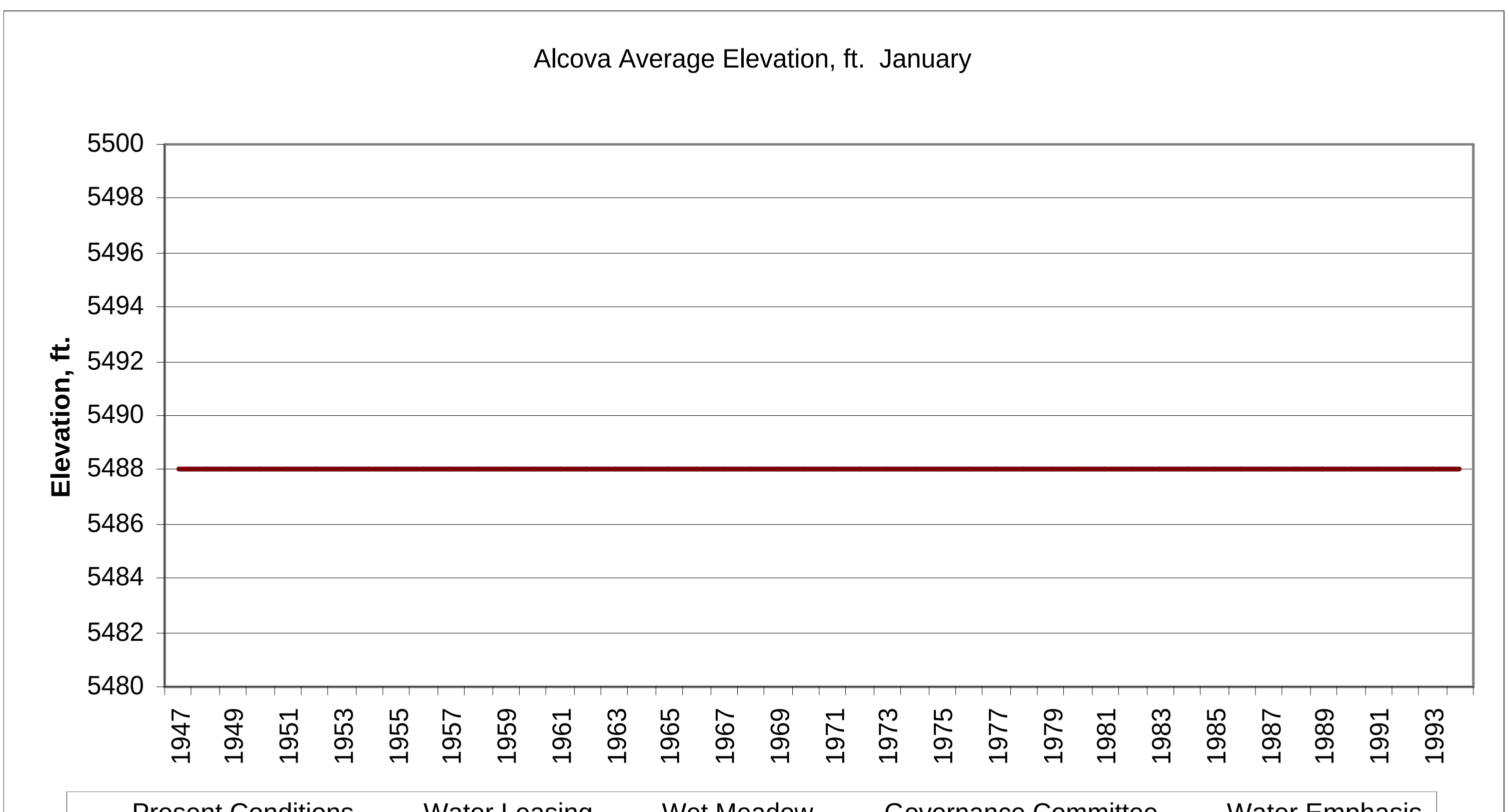
Alcova Reservoir Elevations







Alcova Average Elevation, ft. December
Elevation, ft.
5500
5498
5496
5494
5492
5490
5488
5486
5484
5482
5480
1947 1949 1951 1953 1955 1957 1959 1961 1963 1965 1967 1969 1971 1973 1975 1977 1979 1981 1983 1985 1987 1989 1991 1993
Present Conditions
Water Leasing
Wet Meadow
Governance Committee
Water Emphasis



Alcova Average Elevation, ft. January
Elevation, ft.
5500
5498
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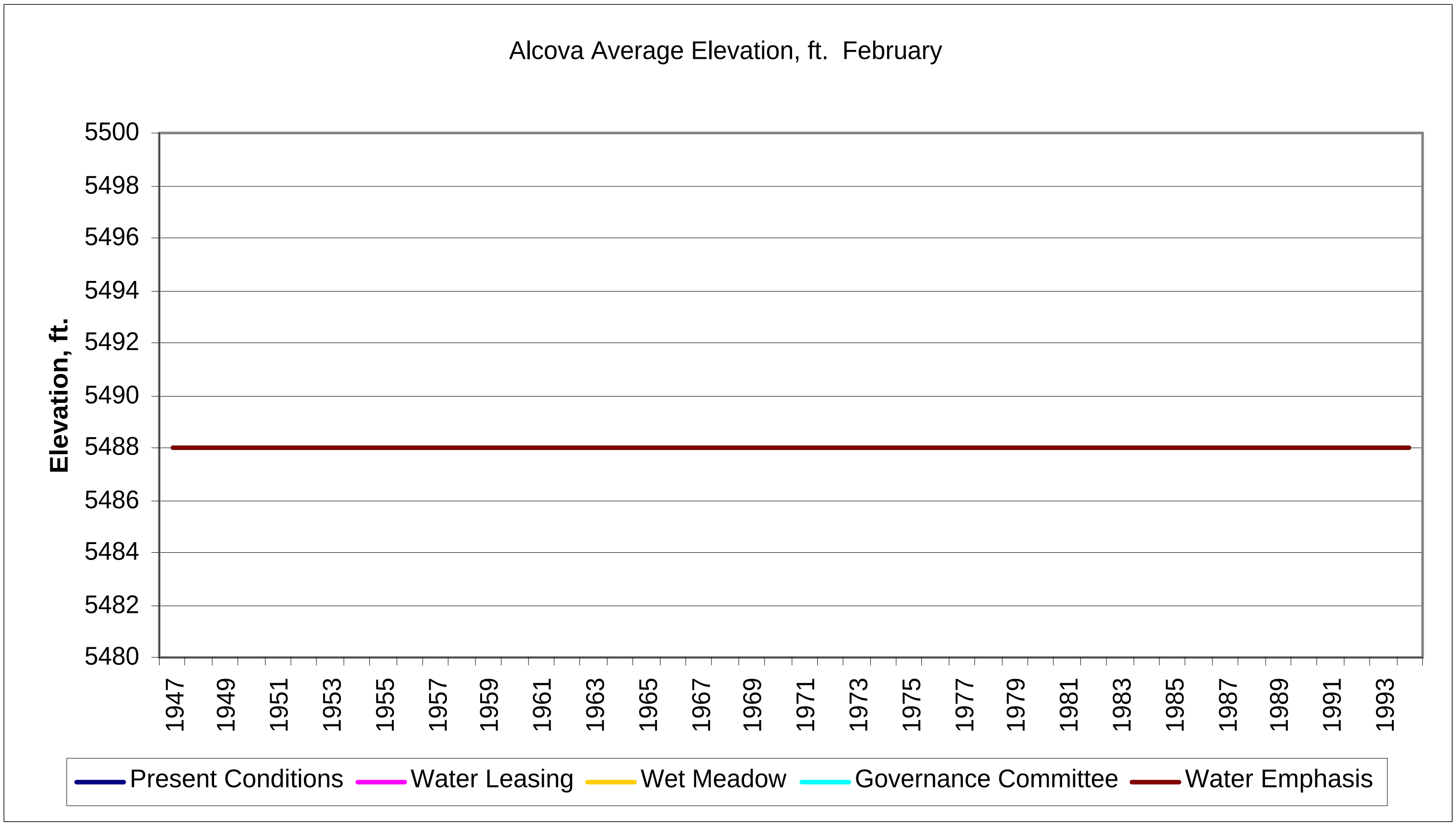
5488
5486
5484
5482
5480
1947 1949 1951 1953 1955 1957 1959 1961 1963 1965 1967 1969 1971 1973 1975 1977 1979 1981 1983 1985 1987 1989 1991 1993



Alcova Average Elevation, ft. February
Elevation, ft.
5500
5498
5496
5494
5492
5490
5488
5486
5484
5482
5480
1947
1949
1951
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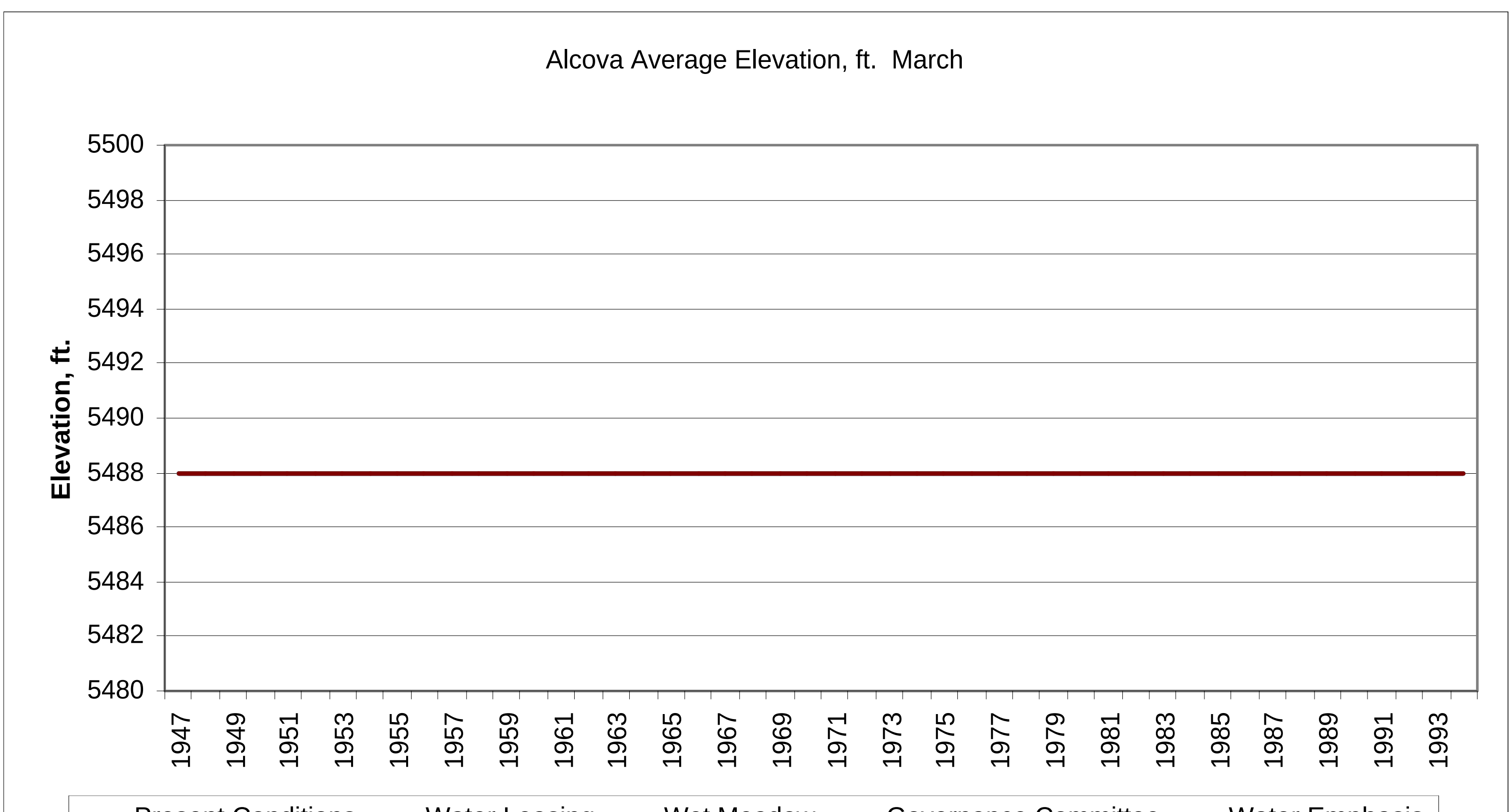
1993
Present Conditions
Water Leasing
Wet Meadow
Governance Committee
Water Emphasis



Alcova Average Elevation, ft. March
Elevation, ft.
5500
5498
5496
5494
5492
5490
5488
5486
5484
5482
5480
1947
1949
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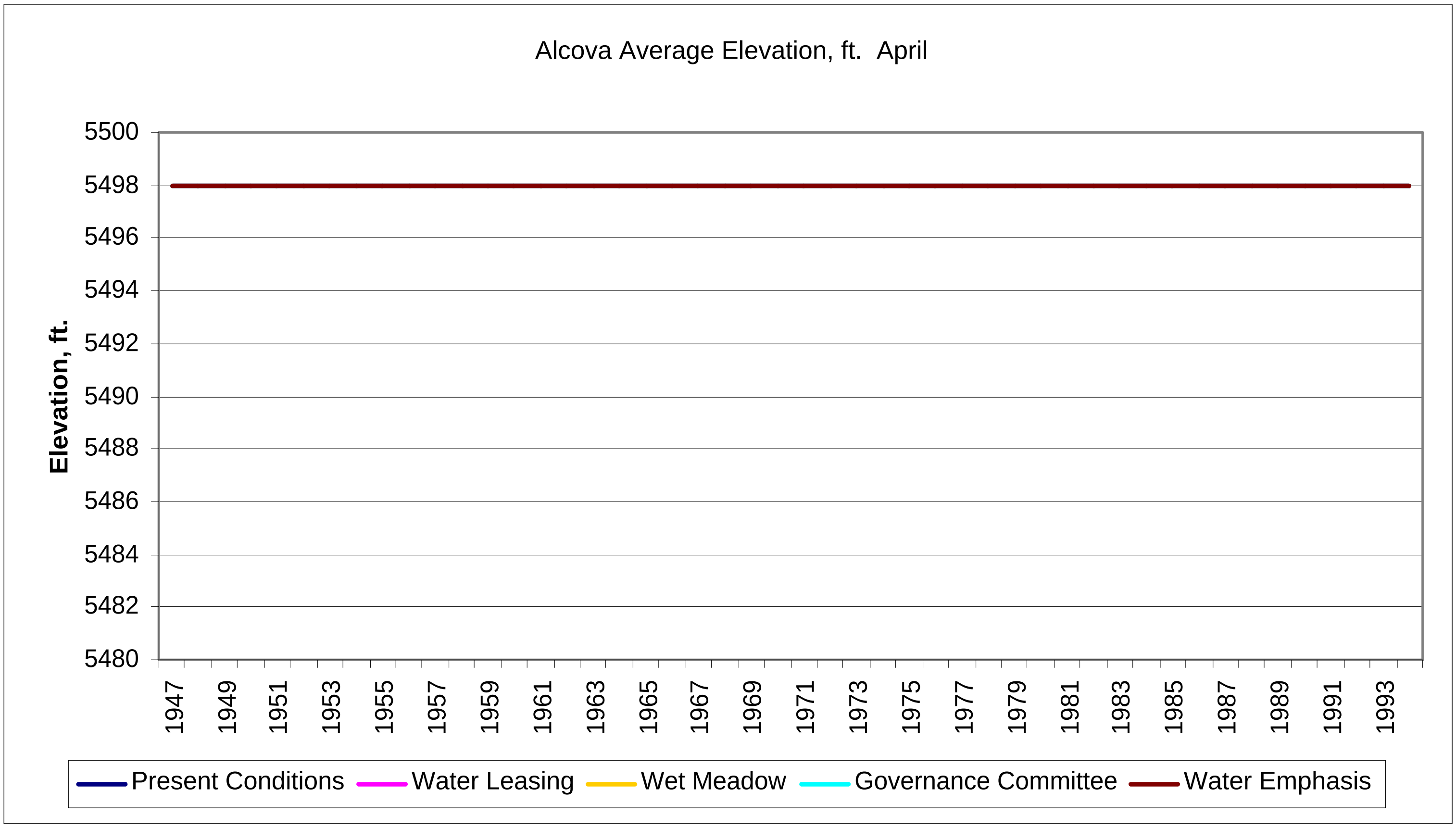
Alcova Average Elevation, ft. April
Elevation, ft.
5500
5498
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5490
5488
5486
5484
5482
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1947
1949
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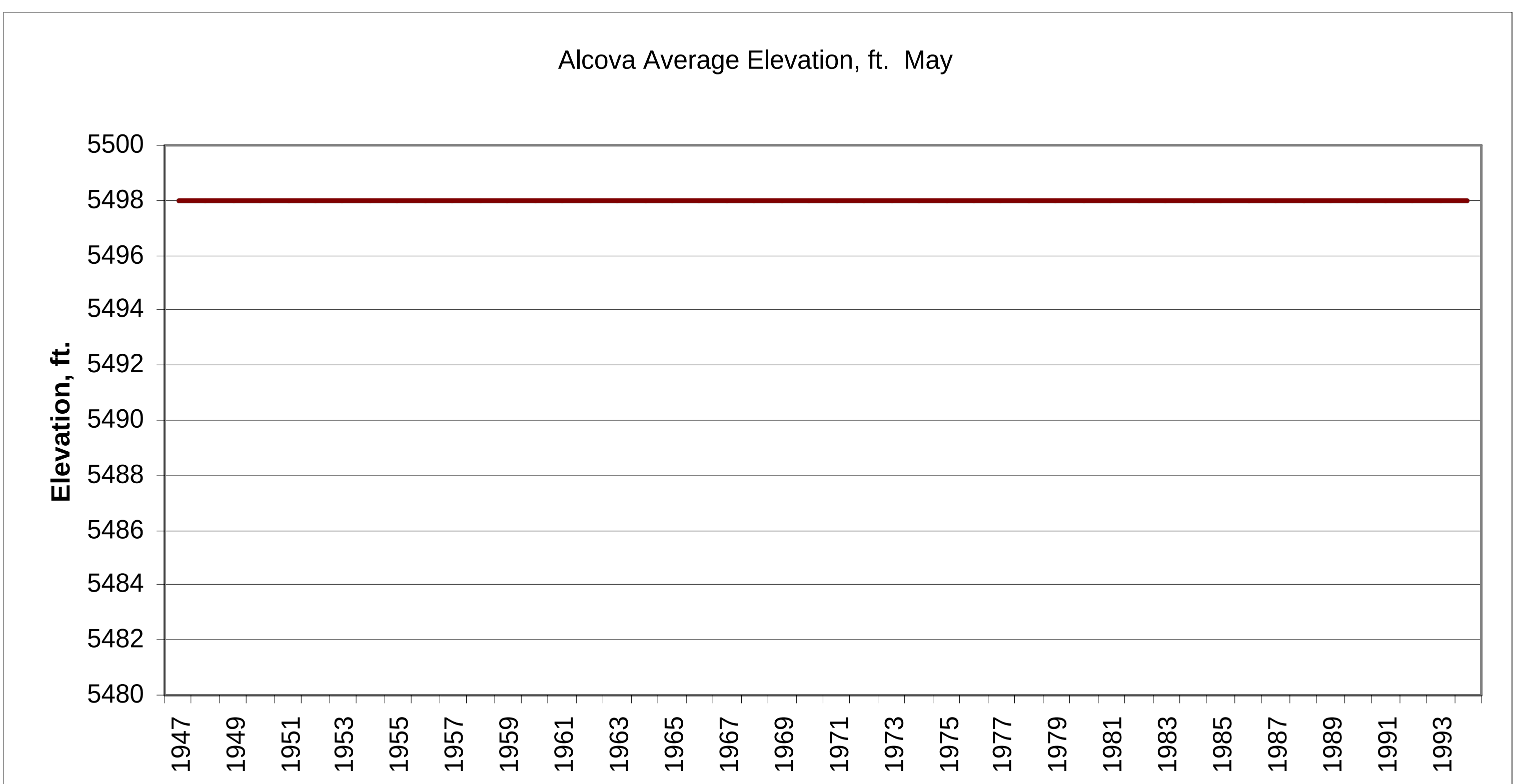
Present Conditions
Water Leasing
Wet Meadow
Governance Committee
Water Emphasis


Alcova Average Elevation, ft. May
Elevation, ft.
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5494
5492
5490
5488
5486
5484
5482
5480
1947
1949
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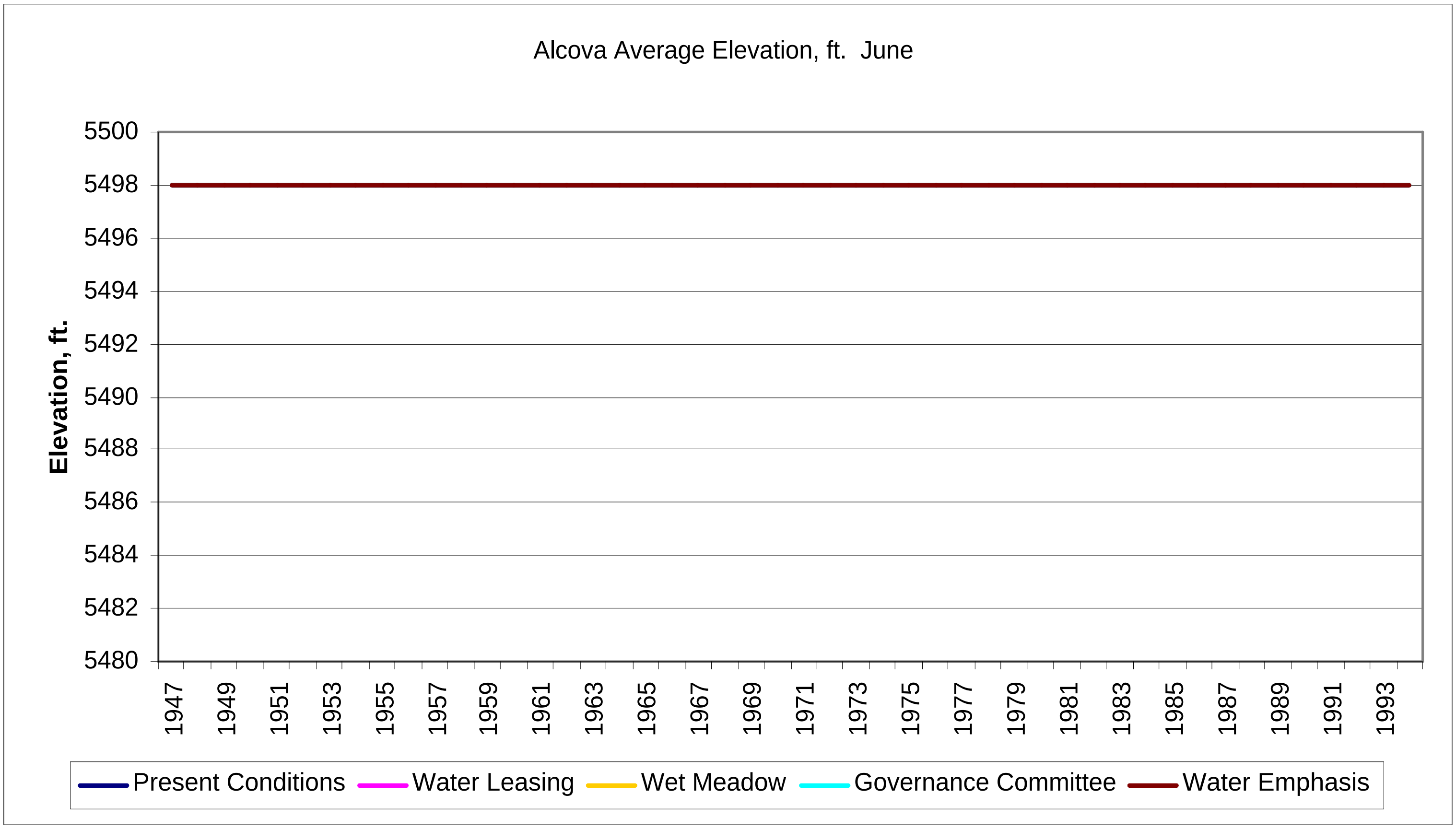

Alcova Average Elevation, ft. June
Elevation, ft.
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5498
5496
5494
5492
5490
5488
5486
5484
5482
5480
1947
1949
1951
1953
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1957
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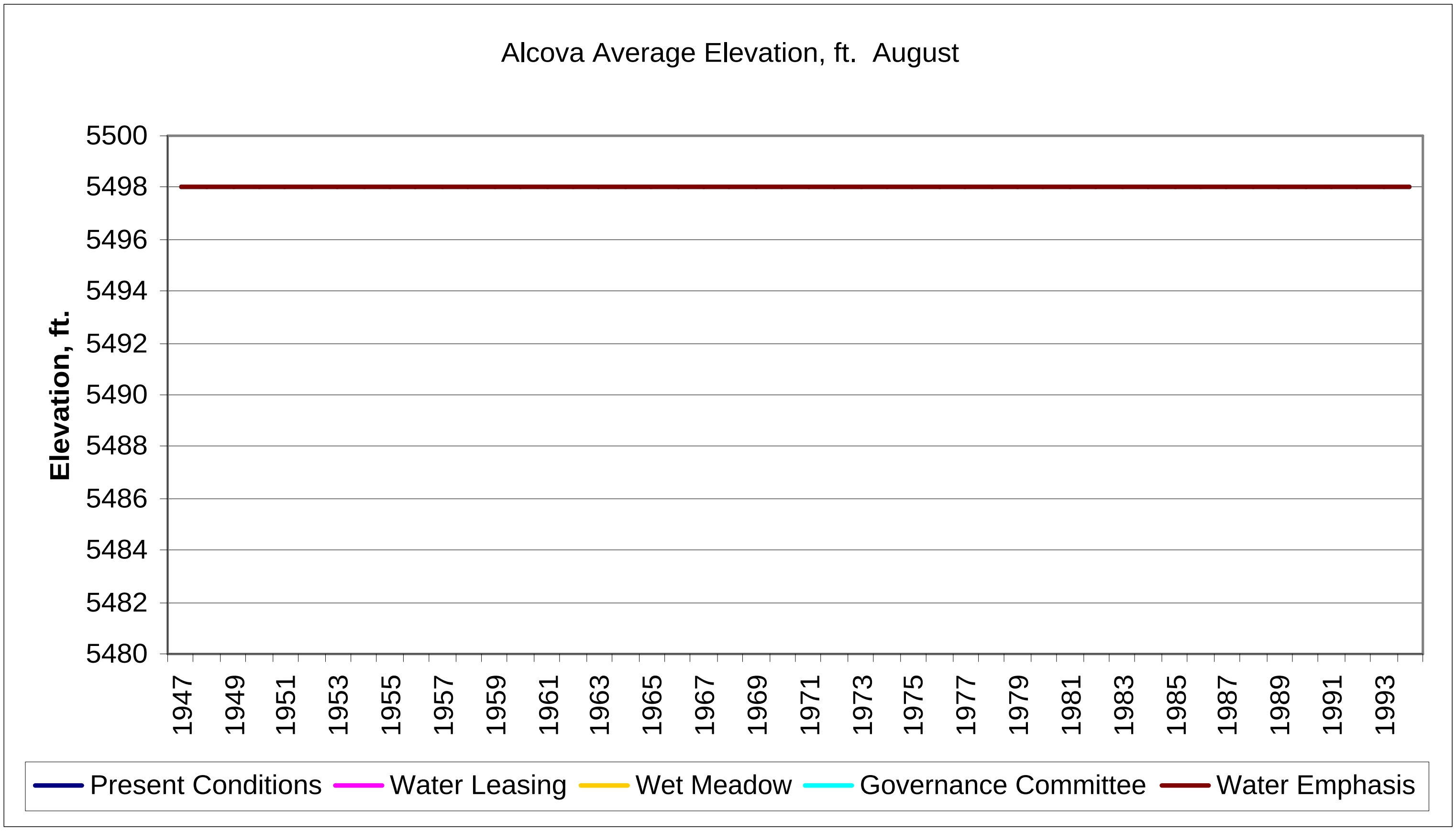
Present Conditions
Water Leasing
Wet Meadow
Governance Committee
Water Emphasis



Alcova Average Elevation, ft. August
Elevation, ft.
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5498
5496
5494
5492
5490
5488
5486
5484
5482
5480
1947
1949
1951
1953
1955
1957
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1961
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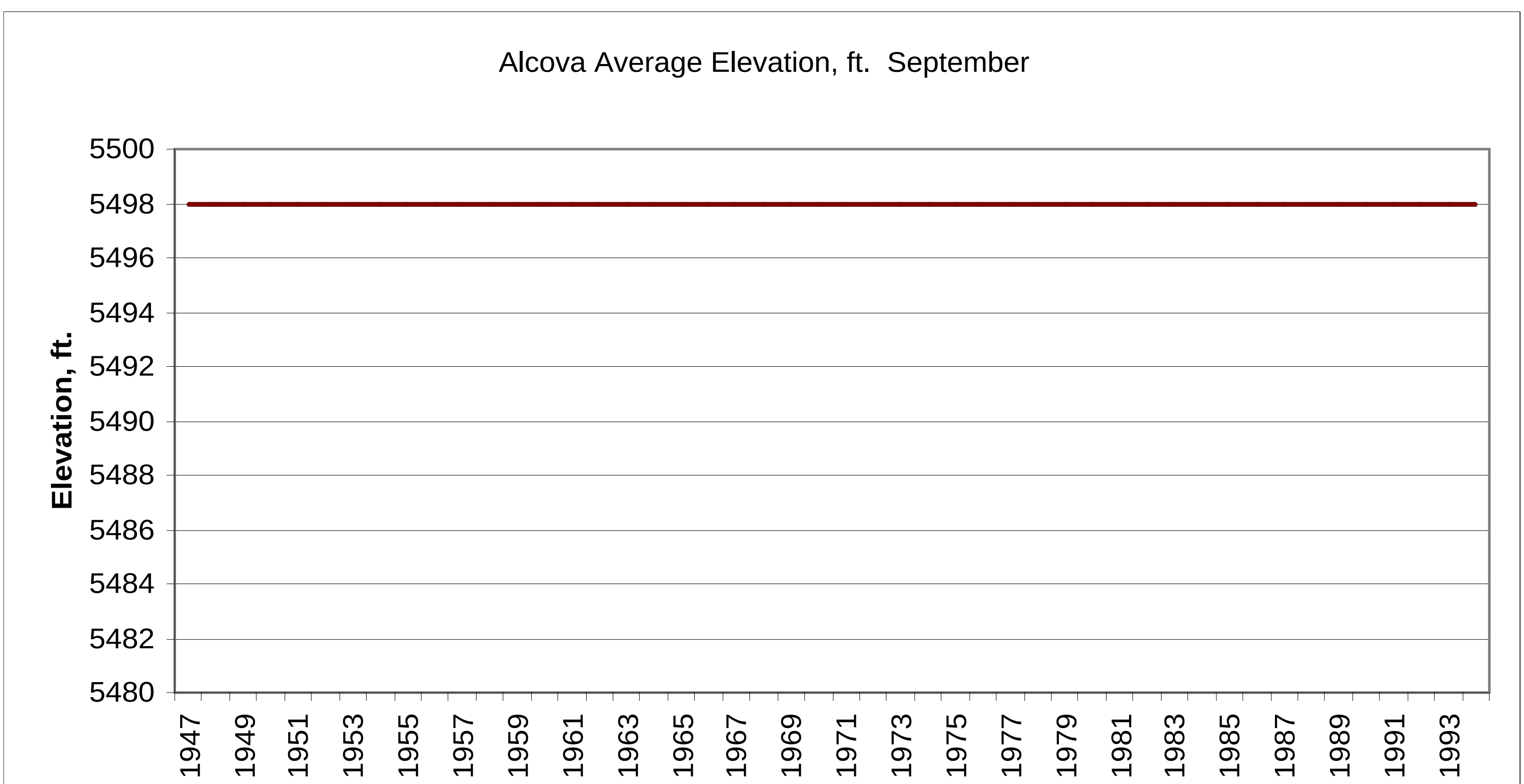
Present Conditions
Water Leasing
Wet Meadow
Governance Committee
Water Emphasis



Alcova Average Elevation, ft. September
Elevation, ft.
5500
5498
5496
5494
5492
5490
5488
5486
5484
5482
5480
1947
1949
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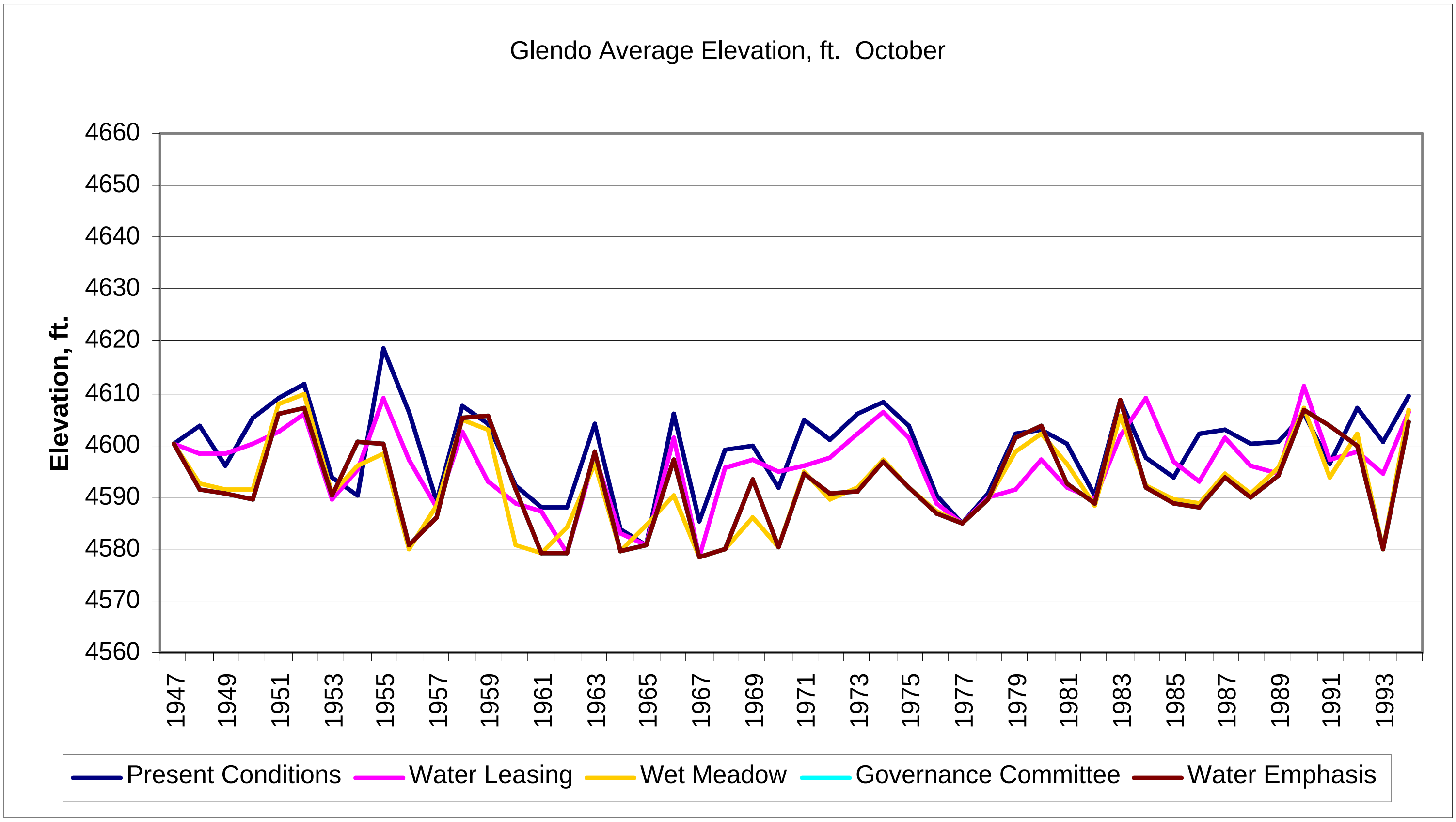
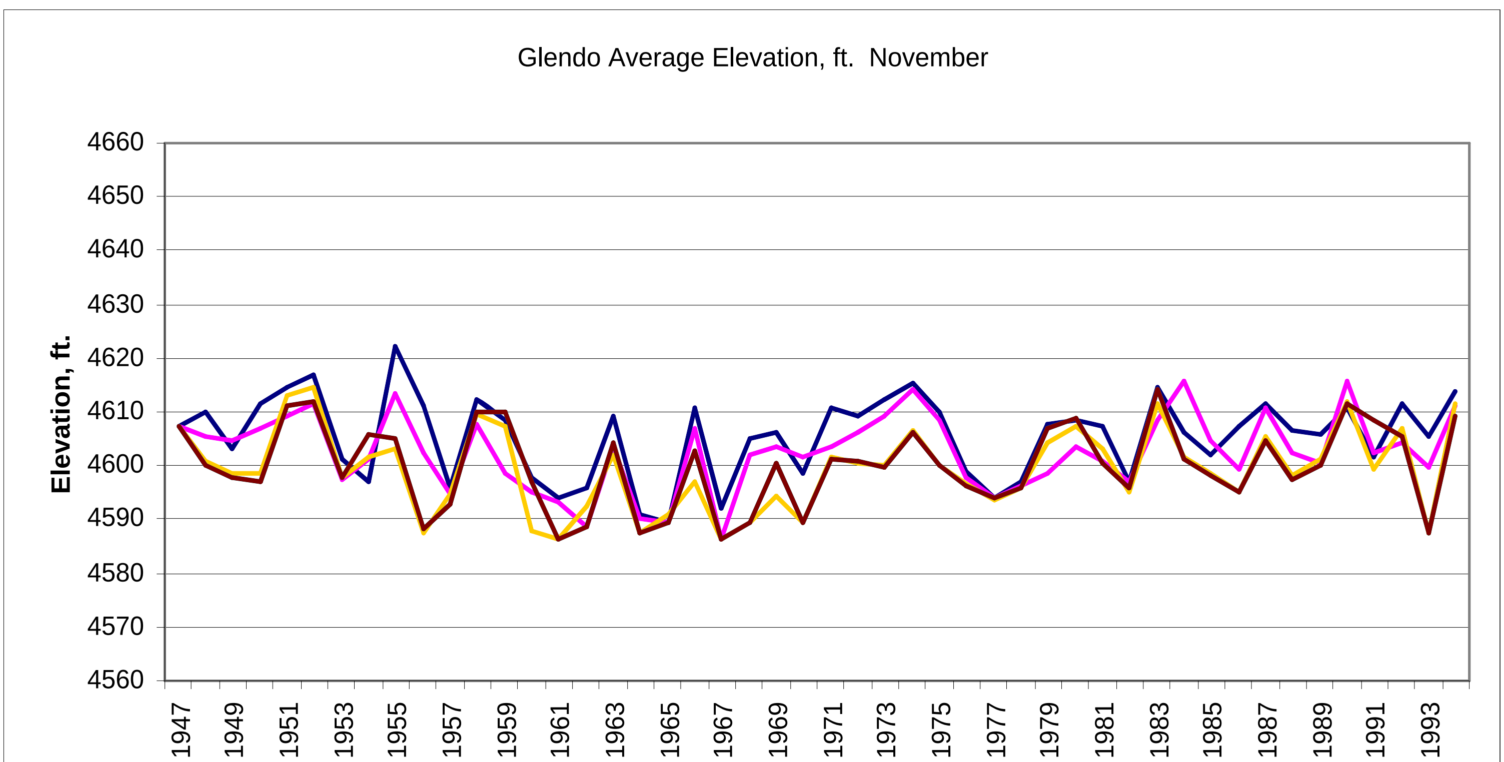
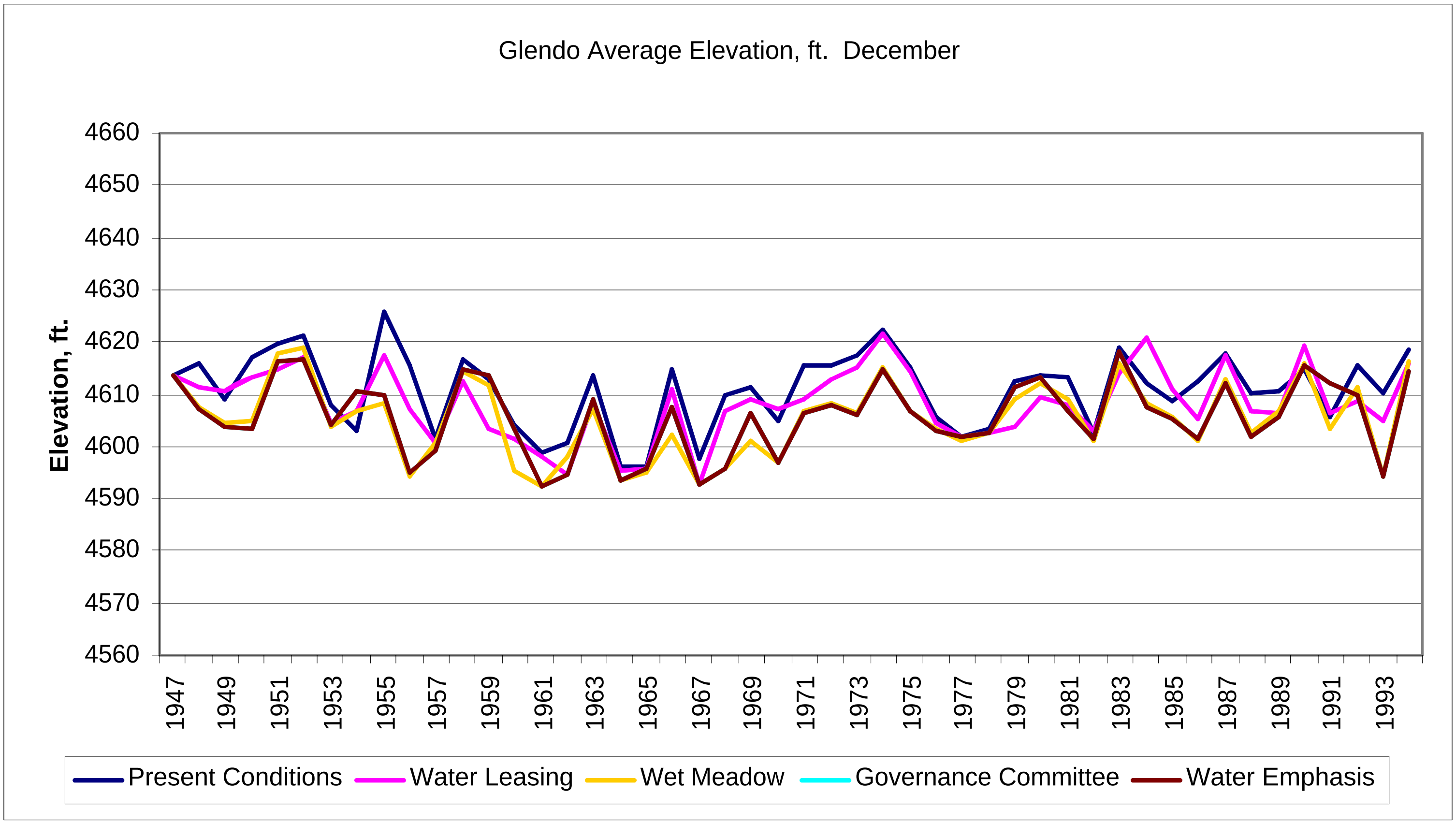
Glendo Reservoir Elevations







Glendo Average Elevation, ft. December
Elevation, ft.
4660
4650
4640
4630
4620
4610
4600
4590
4580
4570
4560
1947
1949
1951
1953
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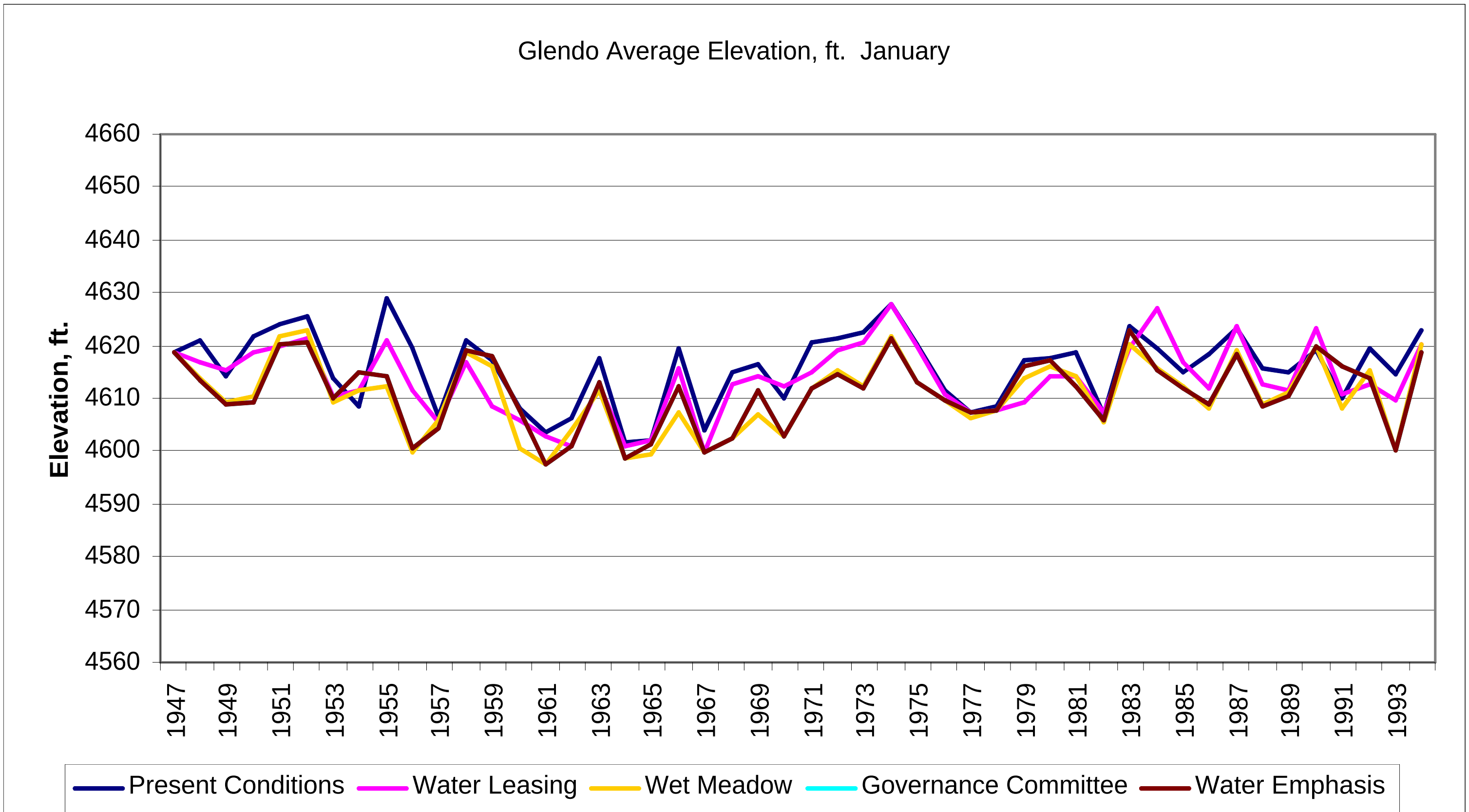
1993
Present Conditions
Water Leasing
Wet Meadow
Governance Committee
Water Emphasis



Glendo Average Elevation, ft. January
Elevation, ft.
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4650
4640
4630
4620
4610
4600
4590
4580
4570
4560
1947
1949
1951
1953
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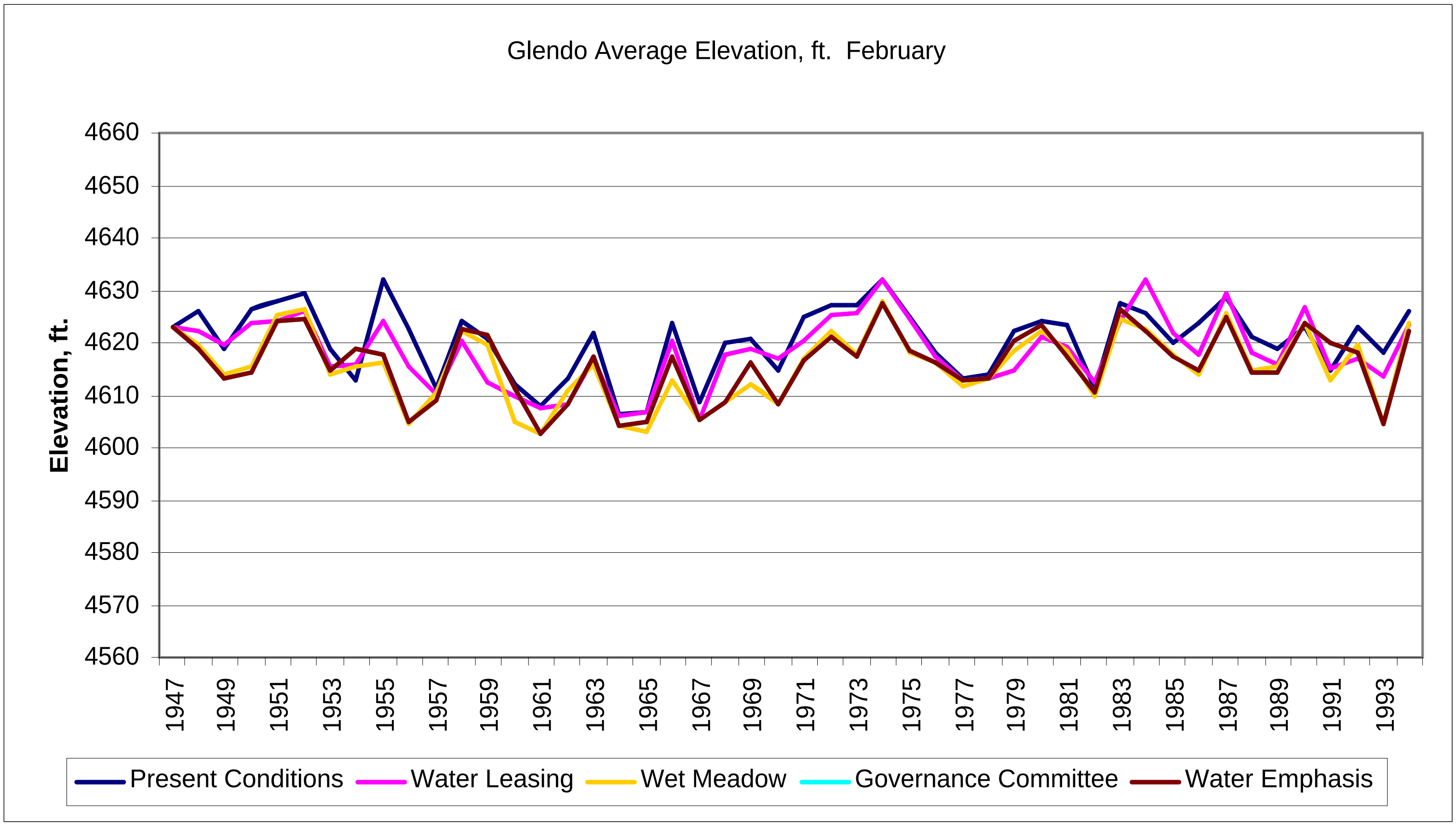
Present Conditions
Water Leasing
Wet Meadow
Governance Committee
Water Emphasis



Glendo Average Elevation, ft. February
Elevation, ft.
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4650
4640
4630
4620
4610
4600
4590
4580
4570
4560
1947
1949
1951
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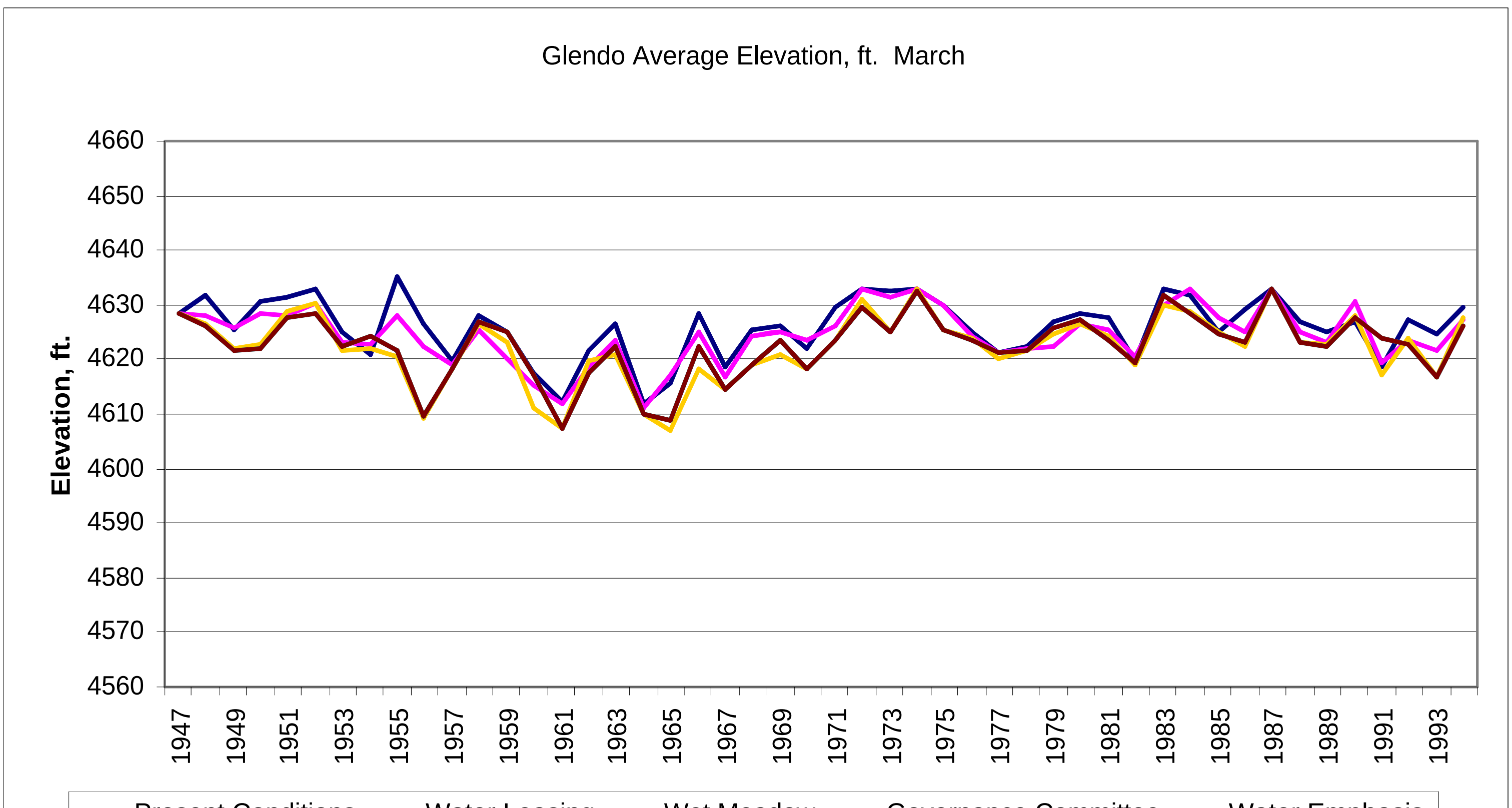
Present Conditions
Water Leasing
Wet Meadow
Governance Committee
Water Emphasis



Glendo Average Elevation, ft. March
Elevation, ft.
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4620
4610
4600
4590
4580
4570
4560
1947
1949
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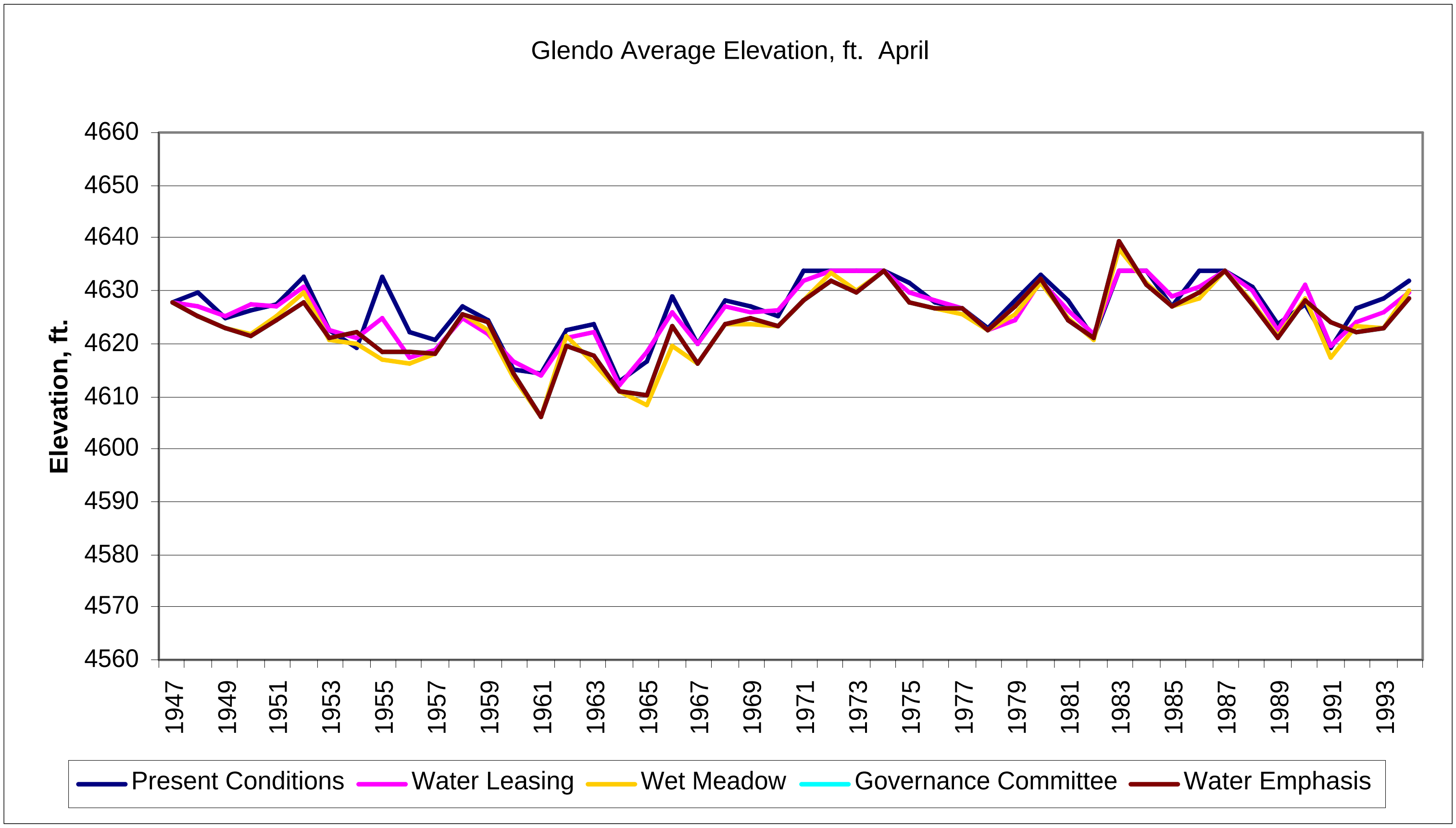
Glendo Average Elevation, ft. April
Elevation, ft.
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4630
4620
4610
4600
4590
4580
4570
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1947
1949
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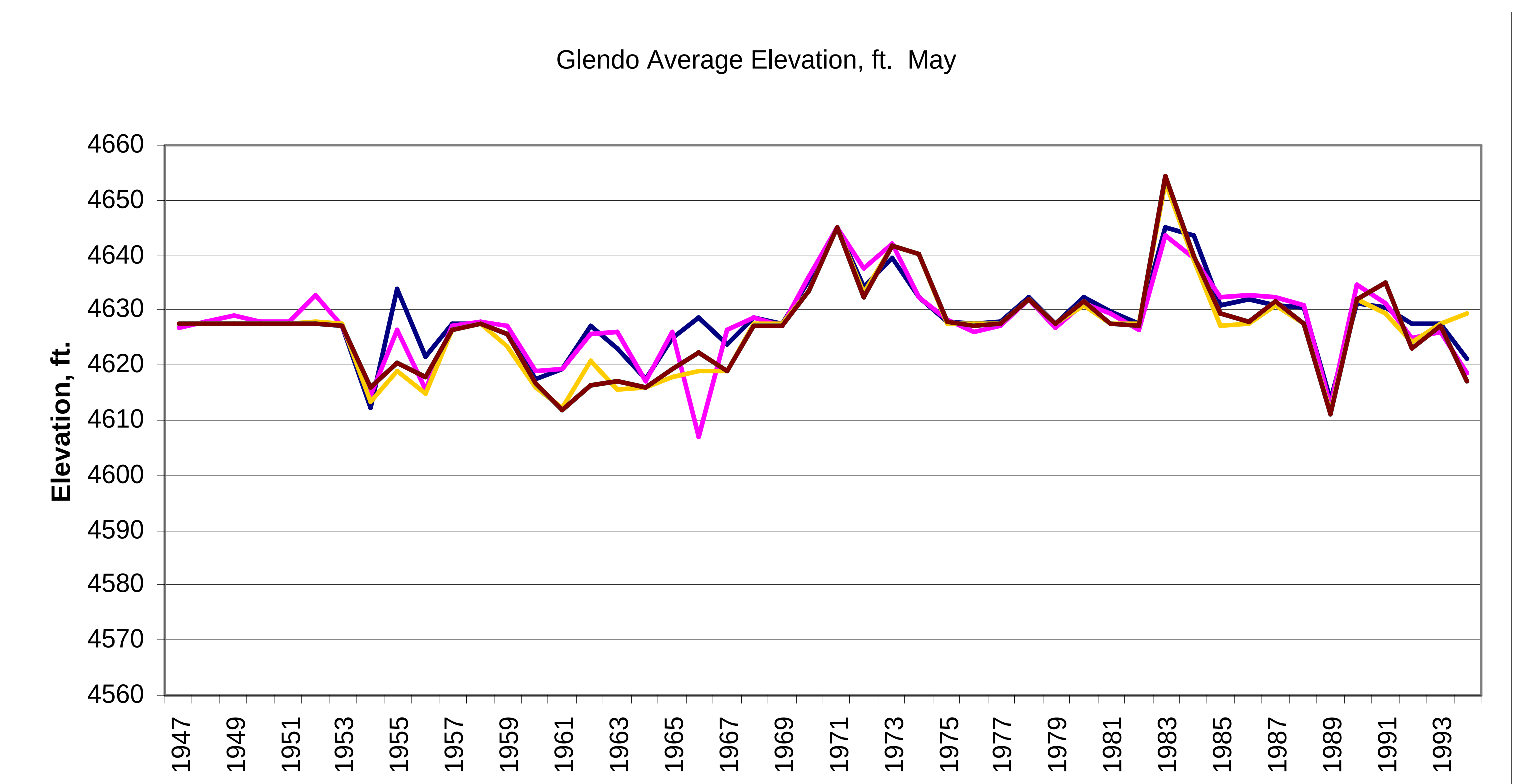
Present Conditions
Water Leasing
Wet Meadow
Governance Committee
Water Emphasis


Glendo Average Elevation, ft. May
Elevation, ft.
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4640
4630
4620
4610
4600
4590
4580
4570
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1947
1949
1951
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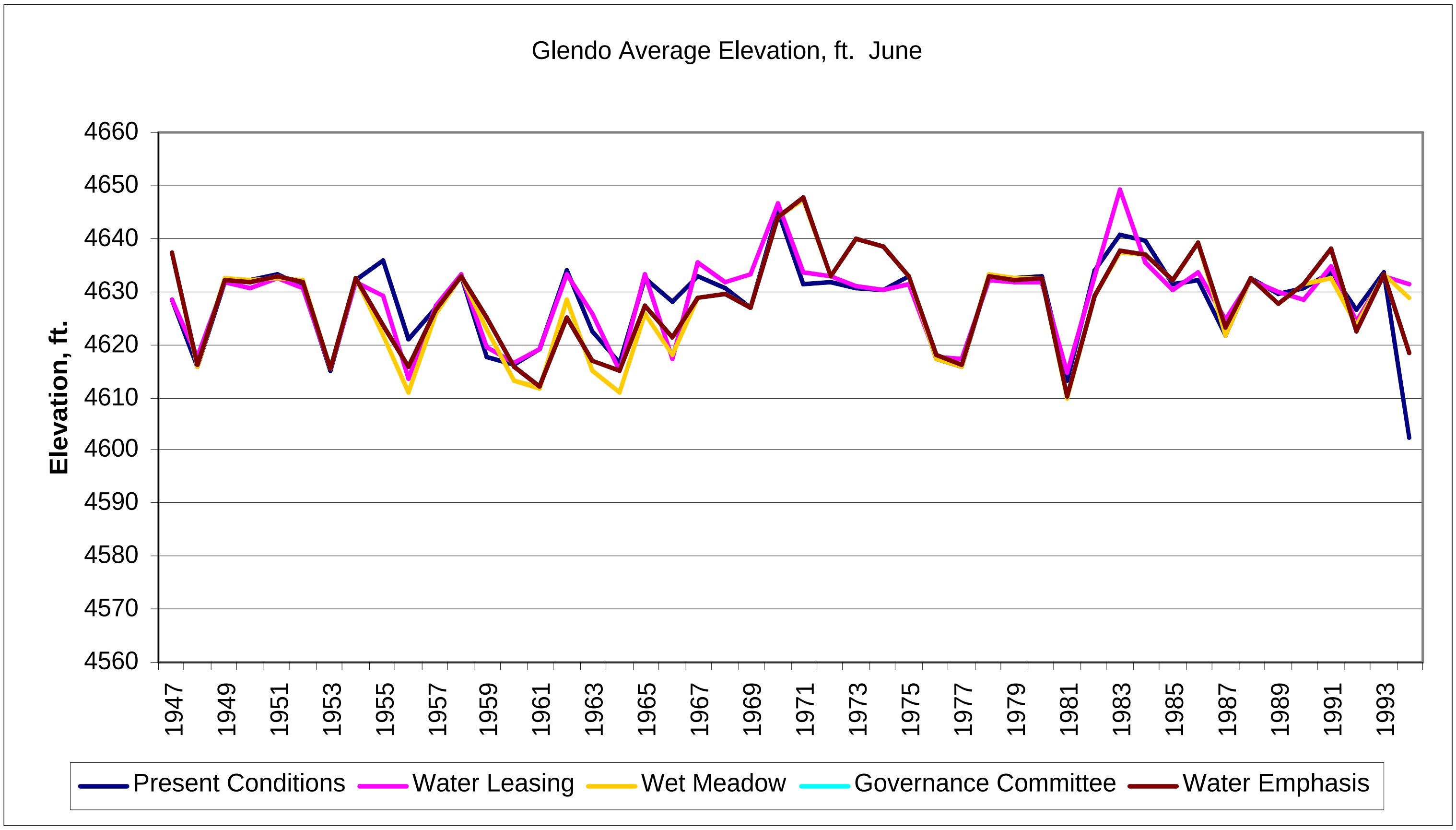
Glendo Average Elevation, ft. June
Elevation, ft.
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4630
4620
4610
4600
4590
4580
4570
4560
1947
1949
1951
1953
1955
1957
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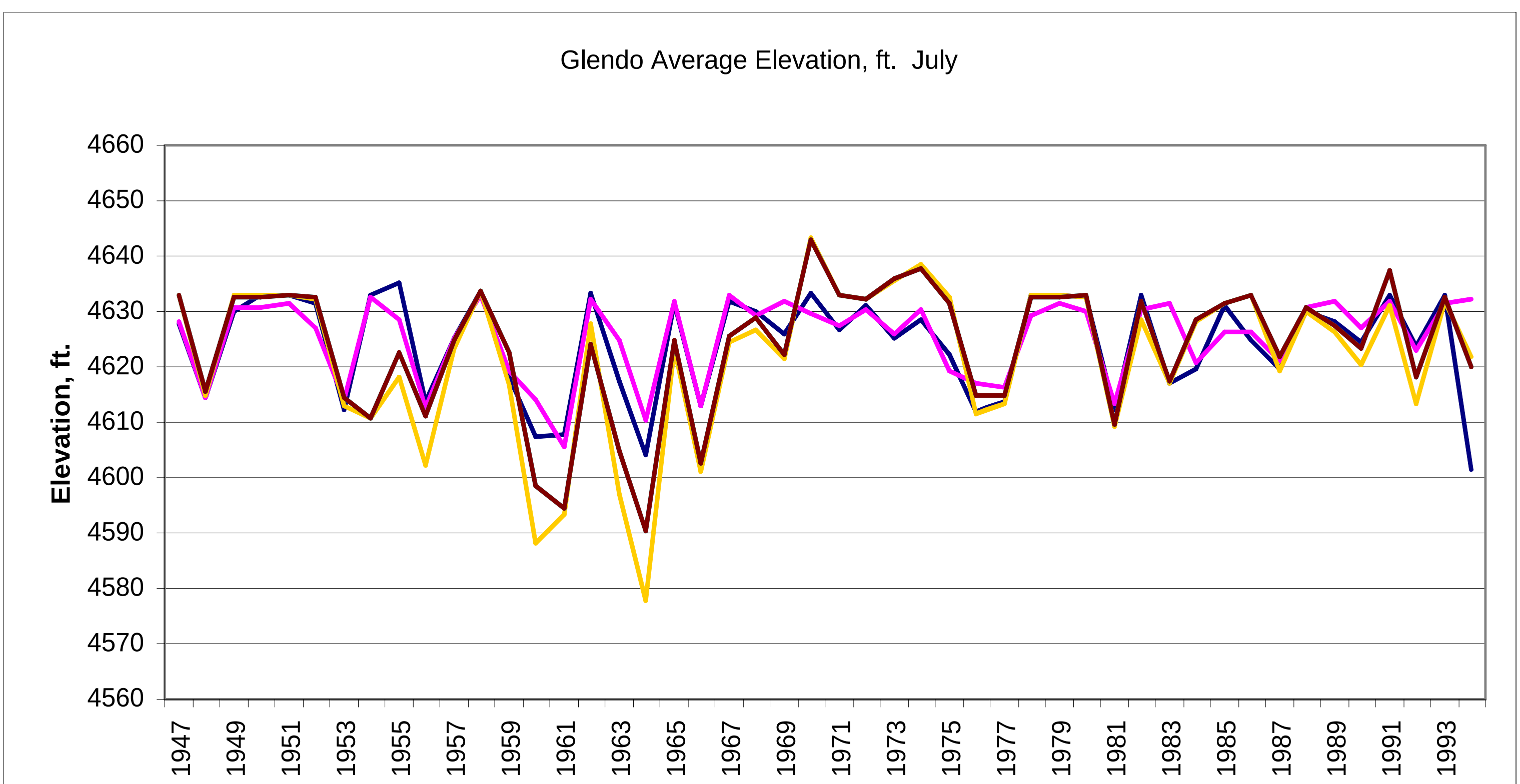
Present Conditions
Water Leasing
Wet Meadow
Governance Committee
Water Emphasis


Glendo Average Elevation, ft. July
Elevation, ft.
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4590
4580
4570
4560
1947
1949
1951
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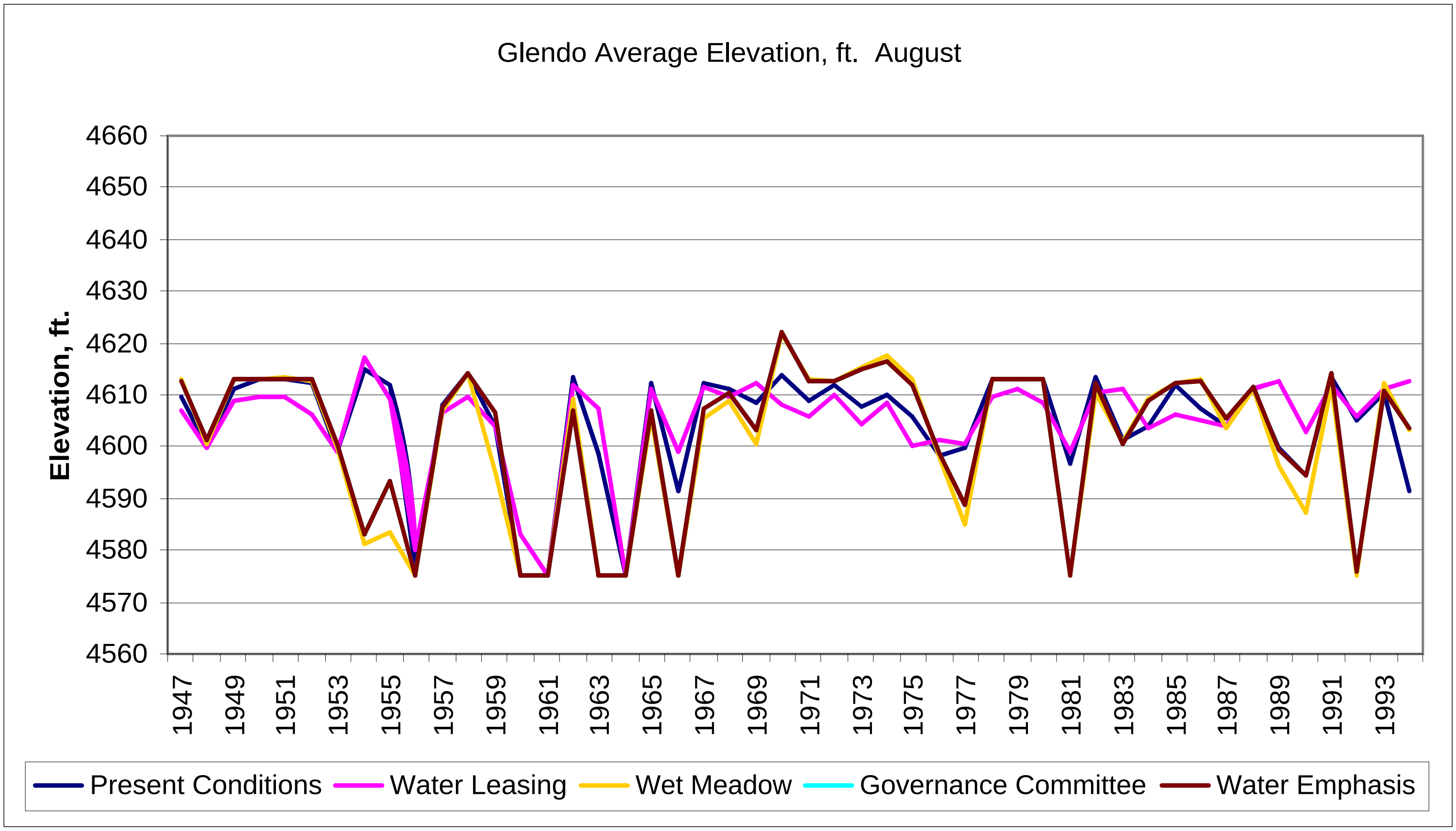
Glendo Average Elevation, ft. August
Elevation, ft.
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4620
4610
4600
4590
4580
4570
4560
1947
1949
1951
1953
1955
1957
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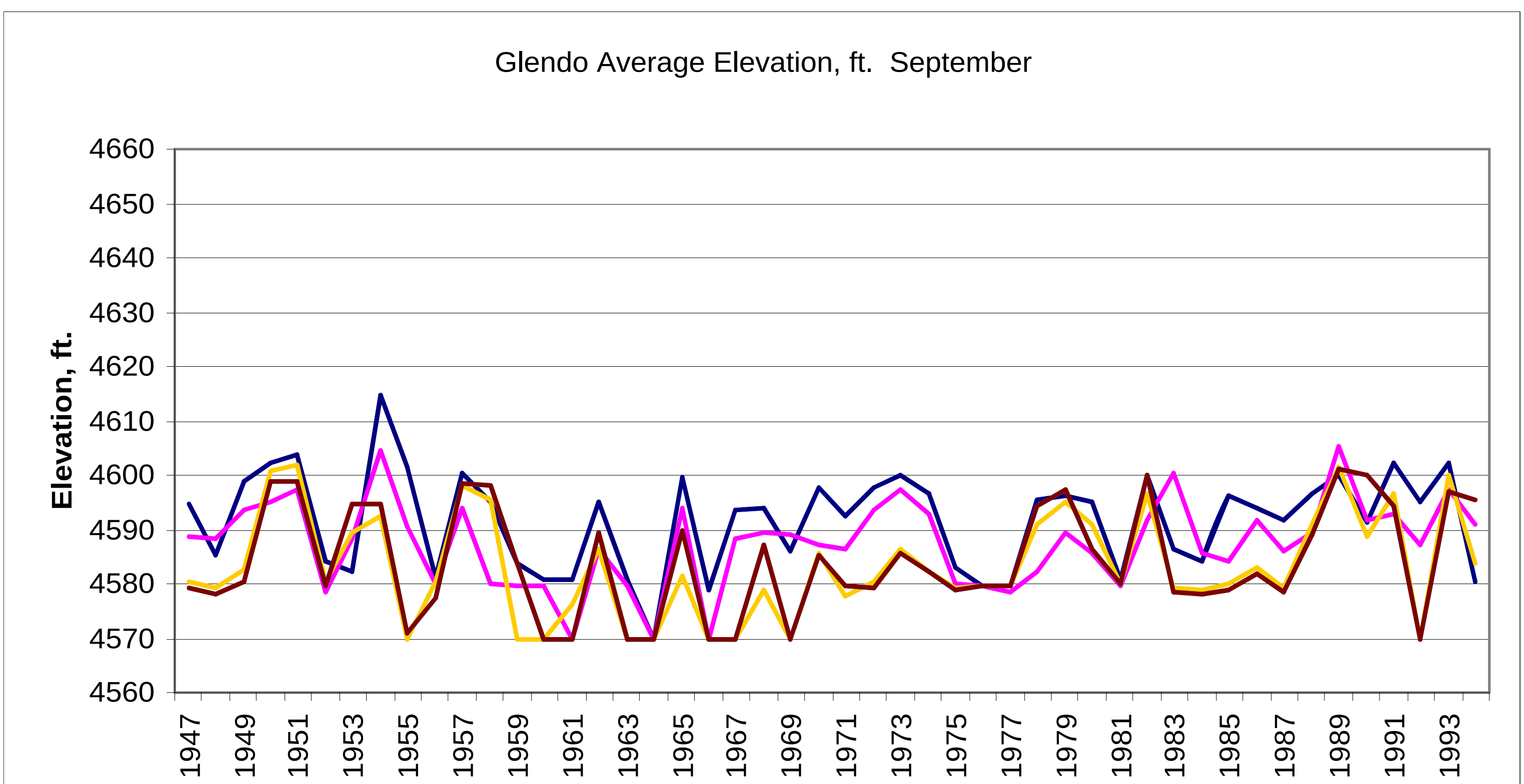
Present Conditions
Water Leasing
Wet Meadow
Governance Committee
Water Emphasis


Glendo Average Elevation, ft. September
Elevation, ft.
4660
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4640
4630
4620
4610
4600
4590
4580
4570
4560
1947
1949
1951
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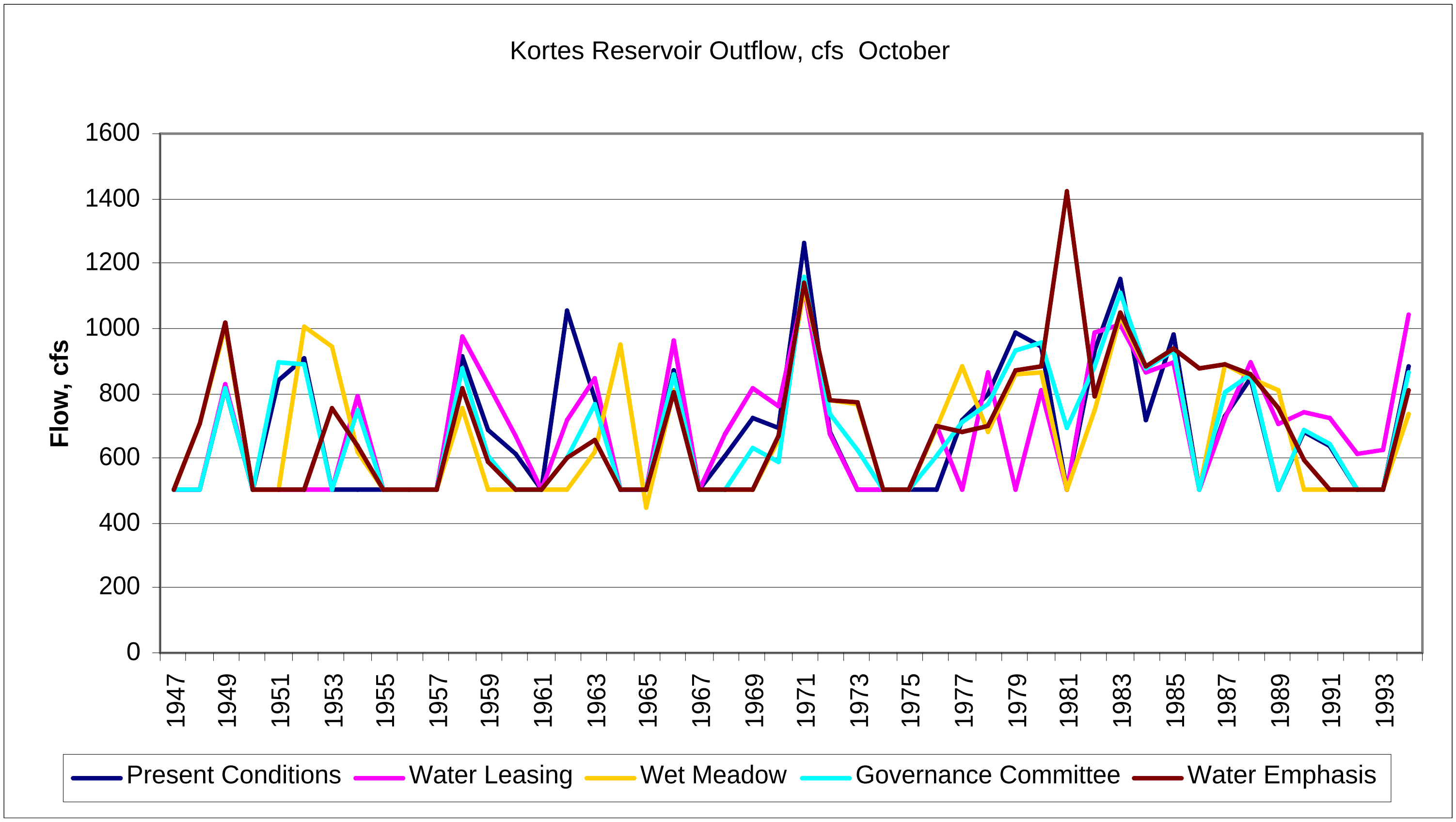
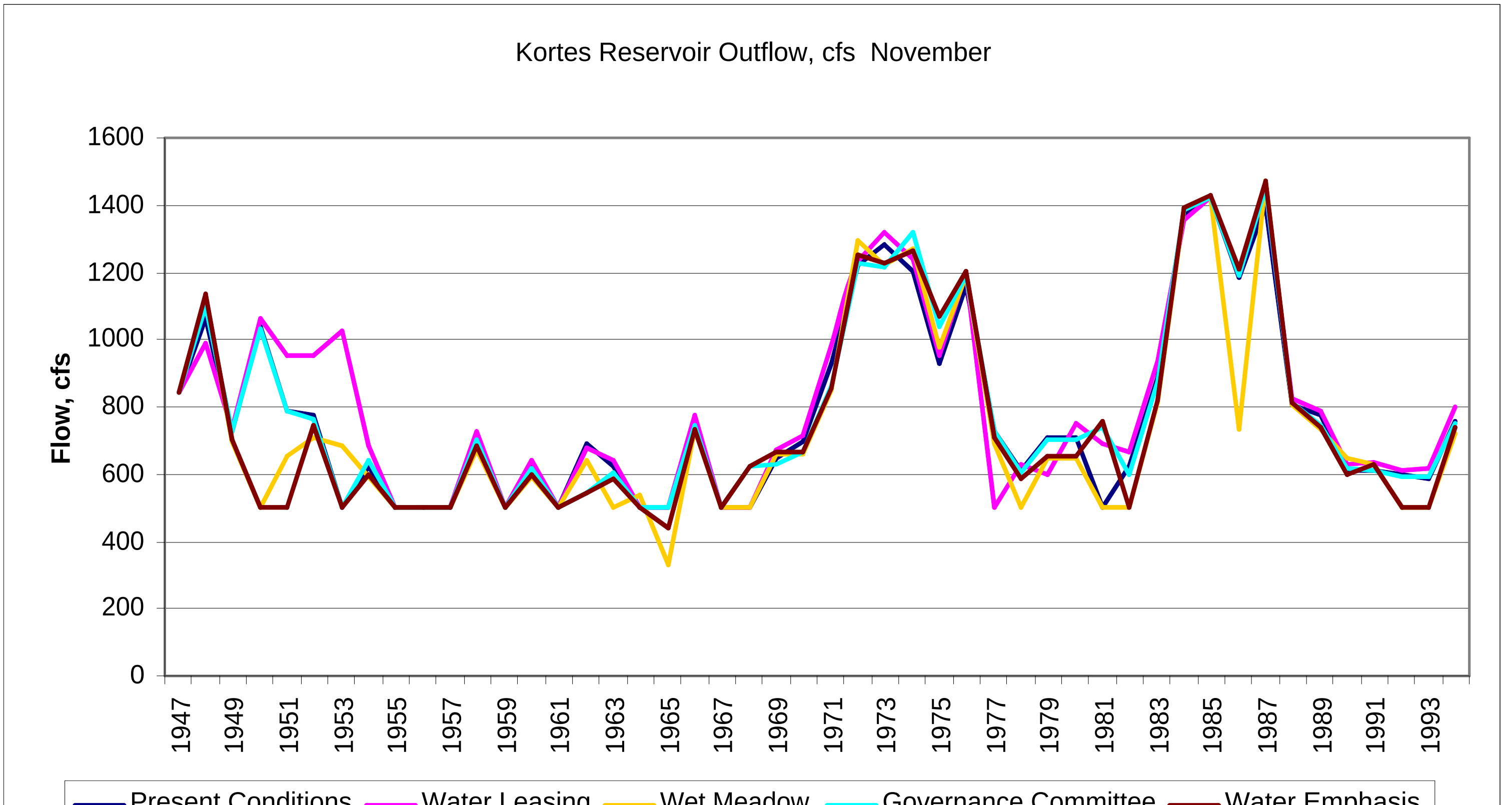
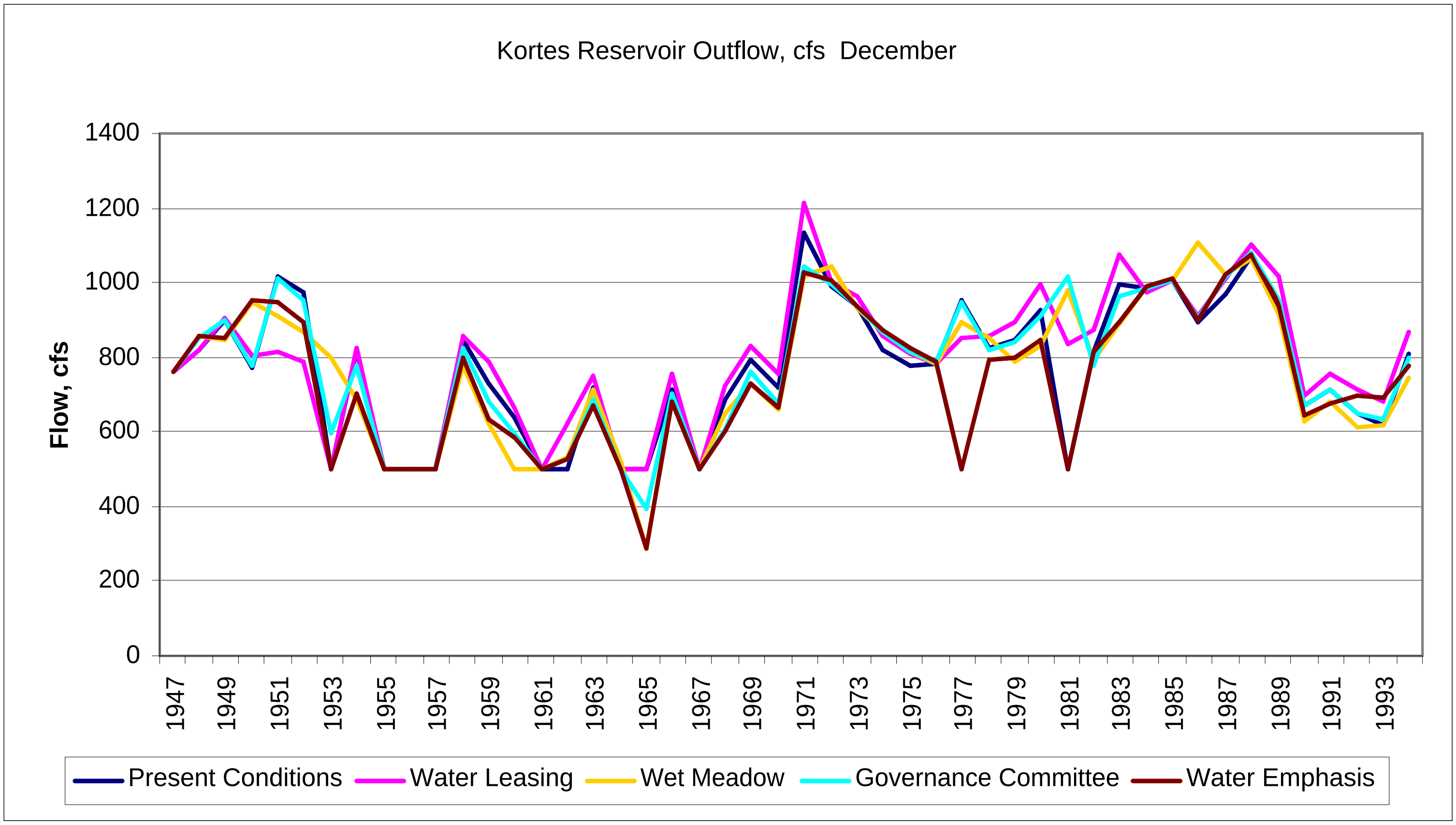
1991
1993

Kortes Reservoir Outflow







Kortes Reservoir Outflow, cfs December
Flow, cfs
0
200
400
600
800
1000
1200
1400
1947
1949
1951
1953
1955
1957
1959
1961
1963
1965
1967
1969
1971
1973
1975
1977
1979
1981
1983
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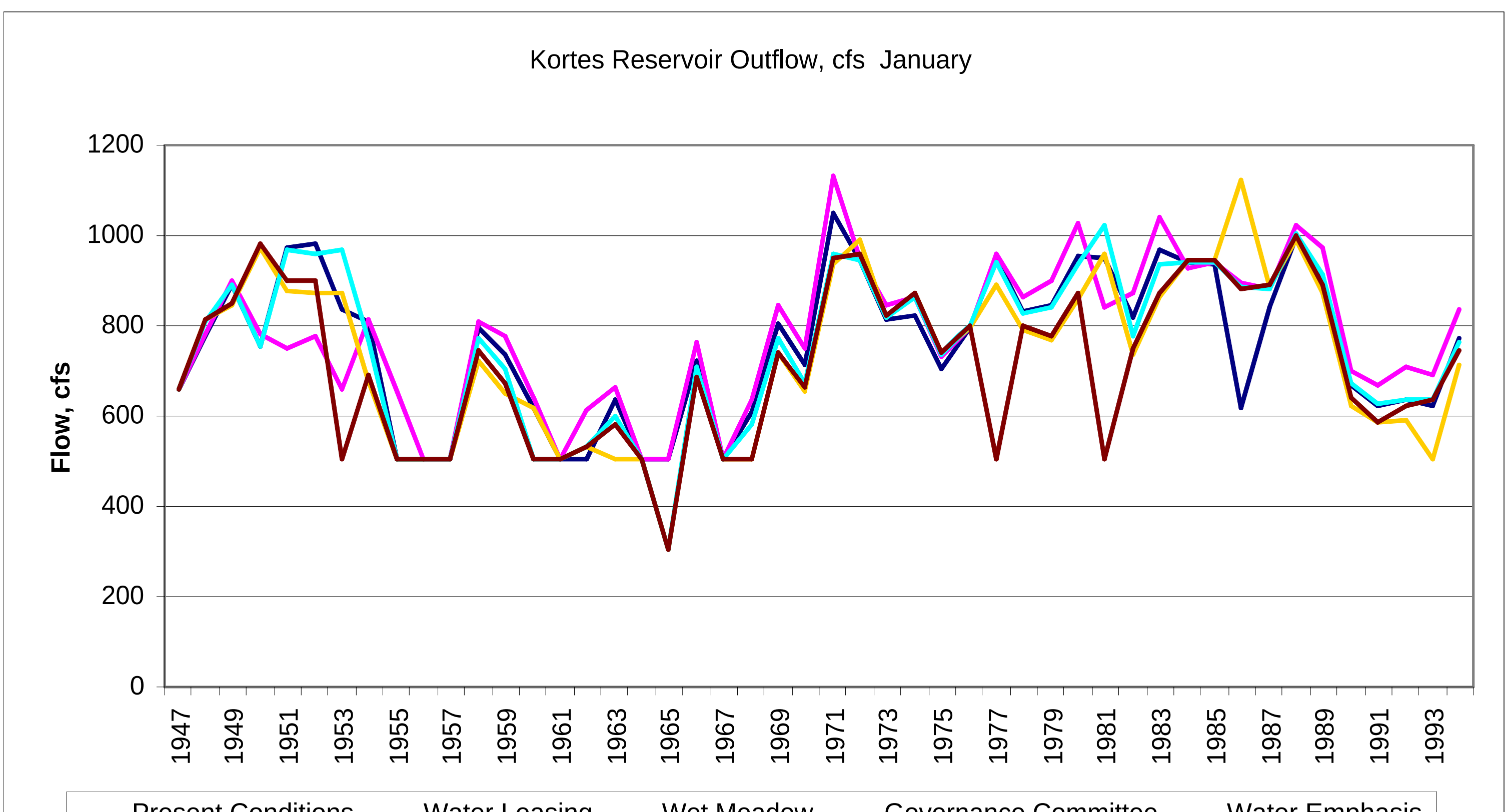
1987
1989
1991
1993
Present Conditions
Water Leasing
Wet Meadow
Governance Committee
Water Emphasis



Kortes Reservoir Outflow, cfs January
Flow, cfs
0
200
400
600
800
1000
1200
1947
1949
1951
1953
1955
1957
1959
1961
1963
1965
1967
1969
1971
1973
1975
1977
1979
1981
1983
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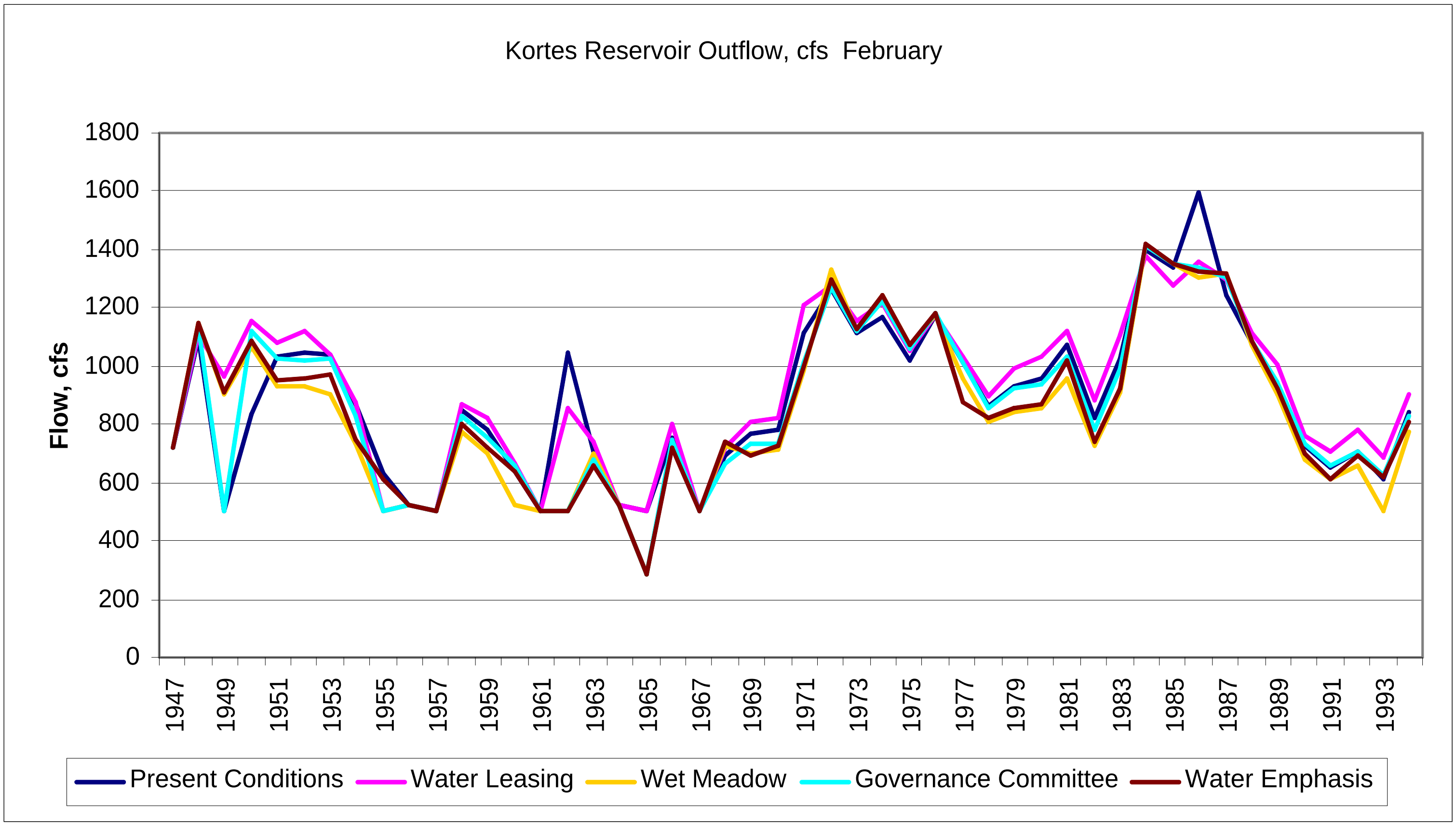
1987
1989
1991
1993


Kortes Reservoir Outflow, cfs February
Flow, cfs
1800
1600
1400
1200
1000
800
600
400
200
0
1947
1949
1951
1953
1955
1957
1959
1961
1963
1965
1967
1969
1971
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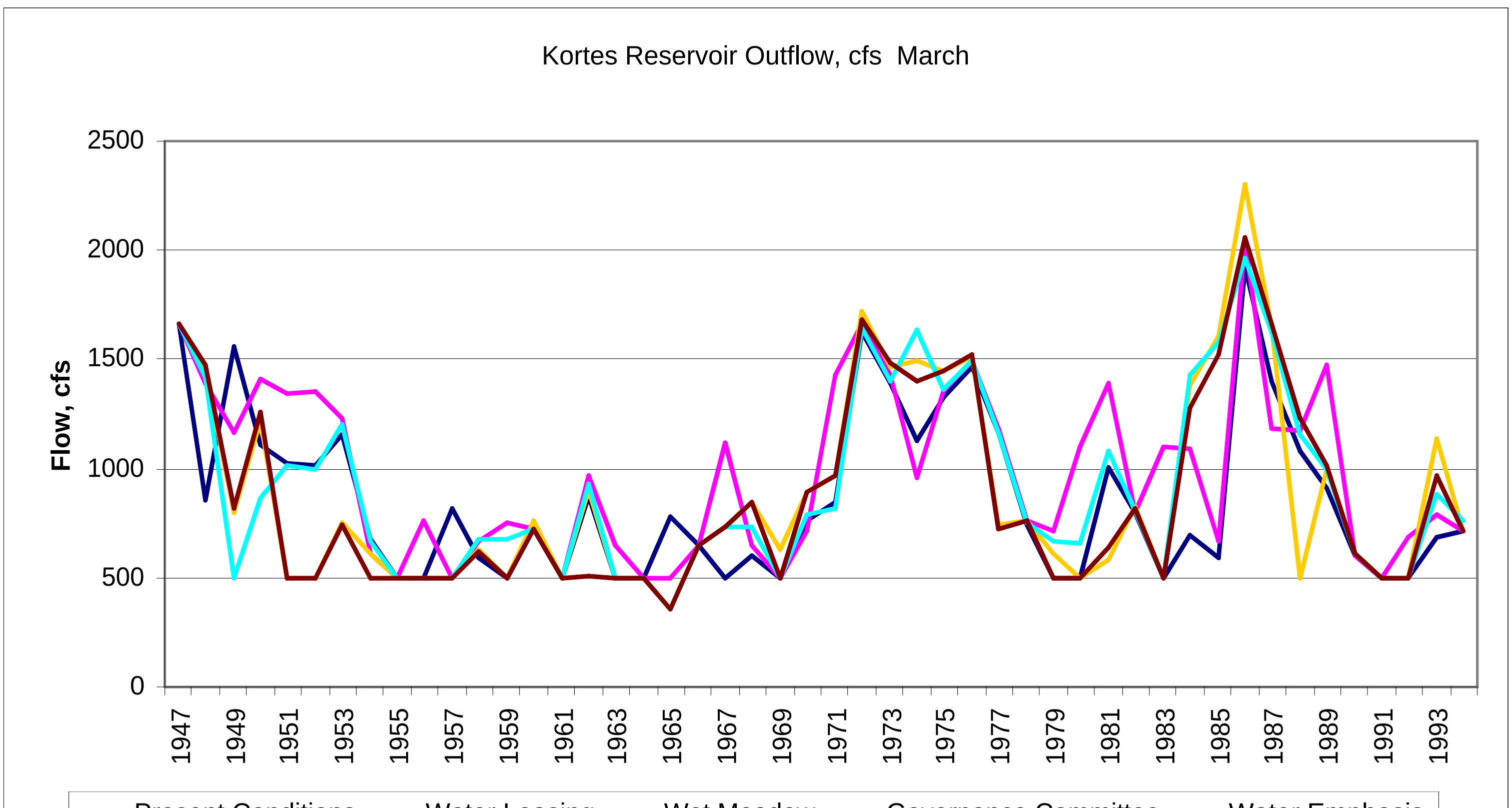
1991
1993
Present Conditions
Water Leasing
Wet Meadow
Governance Committee
Water Emphasis


Kortes Reservoir Outflow, cfs March
Flow, cfs
2500
2000
1500
1000
500
0
1947
1949
1951
1953
1955
1957
1959
1961
1963
1965
1967
1969
1971
1973
1975
1977
1979
1981
1983
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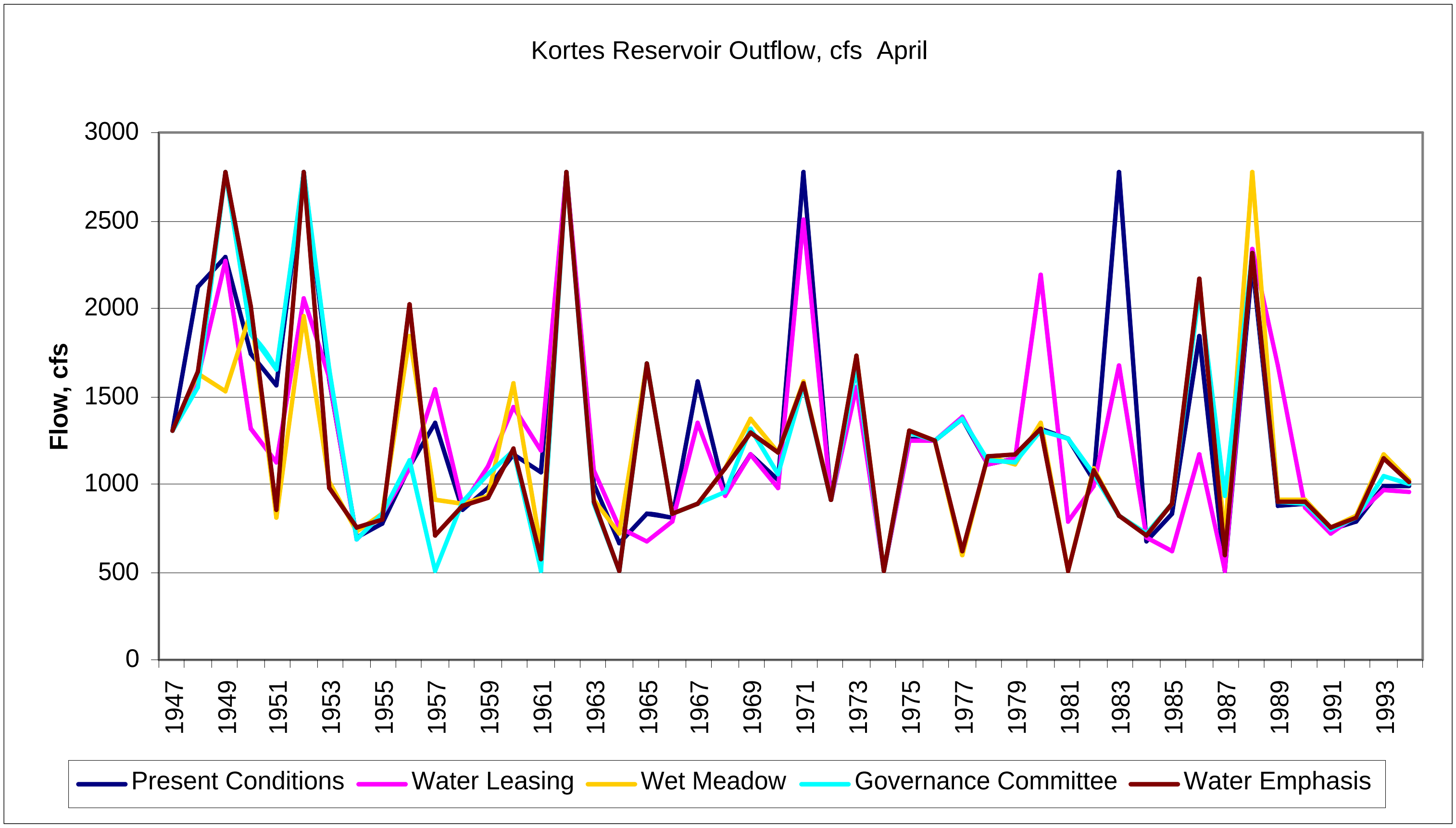
1987
1989
1991
1993


Kortes Reservoir Outflow, cfs April
Flow, cfs
0
500
1000
1500
2000
2500
3000
1947
1949
1951
1953
1955
1957
1959
1961
1963
1965
1967
1969
1971
1973
1975
1977
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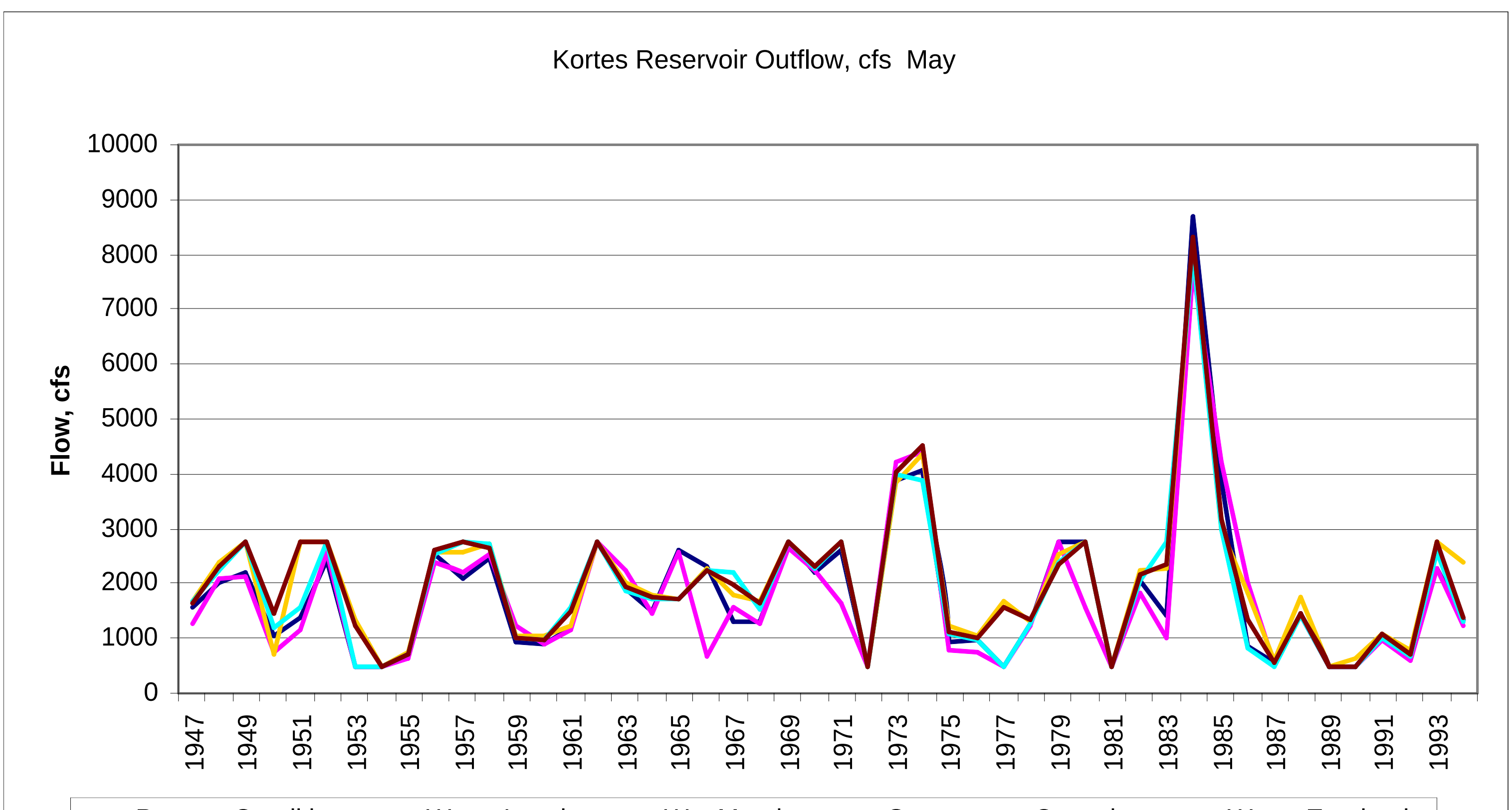
Present Conditions
Water Leasing
Wet Meadow
Governance Committee
Water Emphasis


Kortes Reservoir Outflow, cfs May
Flow, cfs
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
1947
1949
1951
1953
1955
1957
1959
1961
1963
1965
1967
1969
1971
1973
1975
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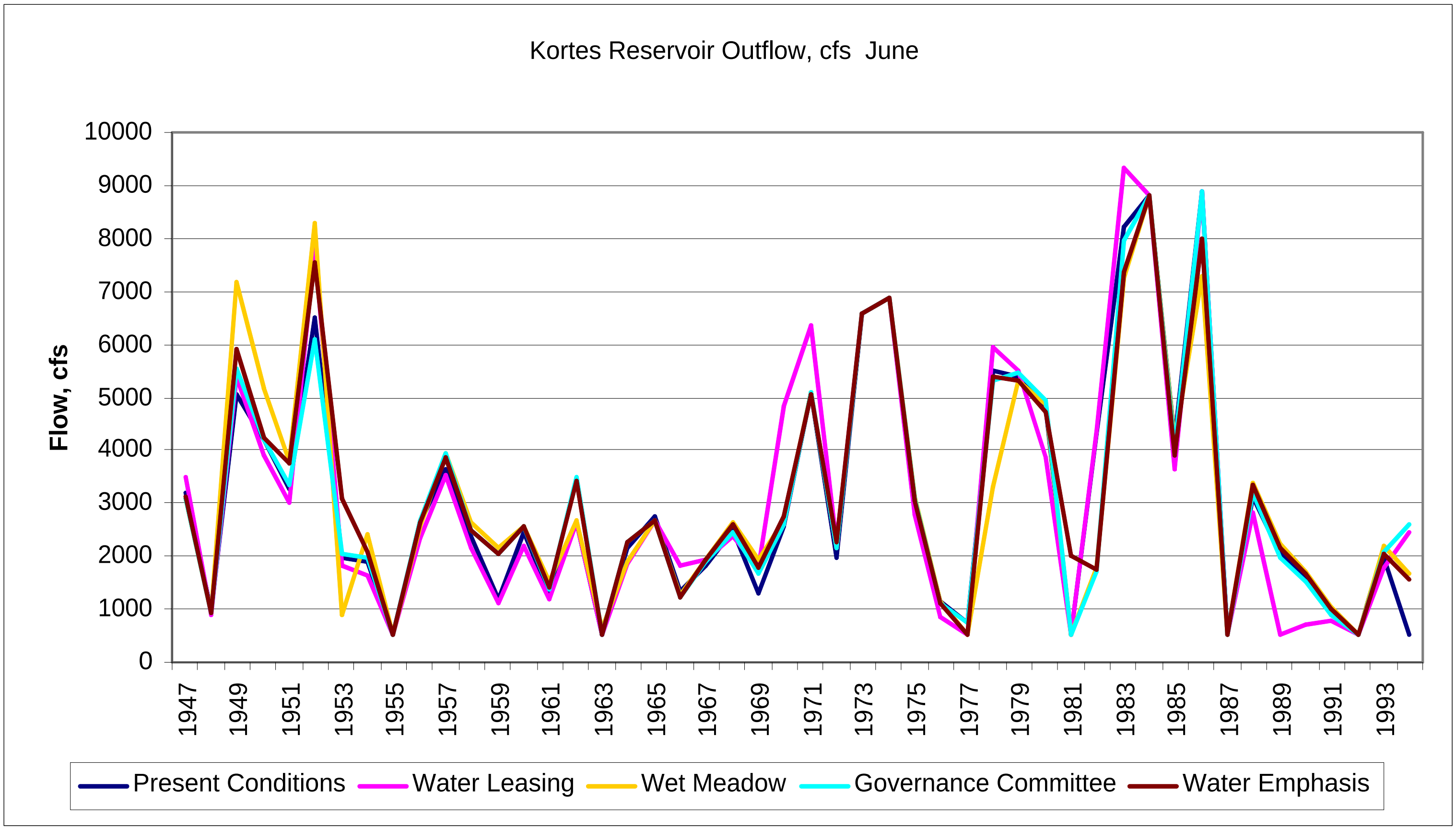
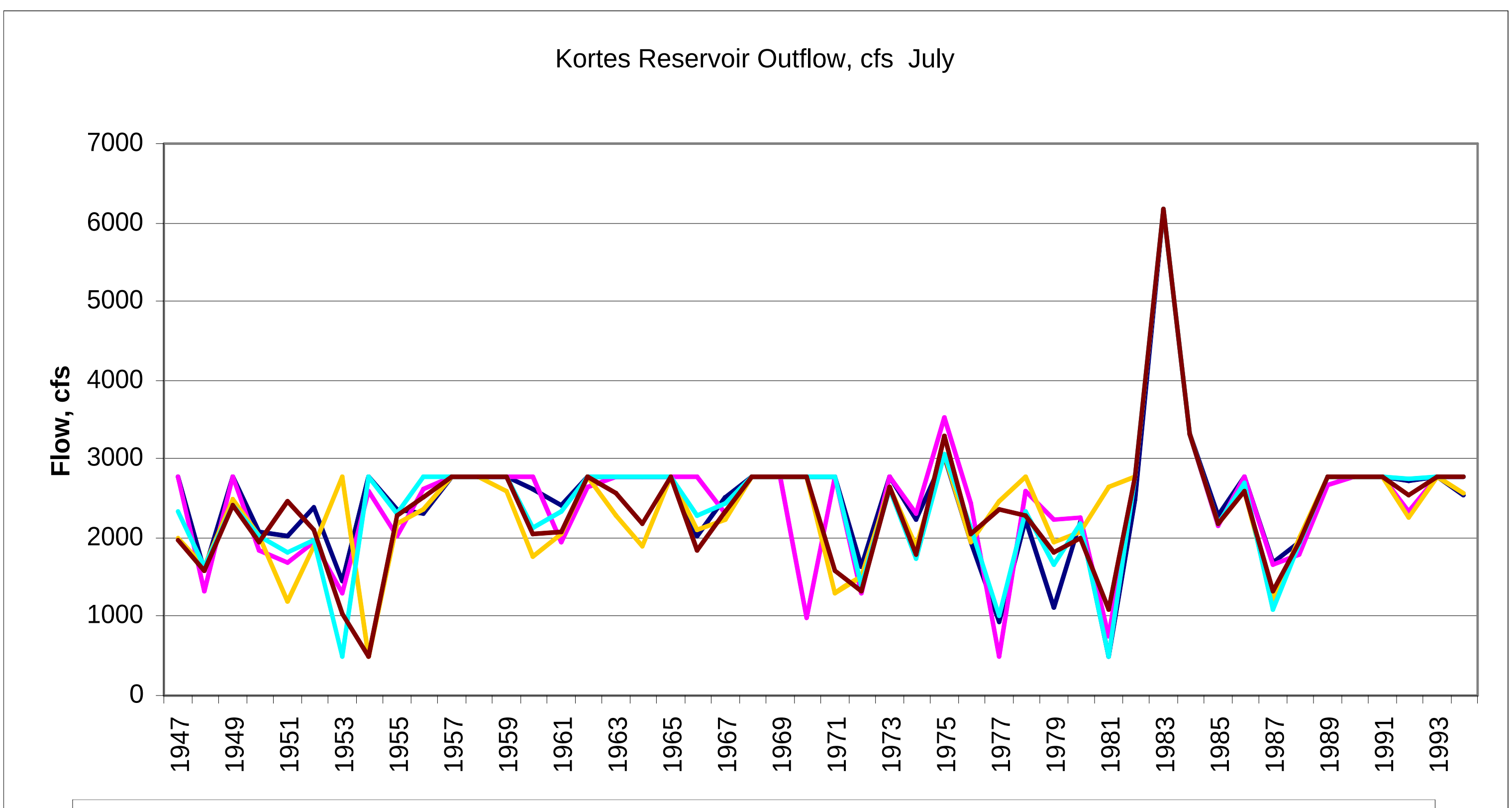
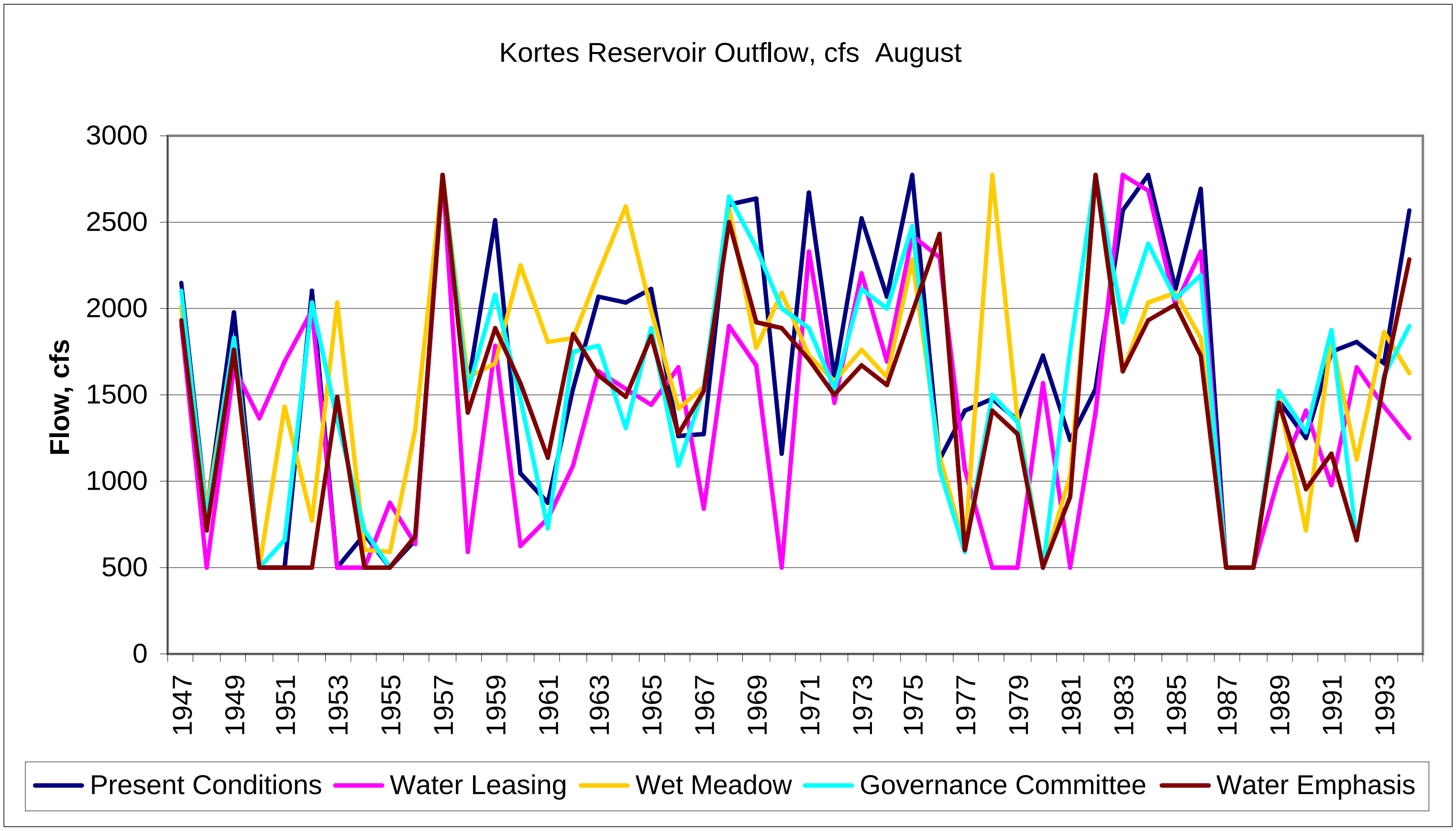
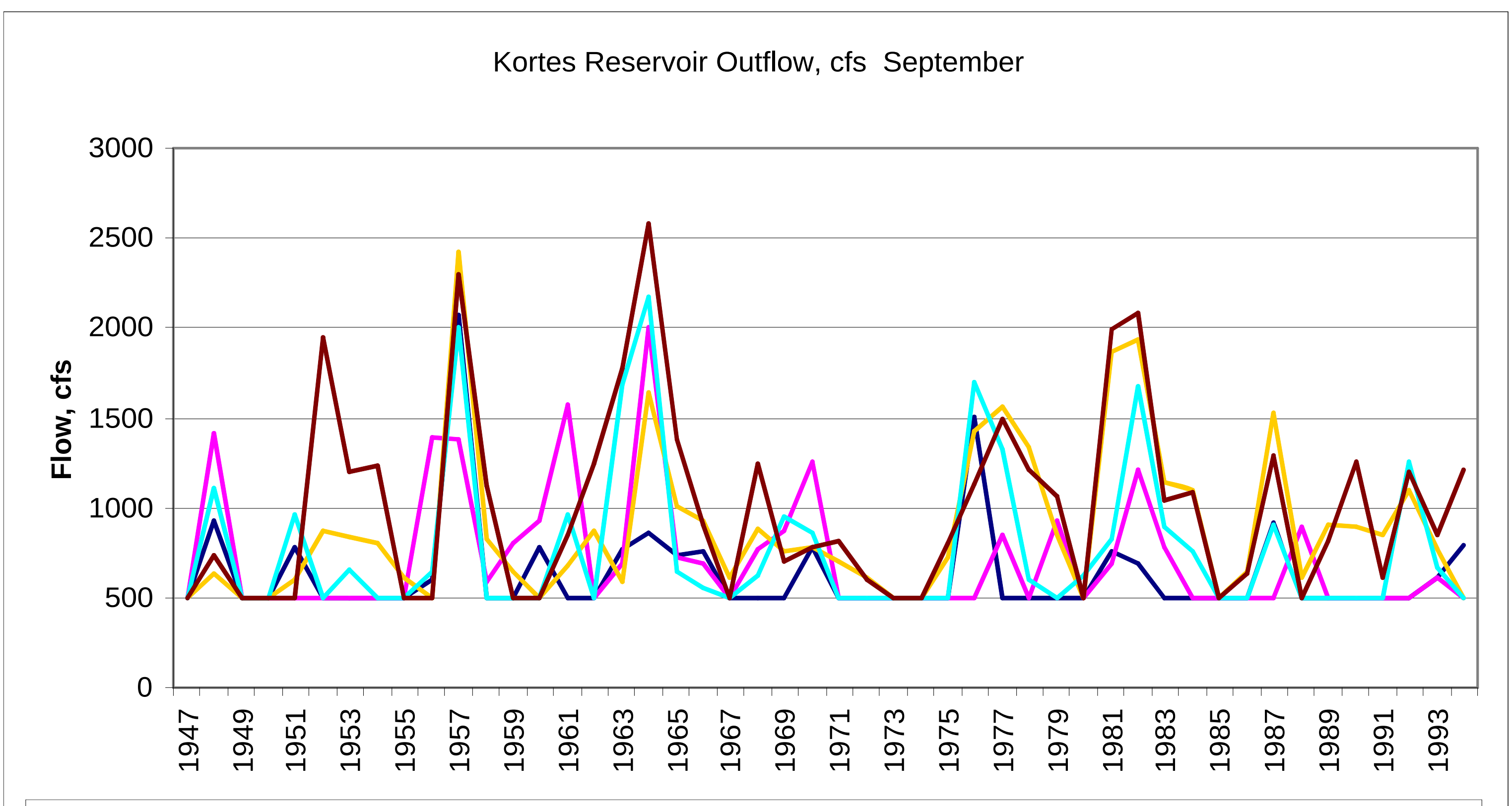
1991
1993

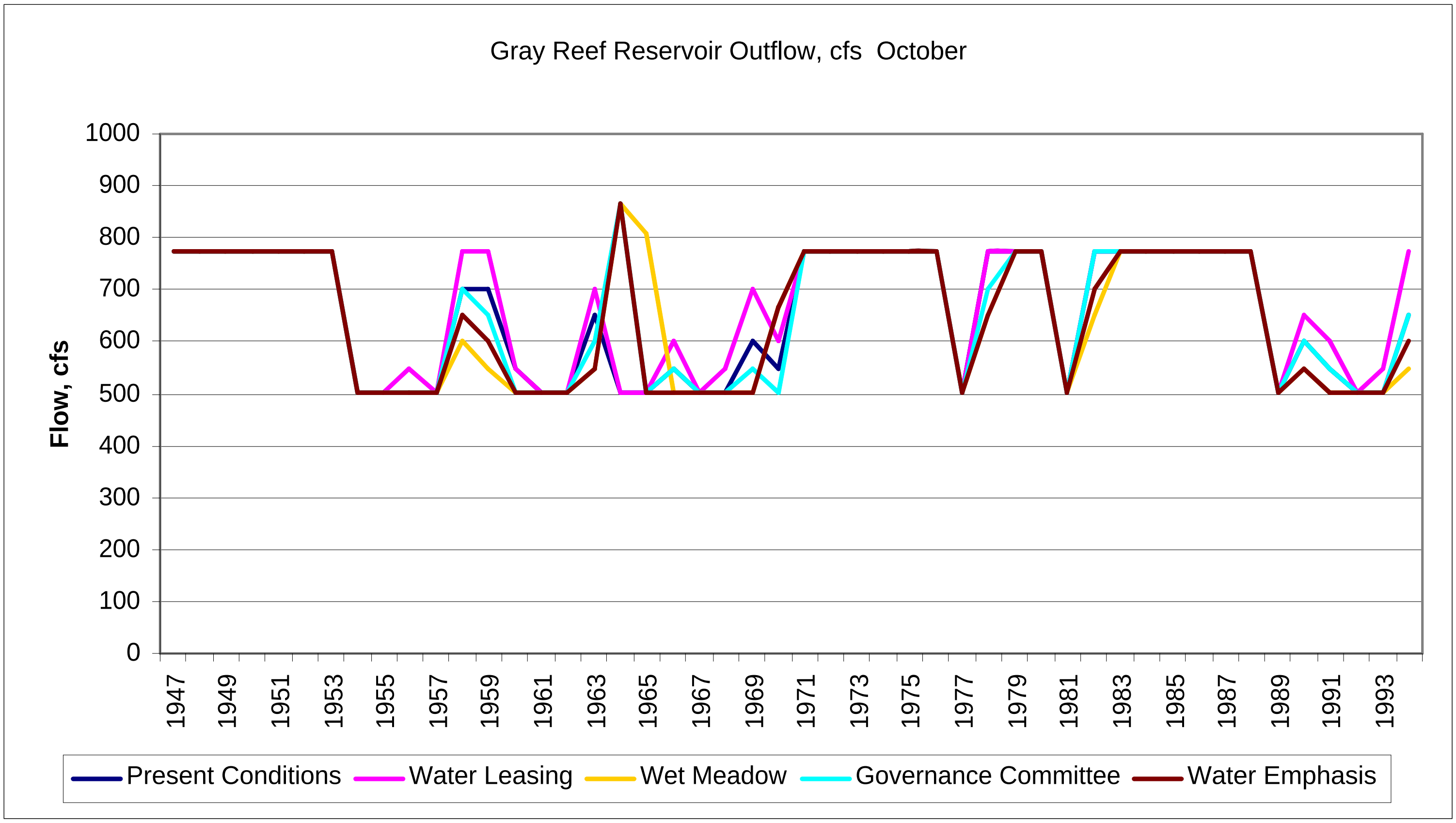

Kortes Reservoir Outflow, cfs June
Flow, cfs
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
1947
1949
1951
1953
1955
1957
1959
1961
1963
1965
1967
1969
1971
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
Present Conditions
Water Leasing
Wet Meadow
Governance Committee
Water Emphasis


Kortes Reservoir Outflow, cfs July
Flow, cfs
7000
6000
5000
4000
3000
2000
1000
0
1947
1949
1951
1953
1955
1957
1959
1961
1963
1965
1967
1969
1971
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993

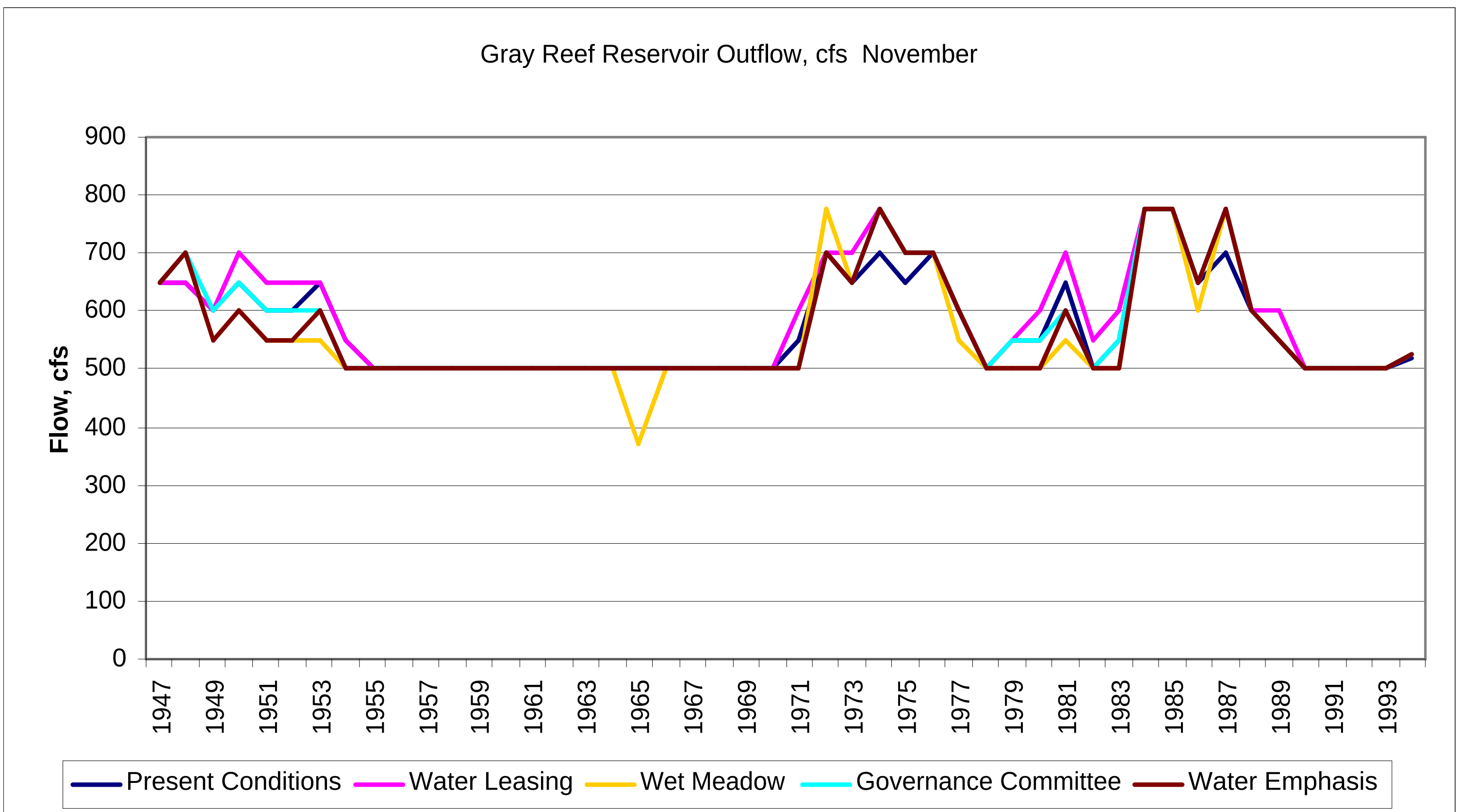

Kortes Reservoir Outflow, cfs August
Flow, cfs
3000
2500
2000
1500
1000
500
0
1947
1949
1951
1953
1955
1957
1959
1961
1963
1965
1967
1969
1971
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
Present Conditions
Water Leasing
Wet Meadow
Governance Committee
Water Emphasis


Kortes Reservoir Outflow, cfs September
Flow, cfs
3000
2500
2000
1500
1000
500
0
1947
1949
1951
1953
1955
1957
1959
1961
1963
1965
1967
1969
1971
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993

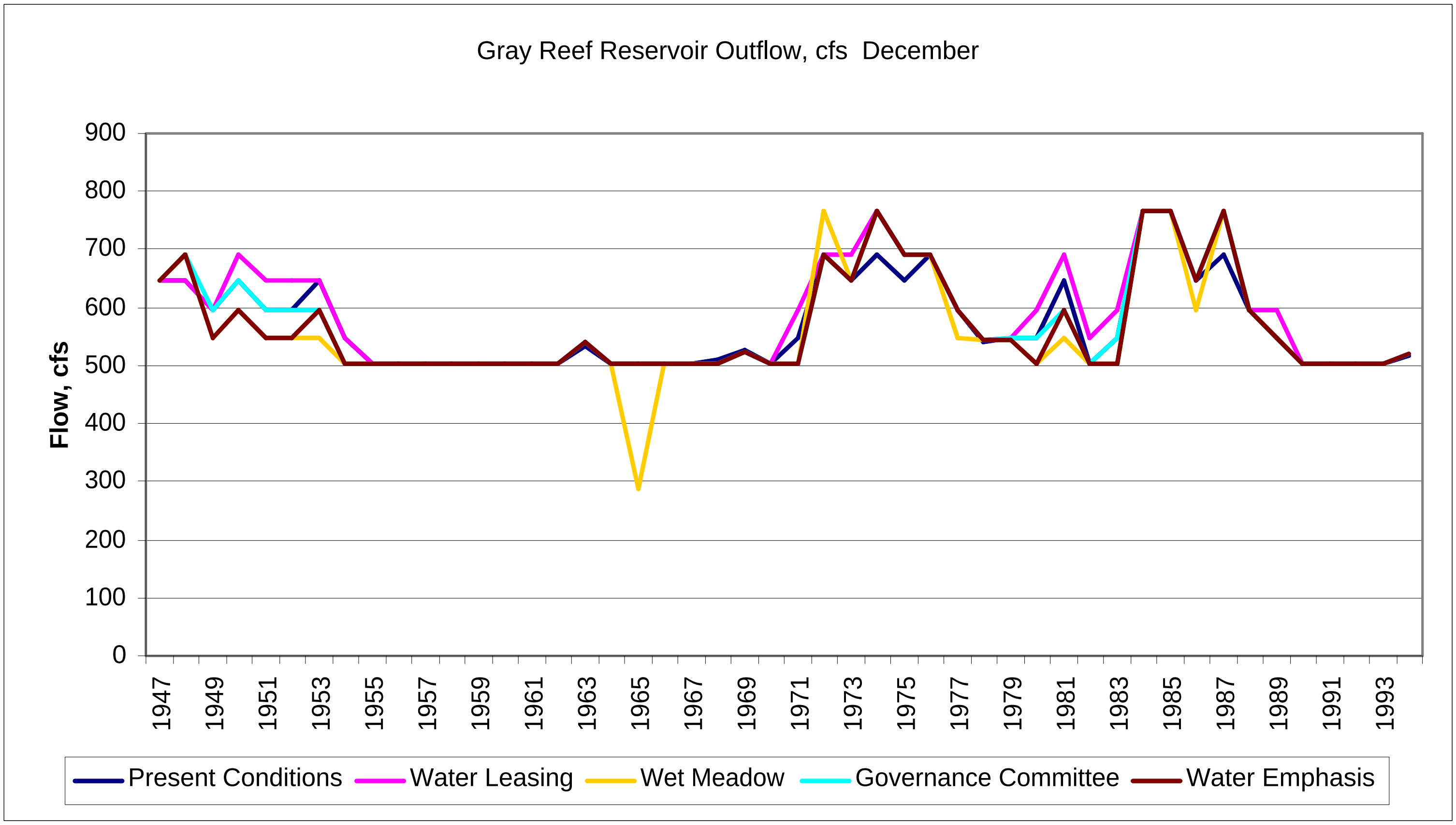
Gray Reef Reservoir Outflow

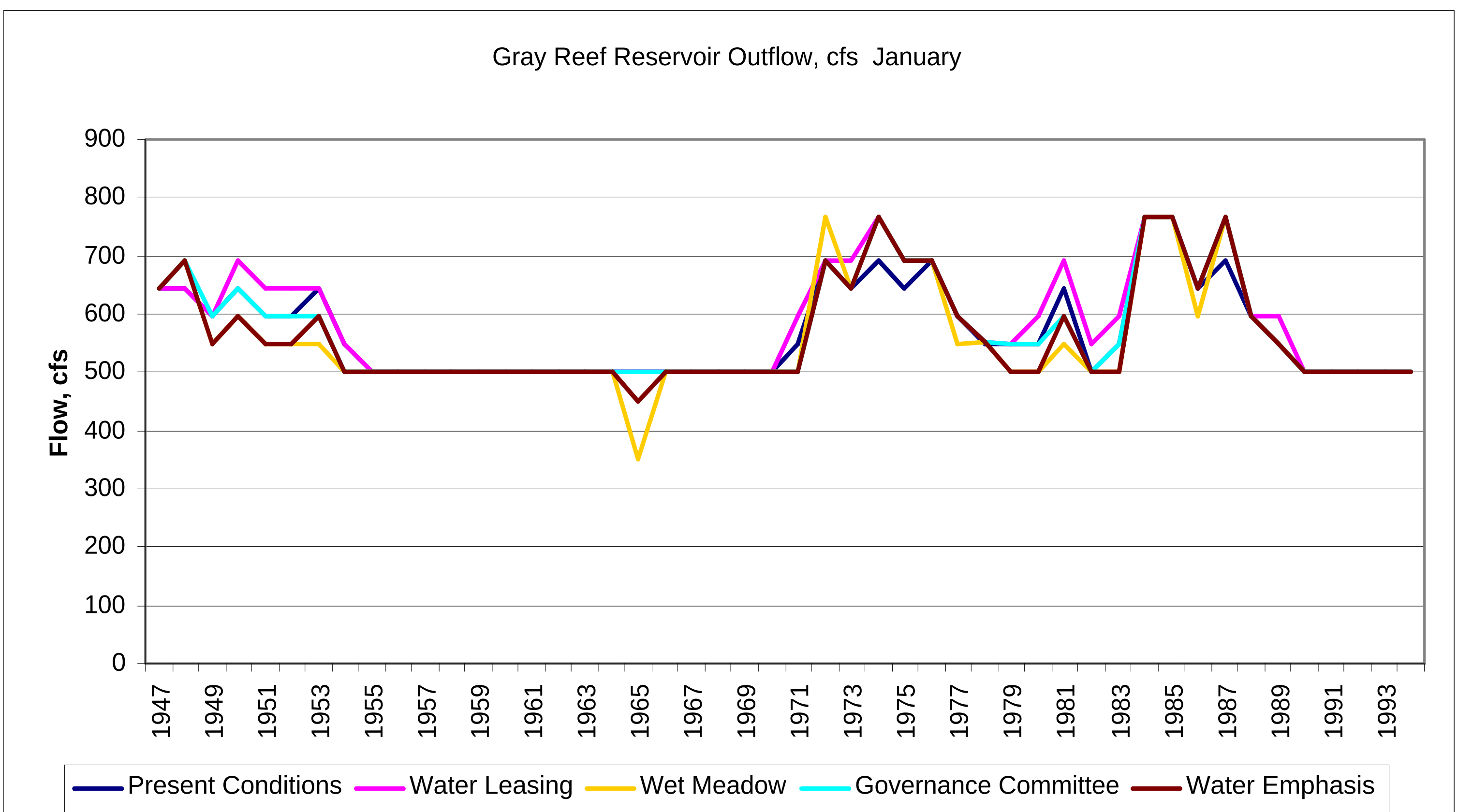


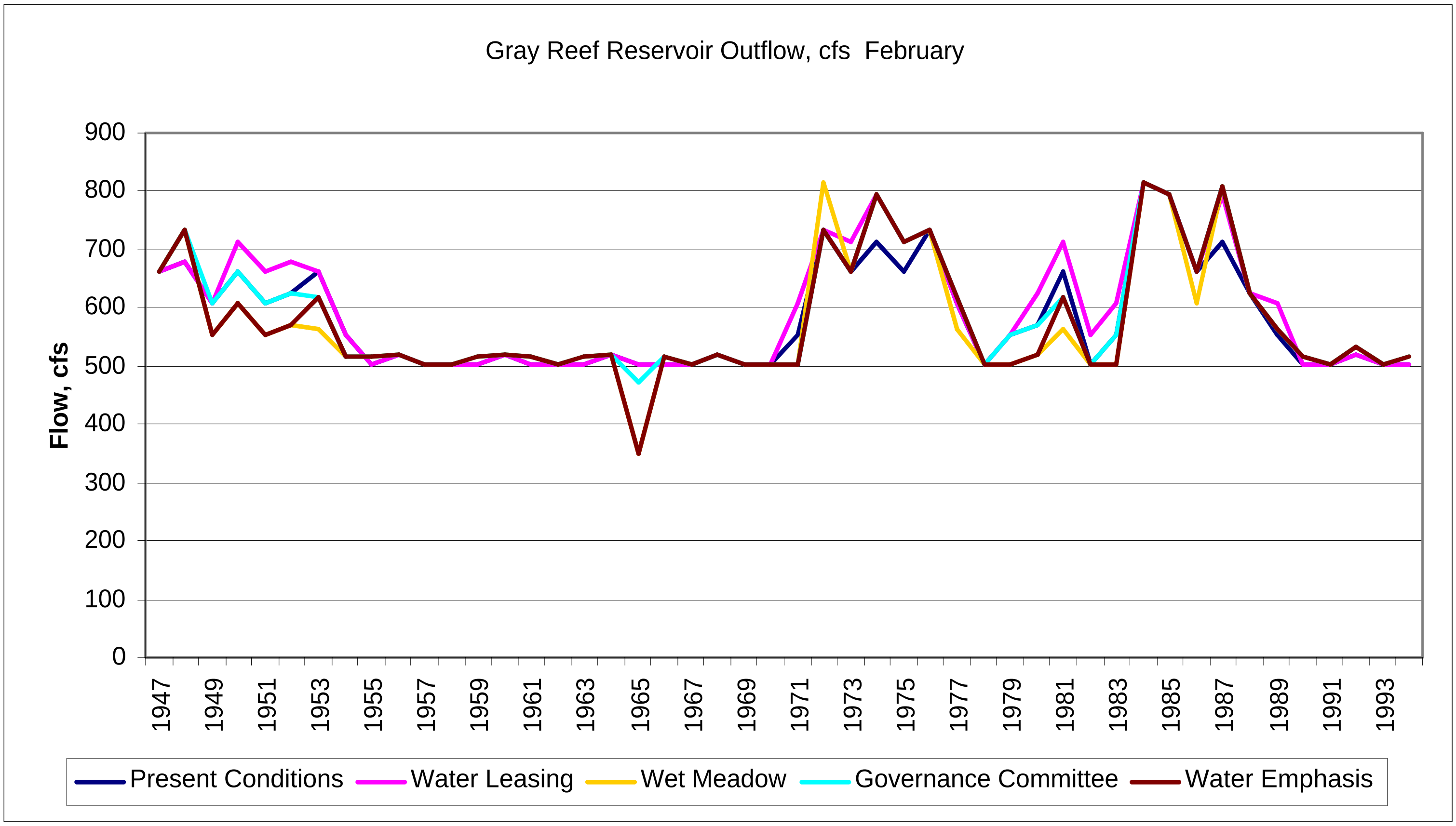
Gray Reef Reservoir Outflow, cfs October
Flow, cfs
1000
900
800
700
600
500
400
300
200
100
0
1947
1949
1951
1953
1955
1957
1959
1961
1963
1965
1967
1969
1971
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
Present Conditions
Water Leasing
Wet Meadow
Governance Committee
Water Emphasis



Gray Reef Reservoir Outflow, cfs November
Flow, cfs
900
800
700
600
500
400
300
200
100
0
1947
1949
1951
1953
1955
1957
1959
1961
1963
1965
1967
1969
1971
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
Present Conditions
Water Leasing
Wet Meadow
Governance Committee
Water Emphasis


Gray Reef Reservoir Outflow, cfs December
Flow, cfs
0
100
200
300
400
500
600
700
800
900
1947
1949
1951
1953
1955
1957
1959
1961
1963
1965
1967
1969
1971
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
Present Conditions
Water Leasing
Wet Meadow
Governance Committee
Water Emphasis


Gray Reef Reservoir Outflow, cfs January
Flow, cfs
0
100
200
300
400
500
600
700
800
900
1947
1949
1951
1953
1955
1957
1959
1961
1963
1965
1967
1969
1971
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
Present Conditions
Water Leasing
Wet Meadow
Governance Committee
Water Emphasis


Gray Reef Reservoir Outflow, cfs February
Flow, cfs
900
800
700
600
500
400
300
200
100
0
1947
1949
1951
1953
1955
1957
1959
1961
1963
1965
1967
1969
1971
1973
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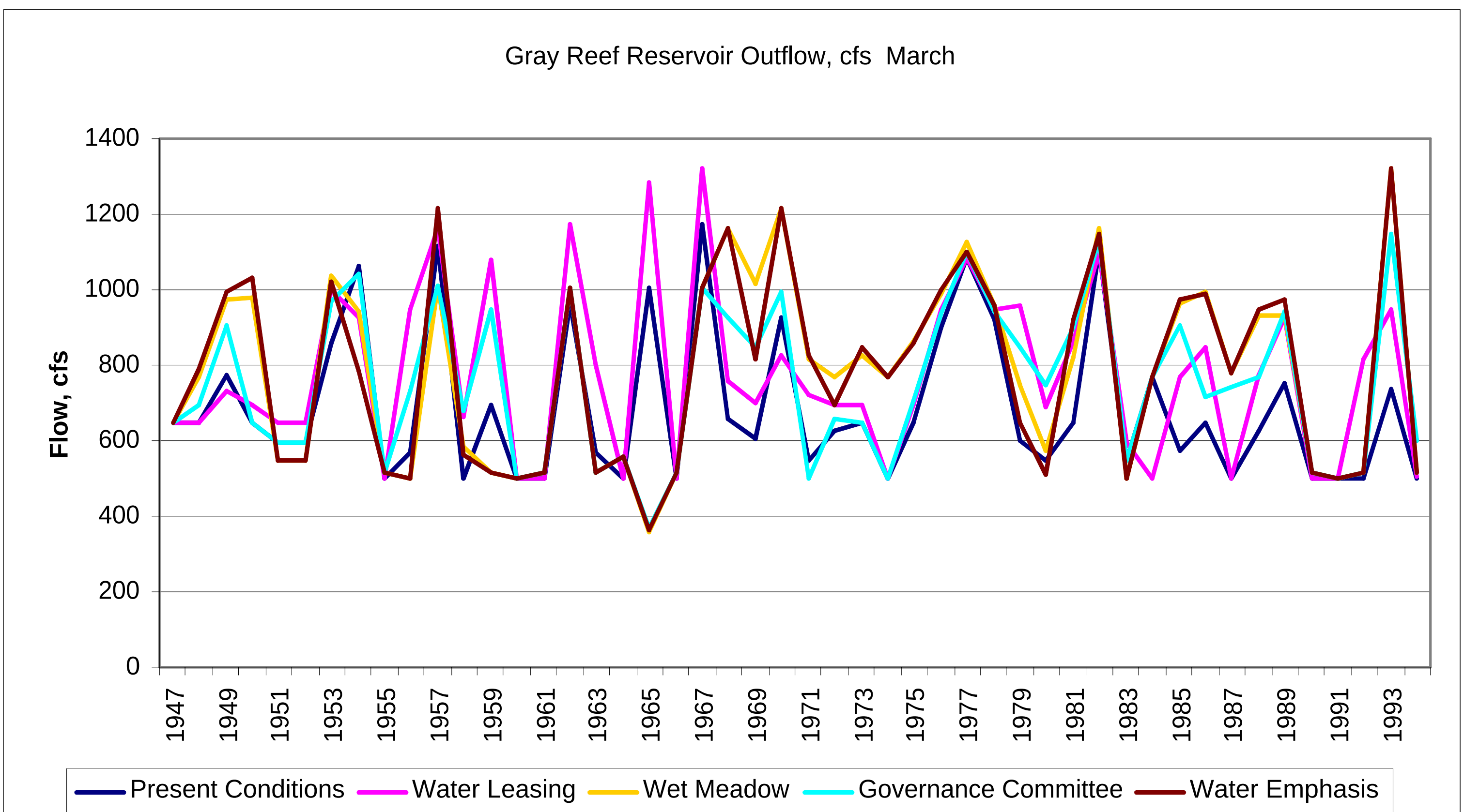
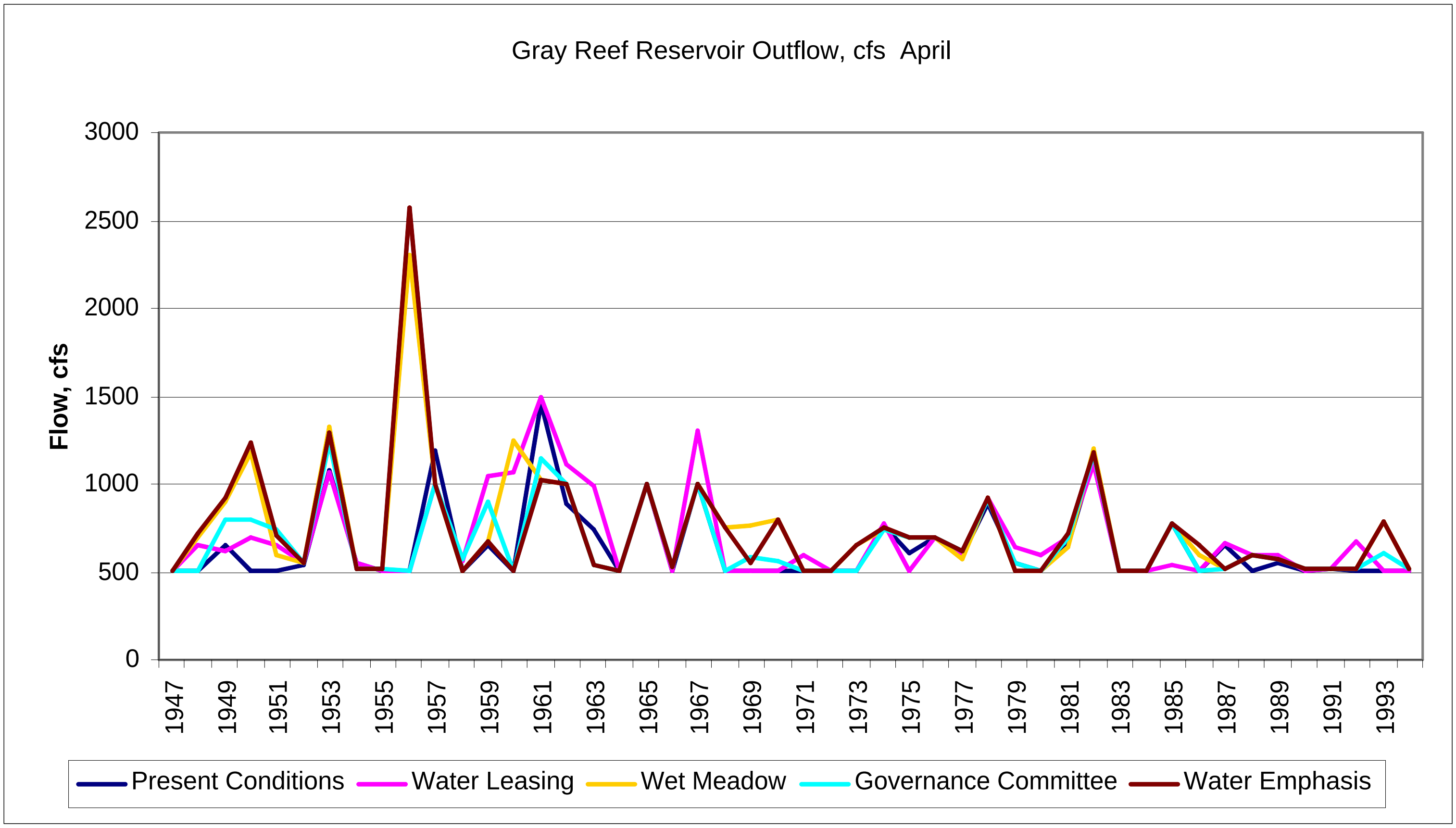
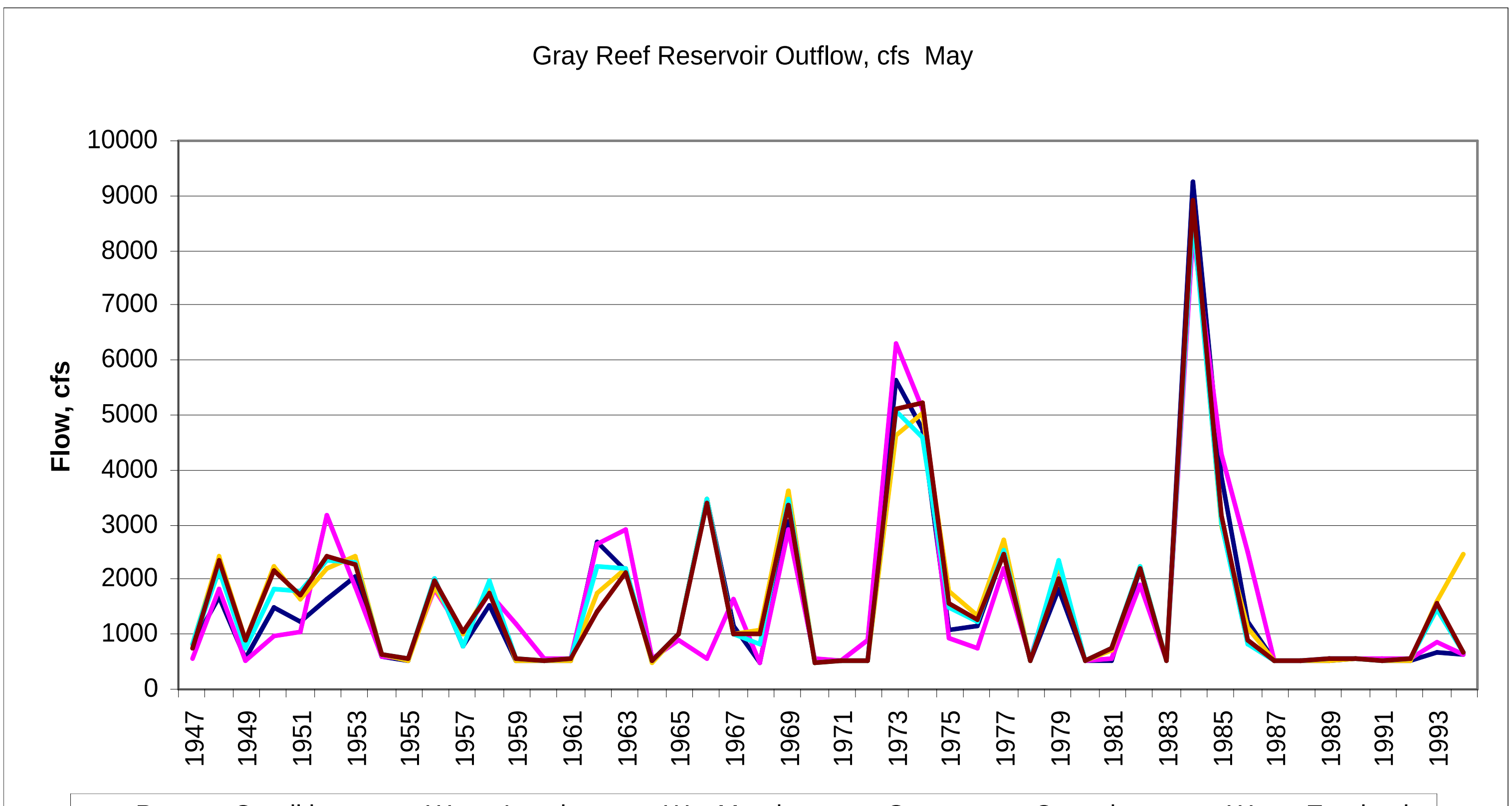
1979
1981
1983
1985
1987
1989
1991
1993
Present Conditions
Water Leasing
Wet Meadow
Governance Committee
Water Emphasis


Gray Reef Reservoir Outflow, cfs March
Flow, cfs
1400
1200
1000
800
600
400
200
0
1947
1949
1951
1953
1955
1957
1959
1961
1963
1965
1967
1969
1971
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
Present Conditions
Water Leasing
Wet Meadow
Governance Committee
Water Emphasis


Gray Reef Reservoir Outflow, cfs April
Flow, cfs
3000
2500
2000
1500
1000
500
0
1947
1949
1951
1953
1955
1957
1959
1961
1963
1965
1967
1969
1971
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
Present Conditions
Water Leasing
Wet Meadow
Governance Committee
Water Emphasis


Gray Reef Reservoir Outflow, cfs May
Flow, cfs
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
1947
1949
1951
1953
1955
1957
1959
1961
1963
1965
1967
1969
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1973
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1977
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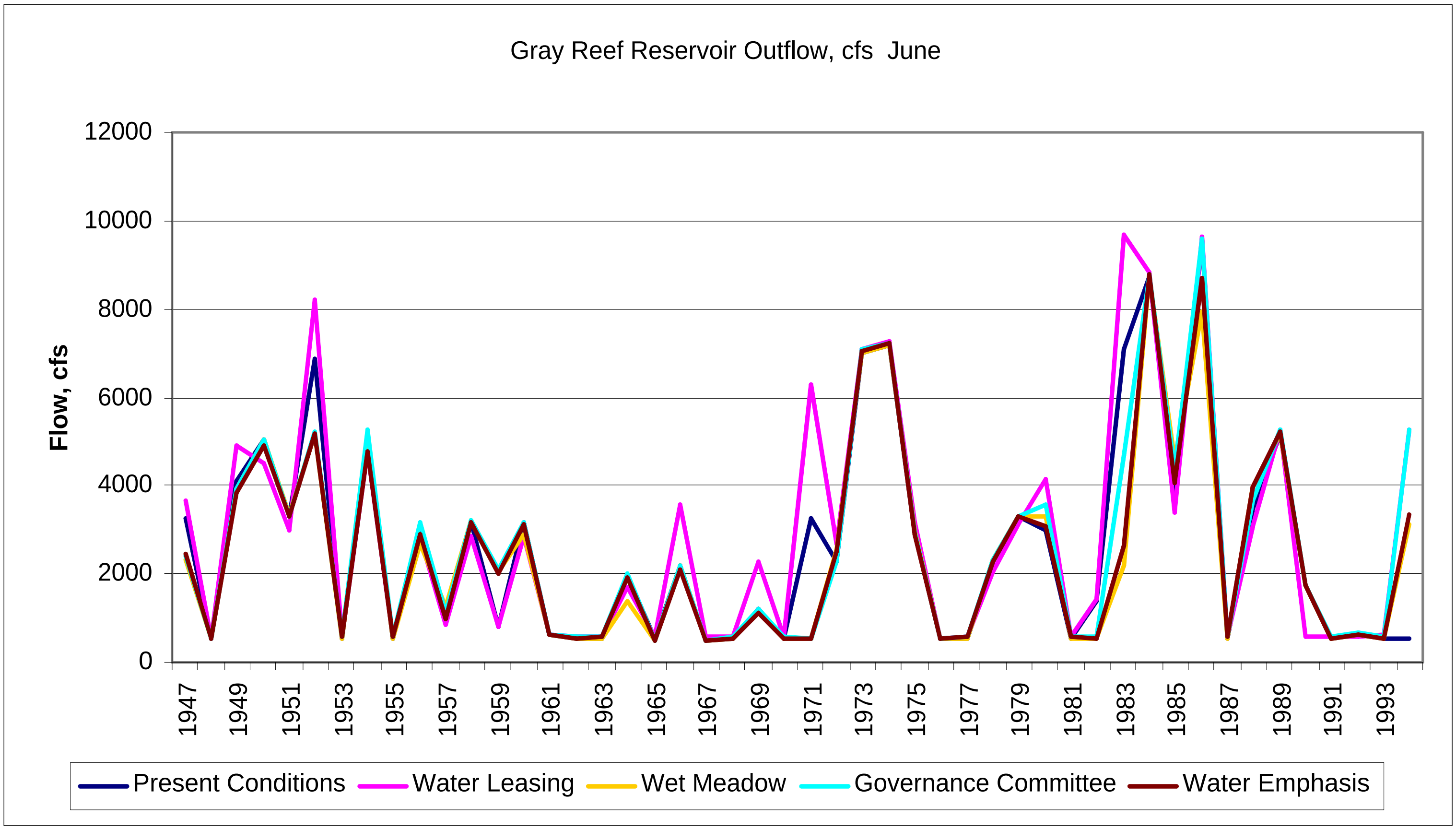
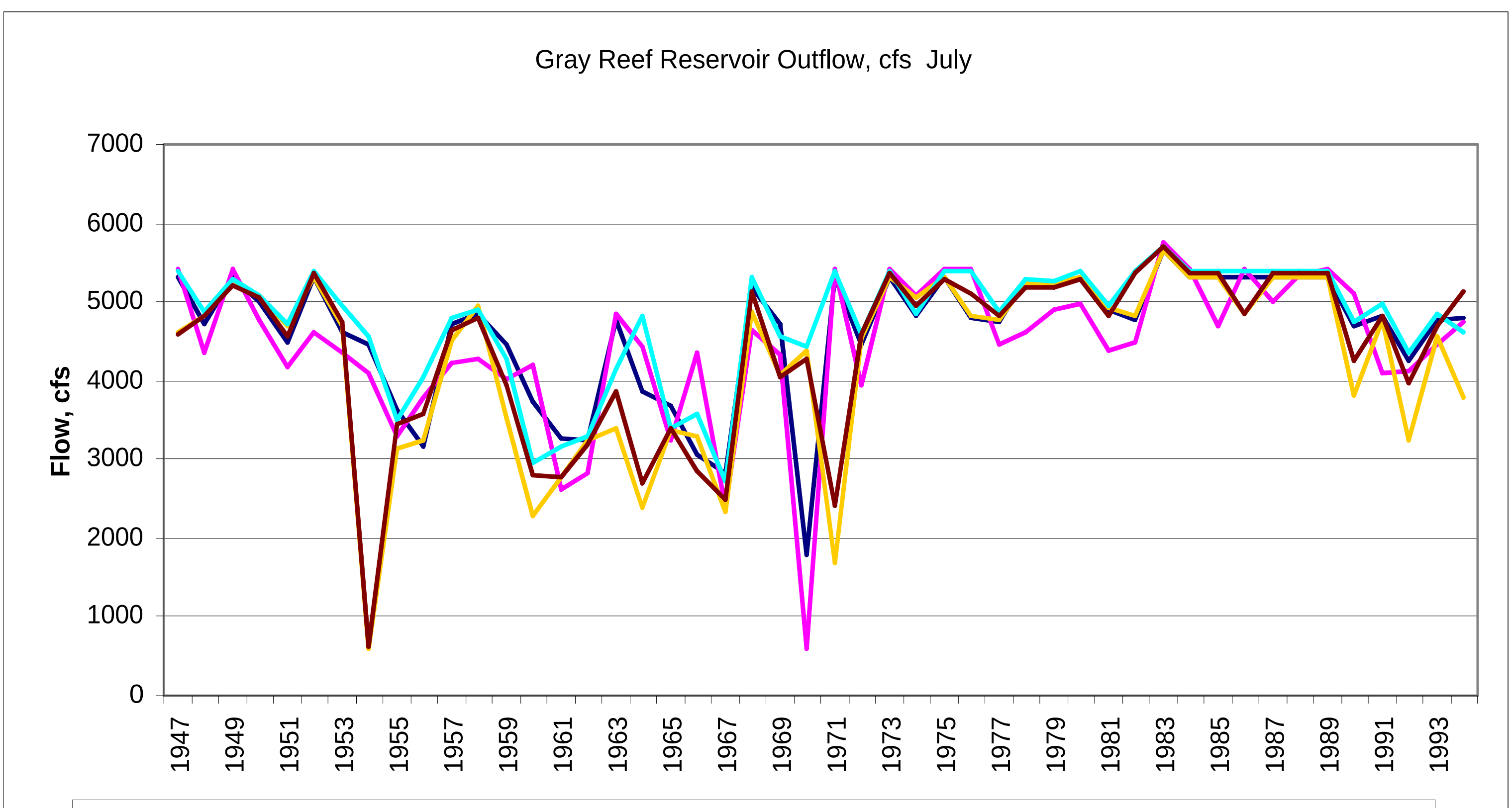
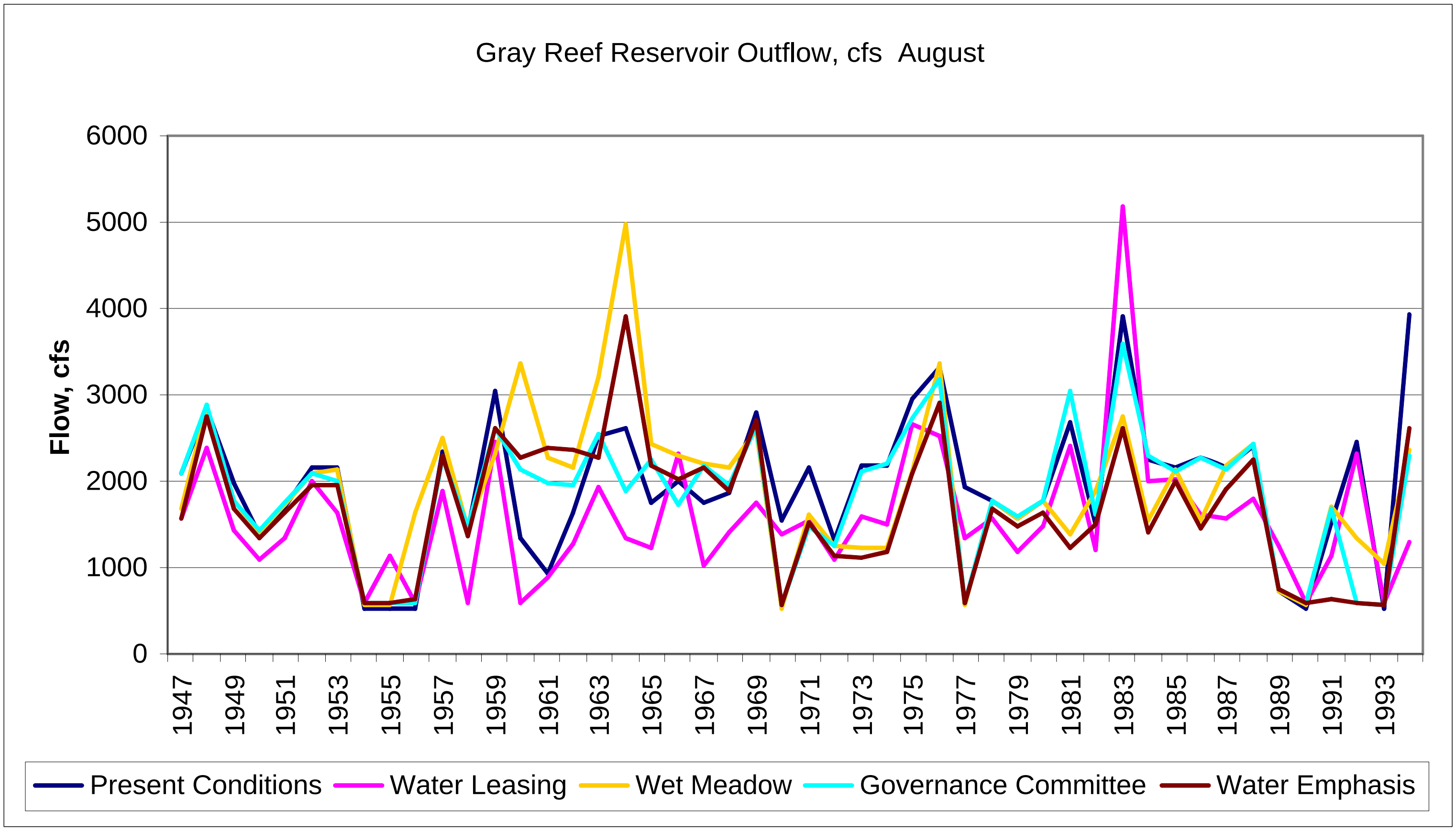
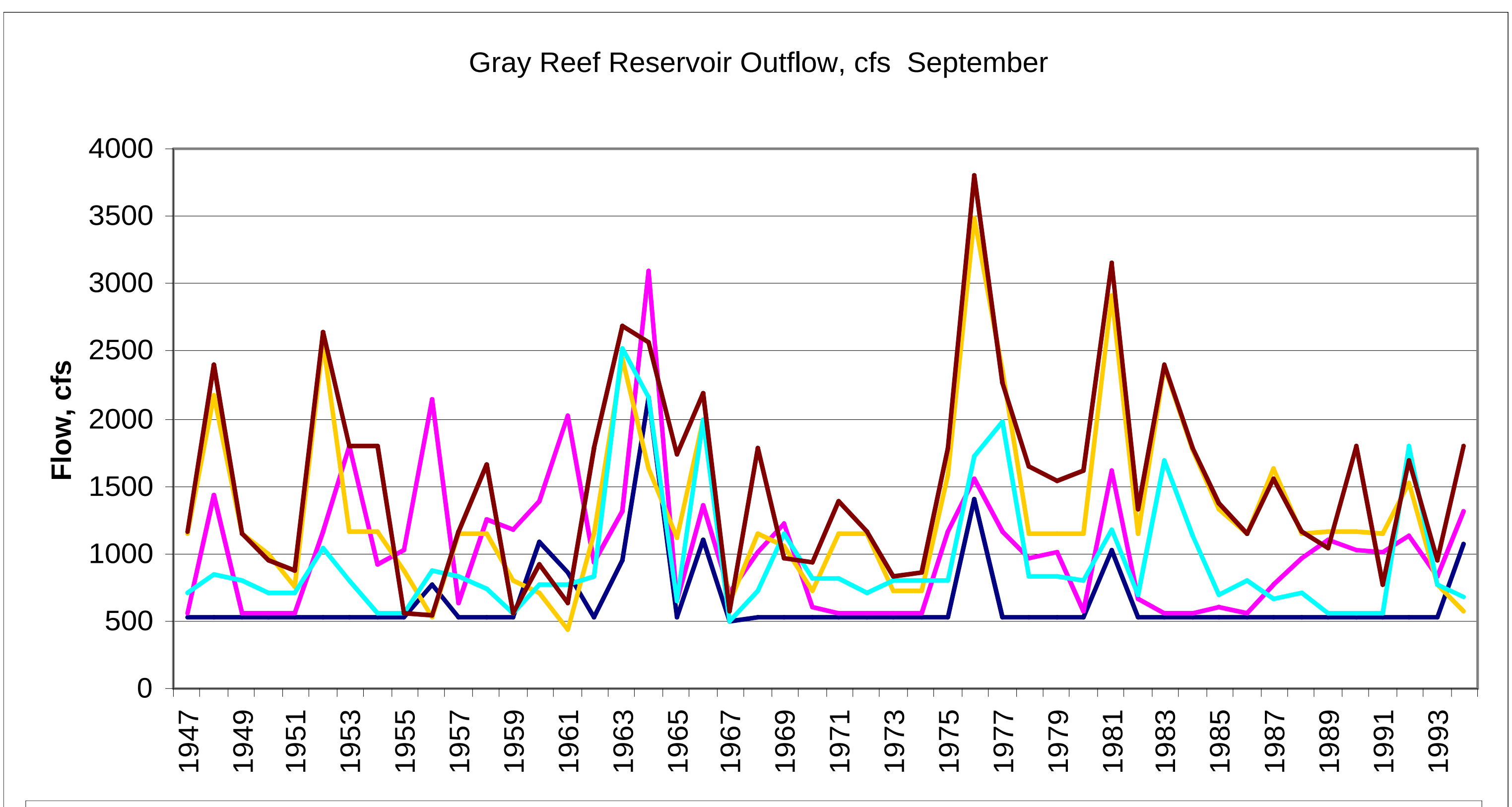
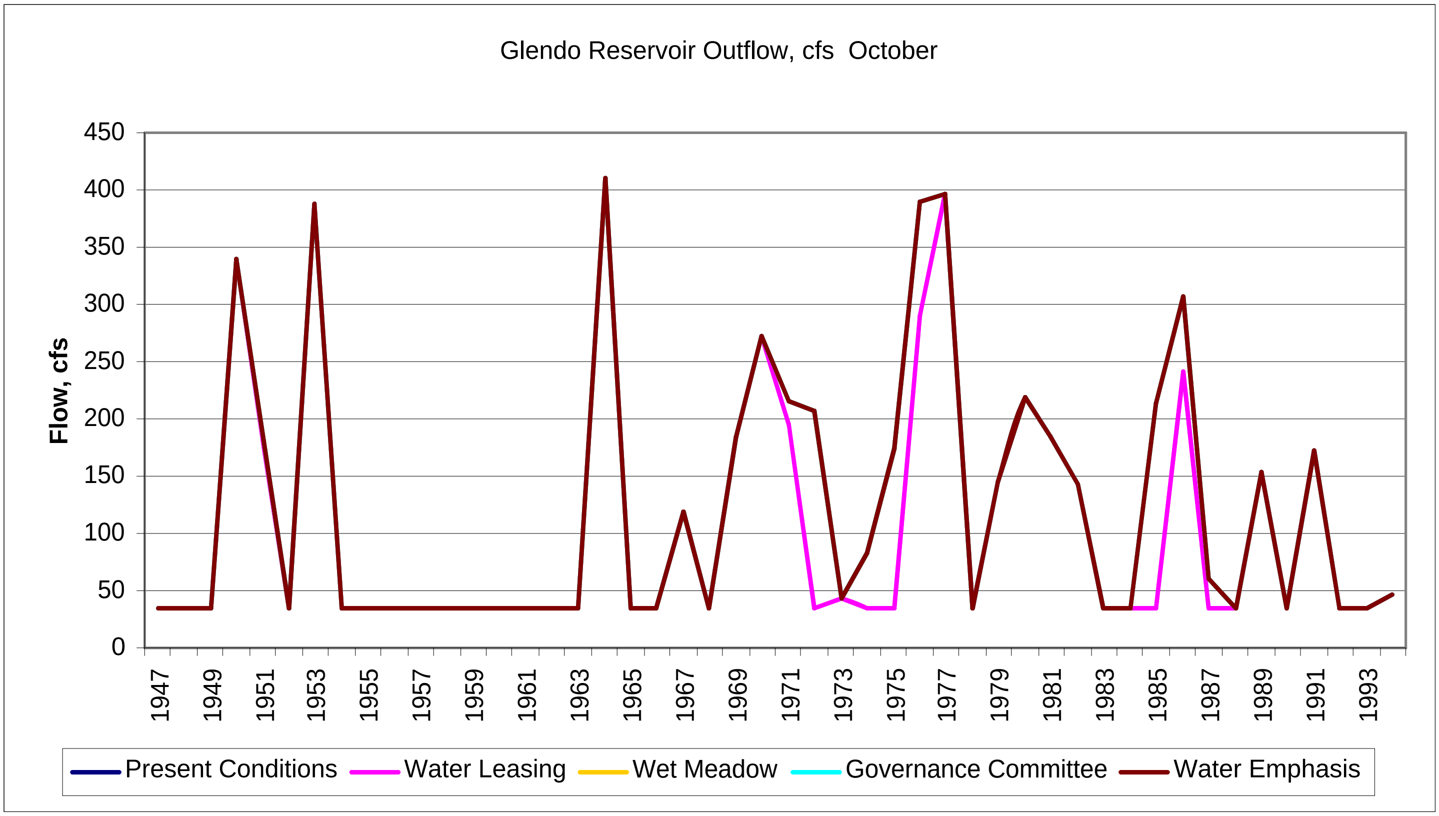
1981
1983
1985
1987
1989
1991
1993


Gray Reef Reservoir Outflow, cfs June
Flow, cfs
12000
10000
8000
6000
4000
2000
0
1947
1949
1951
1953
1955
1957
1959
1961
1963
1965
1967
1969
1971
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
Present Conditions
Water Leasing
Wet Meadow
Governance Committee
Water Emphasis

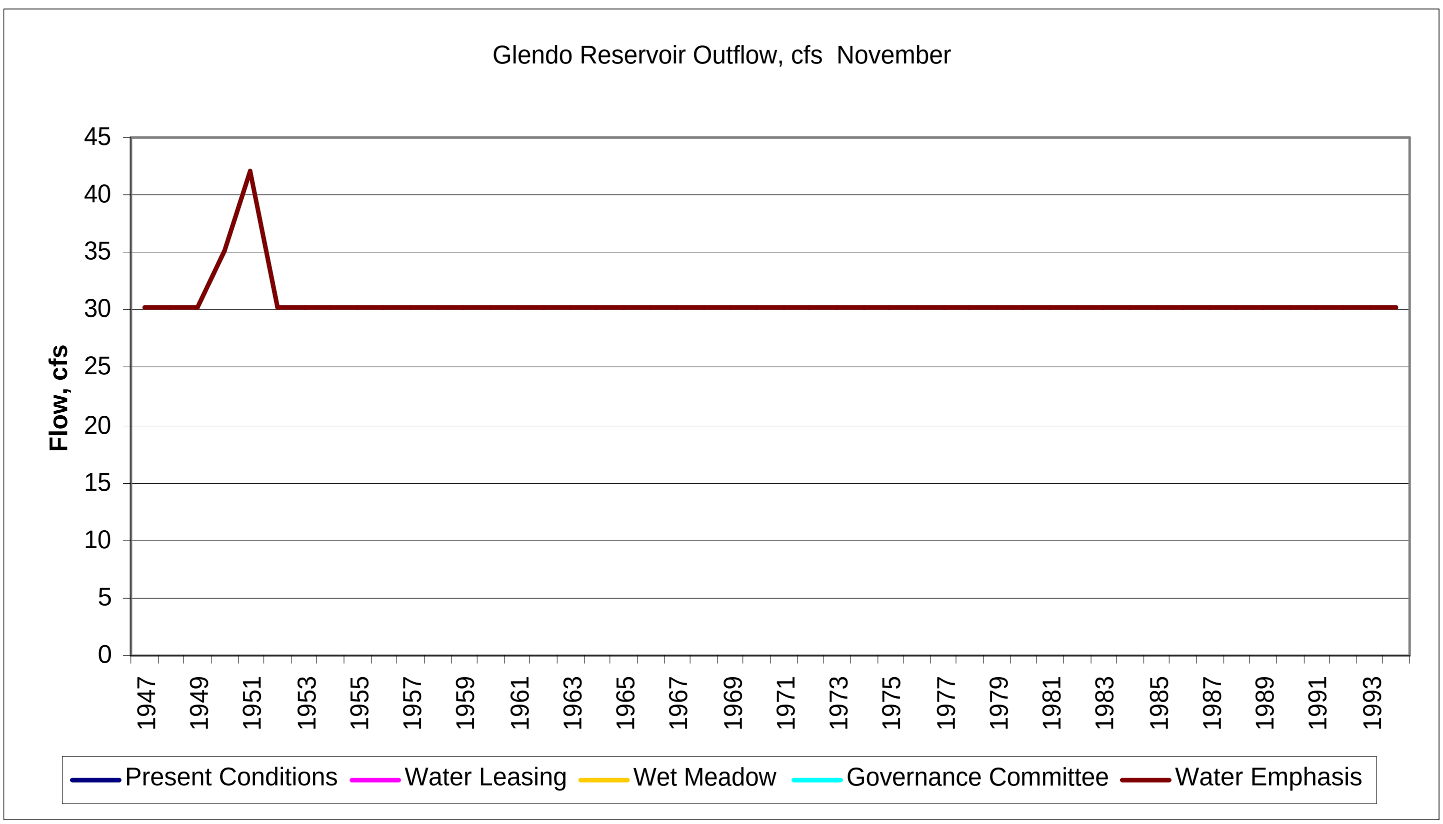

Gray Reef Reservoir Outflow, cfs July
Flow, cfs
7000
6000
5000
4000
3000
2000
1000
0
1947
1949
1951
1953
1955
1957
1959
1961
1963
1965
1967
1969
1971
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993

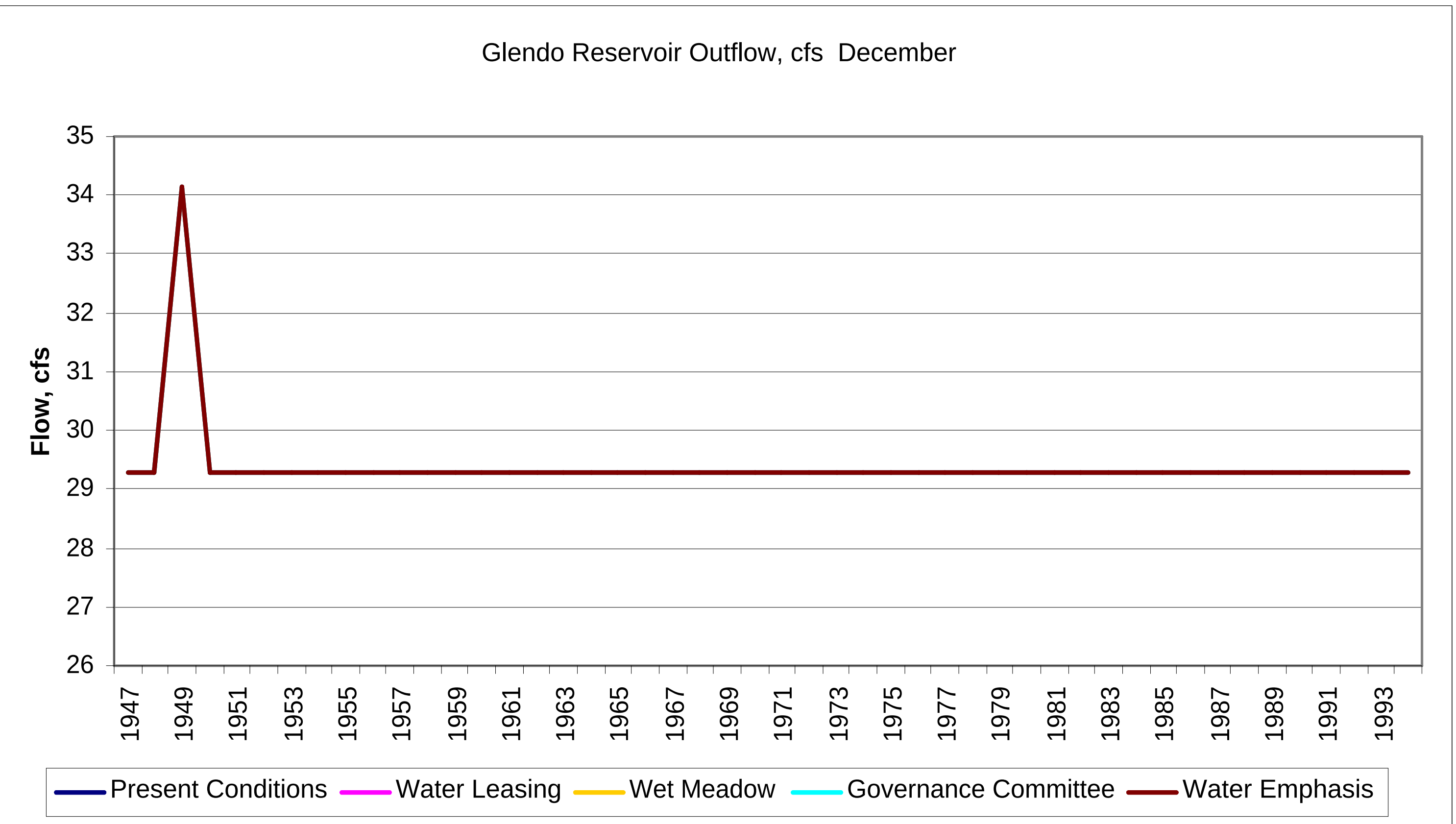

Gray Reef Reservoir Outflow, cfs August
Flow, cfs
6000
5000
4000
3000
2000
1000
0
1947
1949
1951
1953
1955
1957
1959
1961
1963
1965
1967
1969
1971
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
Present Conditions
Water Leasing
Wet Meadow
Governance Committee
Water Emphasis


Gray Reef Reservoir Outflow, cfs September
Flow, cfs
4000
3500
3000
2500
2000
1500
1000
500
0
1947
1949
1951
1953
1955
1957
1959
1961
1963
1965
1967
1969
1971
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993

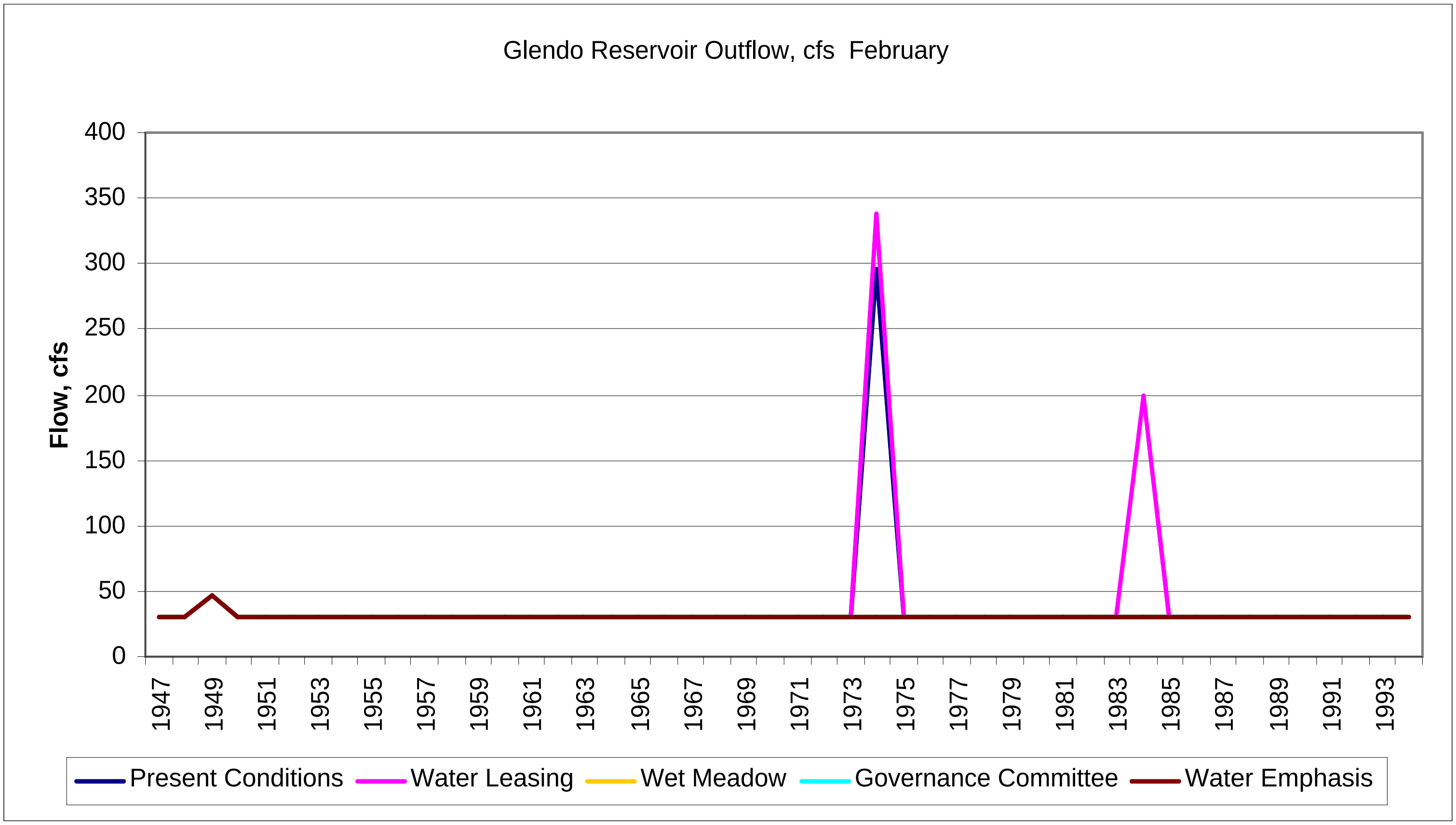


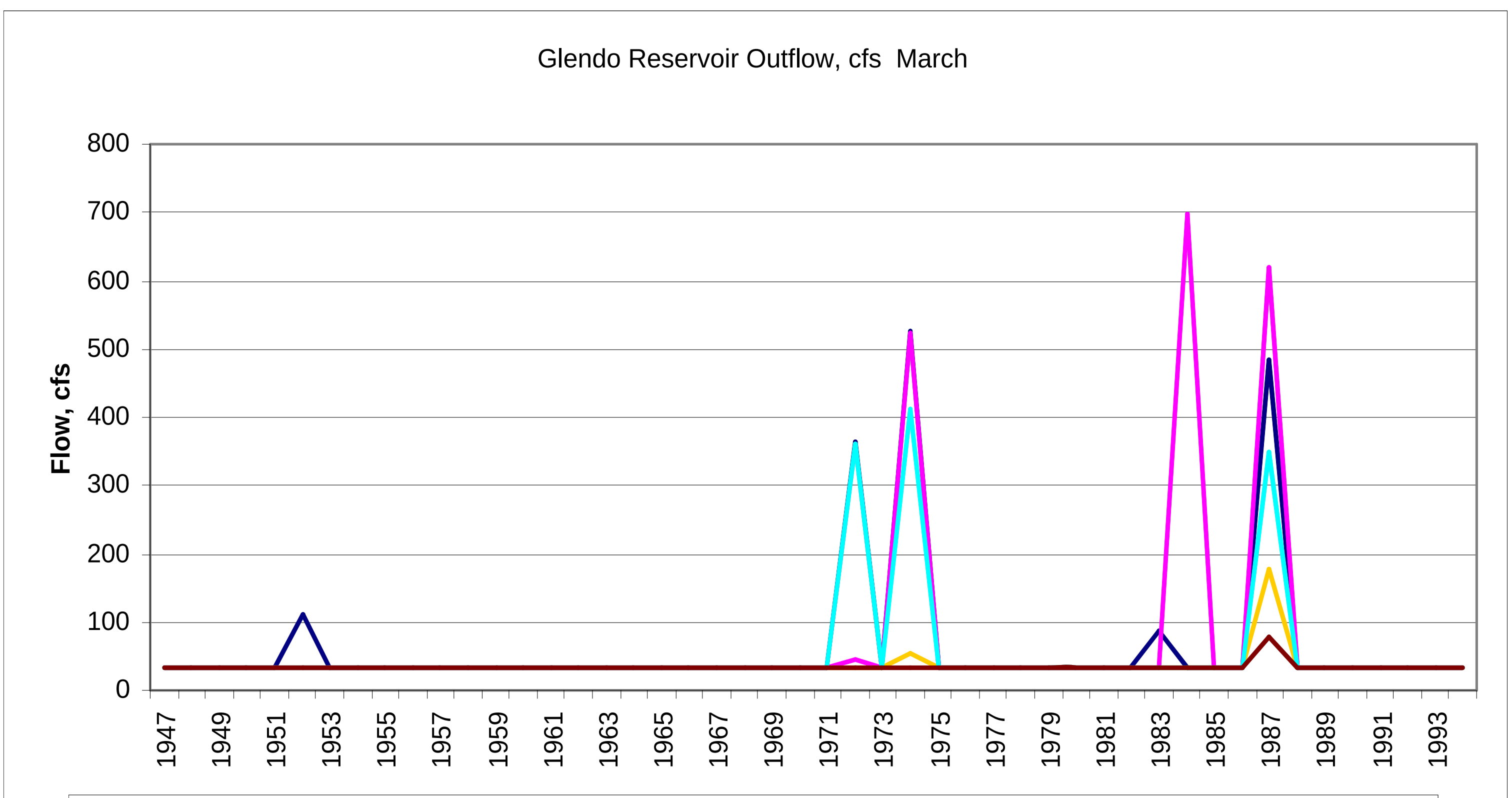
Glendo Reservoir Outflow

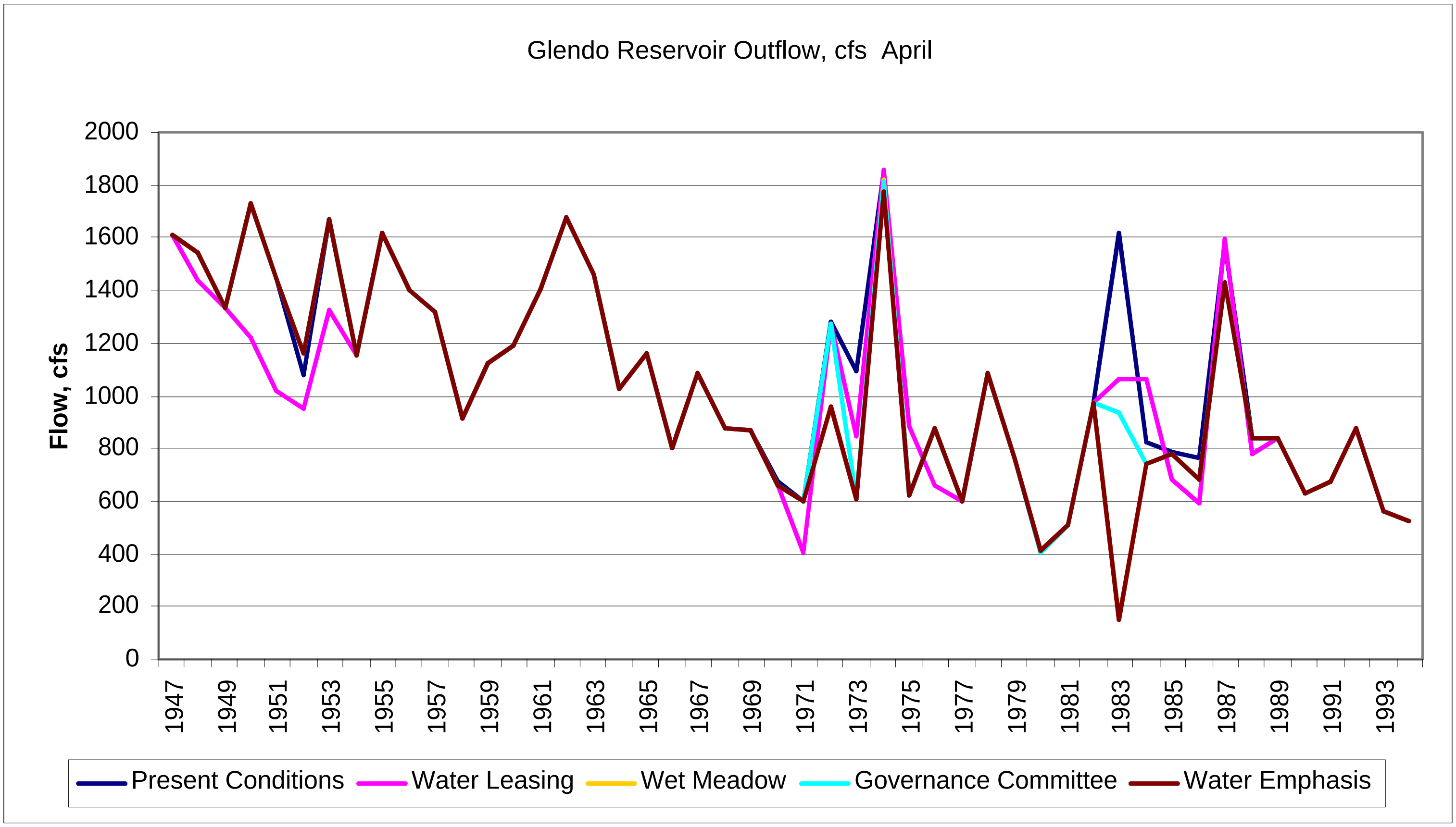



Glendo Reservoir Outflow, cfs December
Flow, cfs
35
34
33
32
31
30
29
28
27
26
1947
1949
1951
1953
1955
1957
1959
1961
1963
1965
1967
1969
1971
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
Present Conditions
Water Leasing
Wet Meadow
Governance Committee
Water Emphasis


Glendo Reservoir Outflow, cfs January
Flow, cfs
60
50
40
30
20
10


Glendo Reservoir Outflow, cfs February
Flow, cfs
400
350
300
250
200
150
100
50
0
1947
1949
1951
1953
1955
1957
1959
1961
1963
1965
1967
1969
1971
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
Present Conditions
Water Leasing
Wet Meadow
Governance Committee
Water Emphasis


Glendo Reservoir Outflow, cfs March
Flow, cfs
800
700
600
500
400
300
200
100
0
1947
1949
1951
1953
1955
1957
1959
1961
1963
1965
1967
1969
1971
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993


Glendo Reservoir Outflow, cfs April
Flow, cfs
2000
1800
1600
1400
1200
1000
800
600
400
200
0
1947
1949
1951
1953
1955
1957
1959
1961
1963
1965
1967
1969
1971
1973
1975
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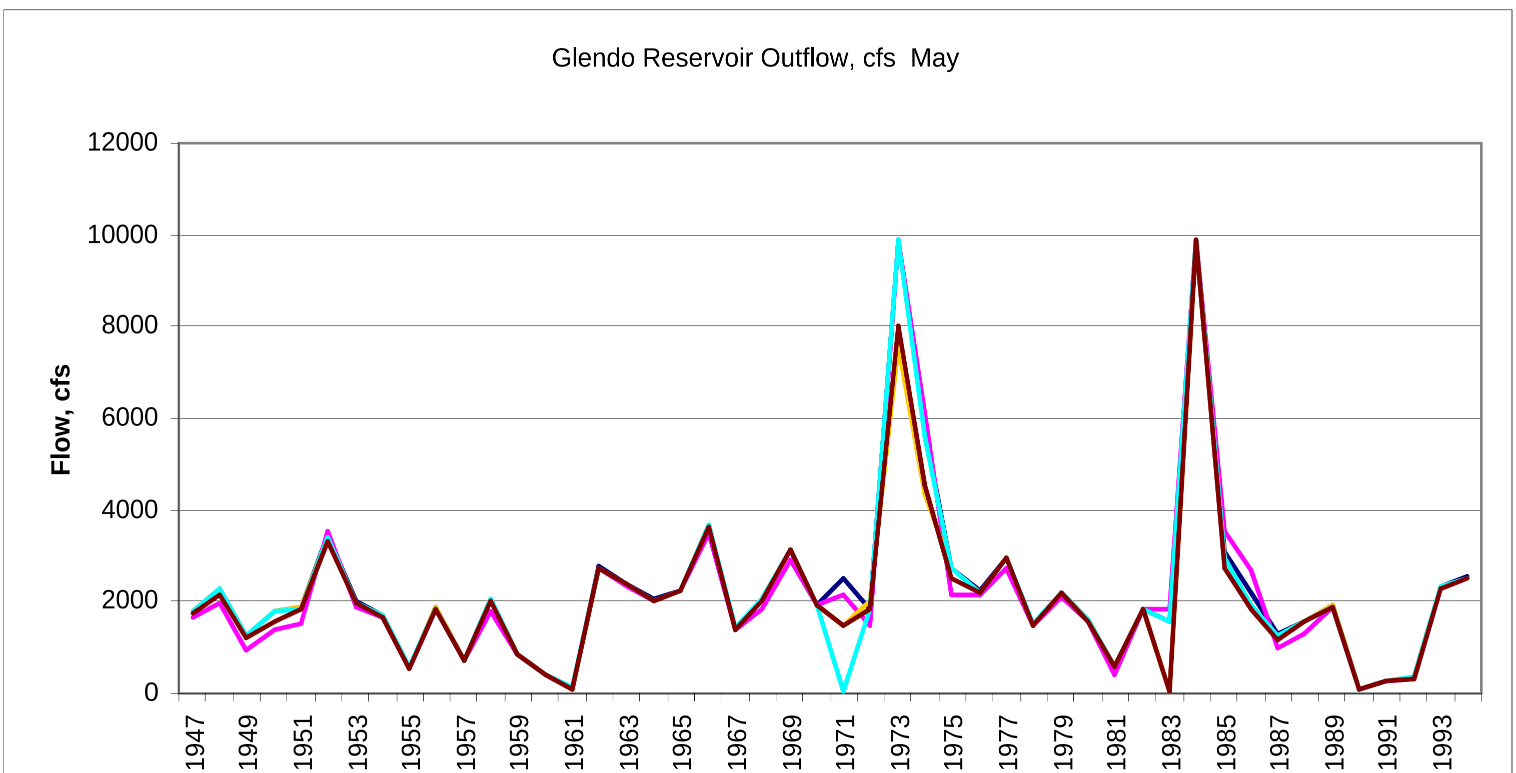
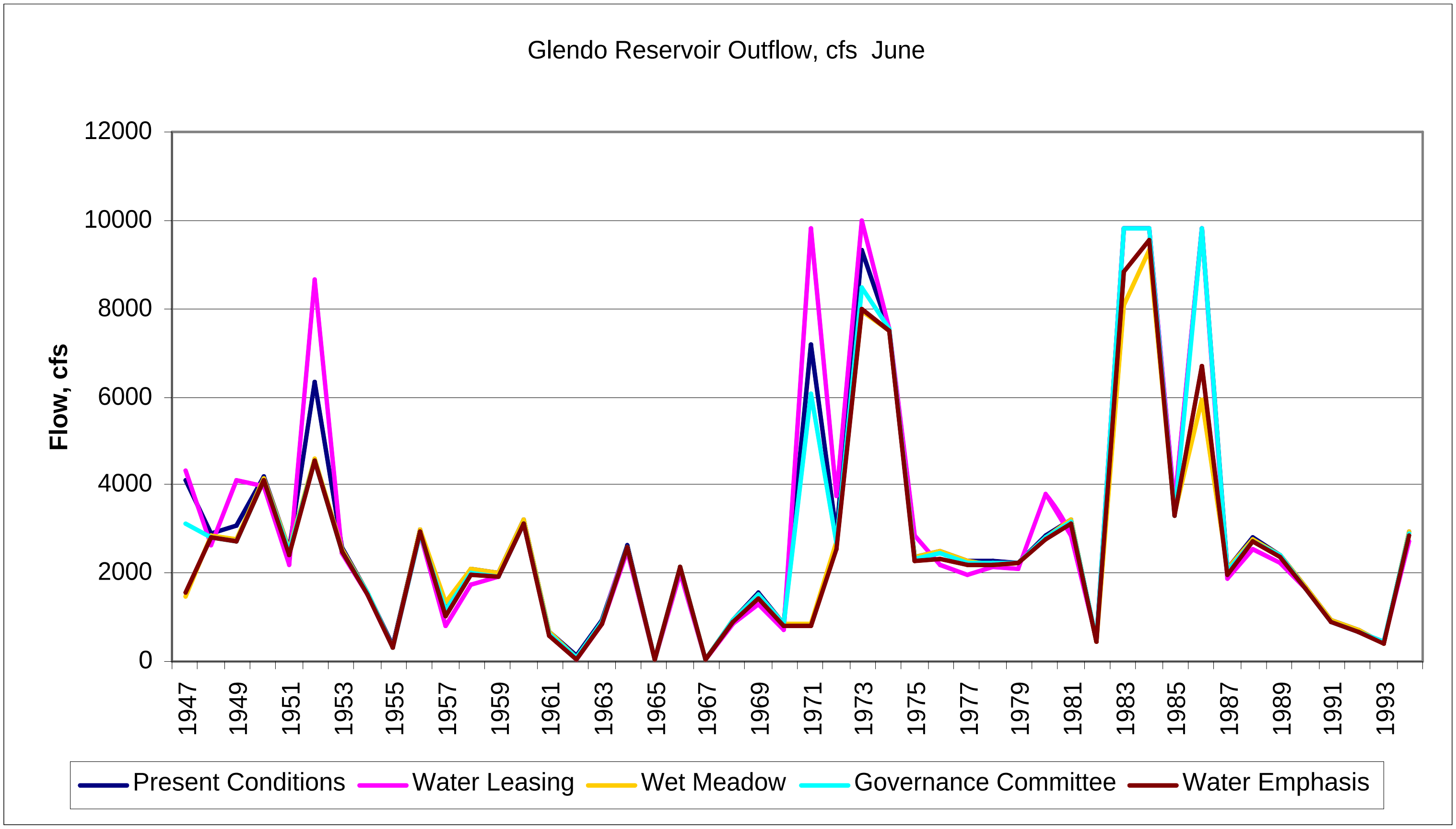
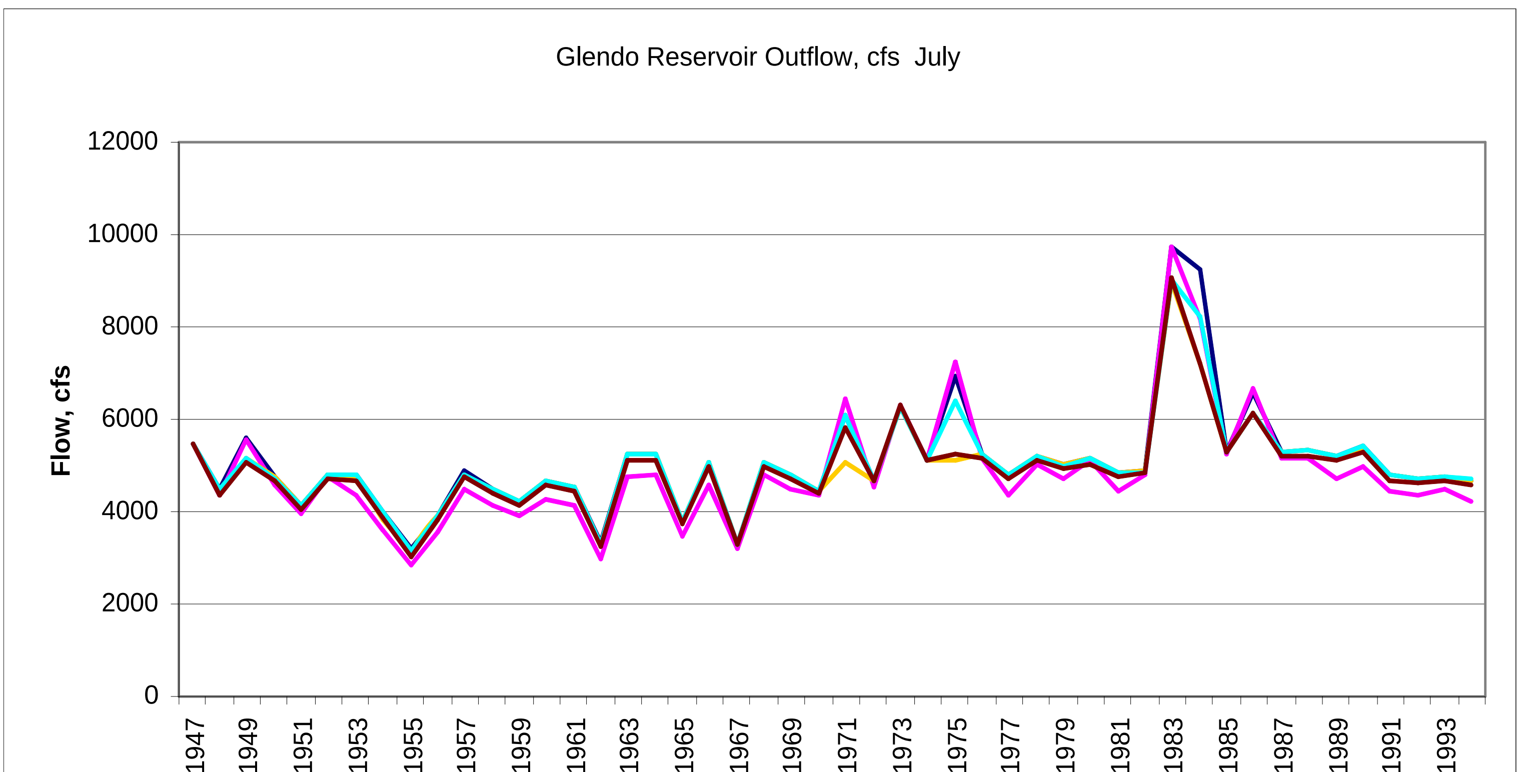
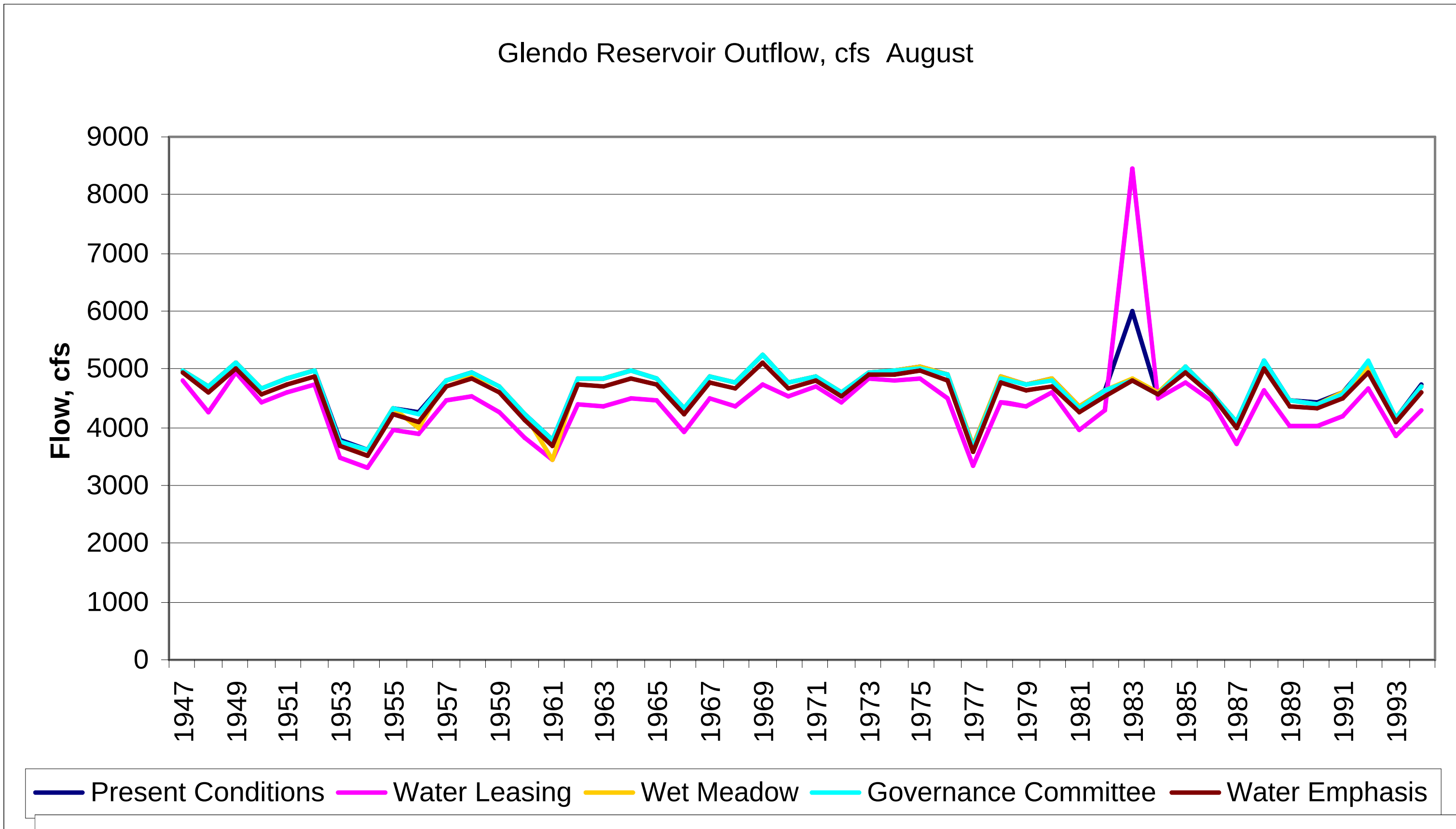
1979
1981
1983
1985
1987
1989
1991
1993
Present Conditions
Water Leasing
Wet Meadow
Governance Committee
Water Emphasis


Glendo Reservoir Outflow, cfs May
Flow, cfs
12000
10000
8000
6000
4000
2000
0
1947
1949
1951
1953
1955
1957
1959
1961
1963
1965
1967
1969
1971
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993


Glendo Reservoir Outflow, cfs June
Flow, cfs
12000
10000
8000
6000
4000
2000
0
1947
1949
1951
1953
1955
1957
1959
1961
1963
1965
1967
1969
1971
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
Present Conditions
Water Leasing
Wet Meadow
Governance Committee
Water Emphasis


Glendo Reservoir Outflow, cfs July
Flow, cfs
12000
10000
8000
6000
4000
2000
0
1947
1949
1951
1953
1955
1957
1959
1961
1963
1965
1967
1969
1971
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993


Glendo Reservoir Outflow, cfs August
Flow, cfs
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
1947
1949
1951
1953
1955
1957
1959
1961
1963
1965
1967
1969
1971
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1983
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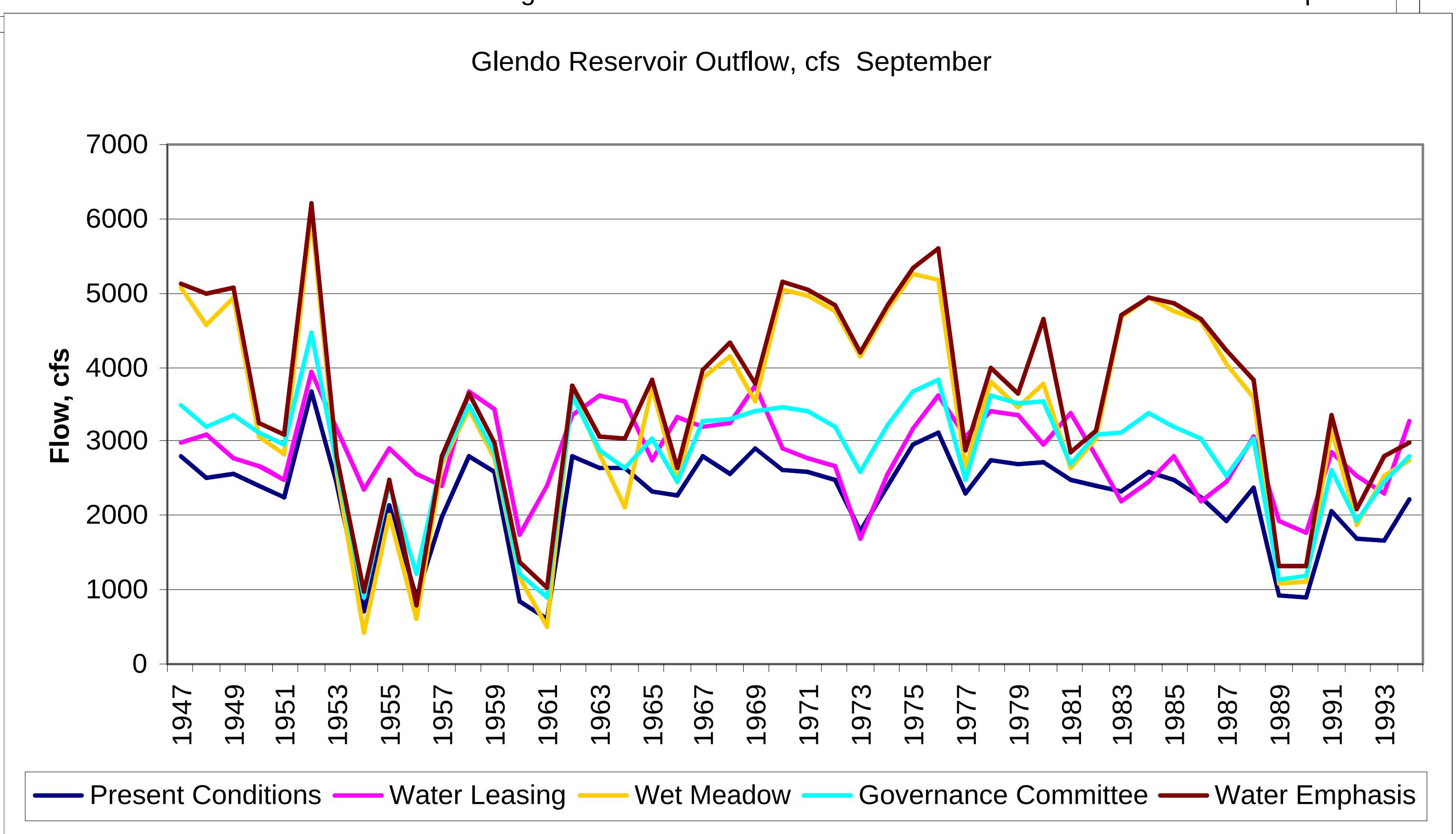
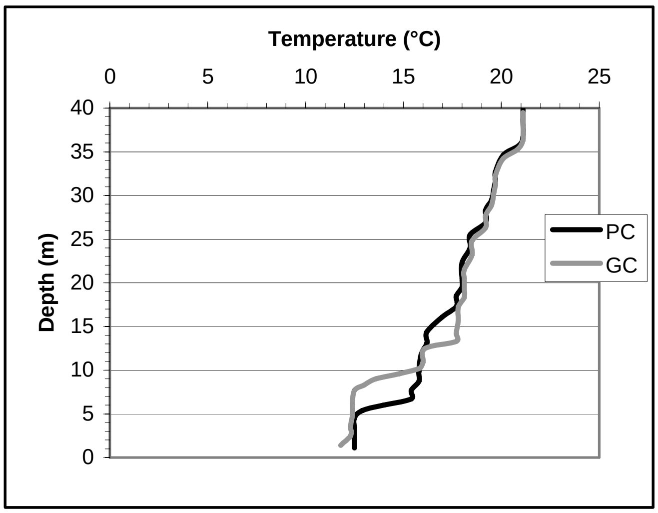
1987
1989
1991
1993
Present Conditions
Water Leasing
Wet Meadow
Governance Committee
Water Emphasis

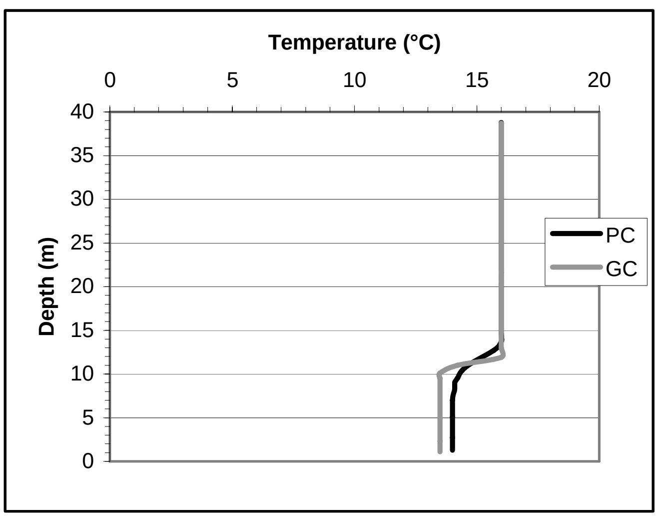

Glendo Reservoir Outflow, cfs September
Flow, cfs
7000
6000
5000
4000
3000
2000
1000
0
1947
1949
1951
1953
1955
1957
1959
1961
1963
1965
1967
1969
1971
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
Present Conditions
Water Leasing
Wet Meadow
Governance Committee
Water Emphasis

Appendix B Pathfinder Reservoir Temperature Modeling Results

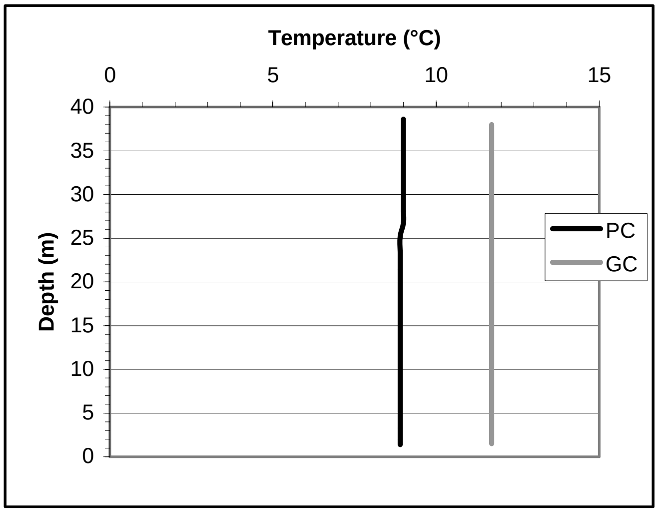
1. Governance Committee



August 4, 1977



September 15, 1977

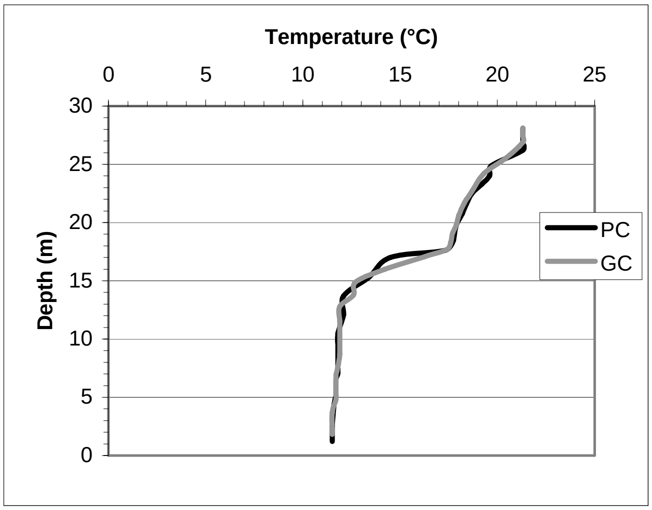


Onset of Isothermal Conditions

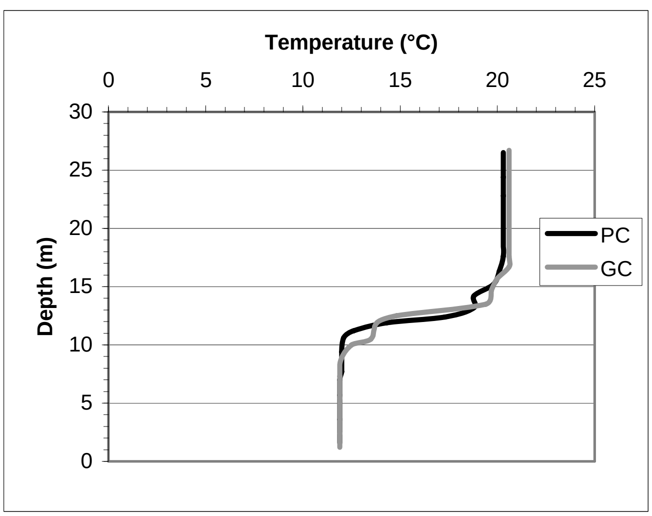
Alternative	Date	Alternative	Date
Present	27-Oct-77	GC Alt.	6-Oct-77

Alternatives Comparison – Critical Year 1961

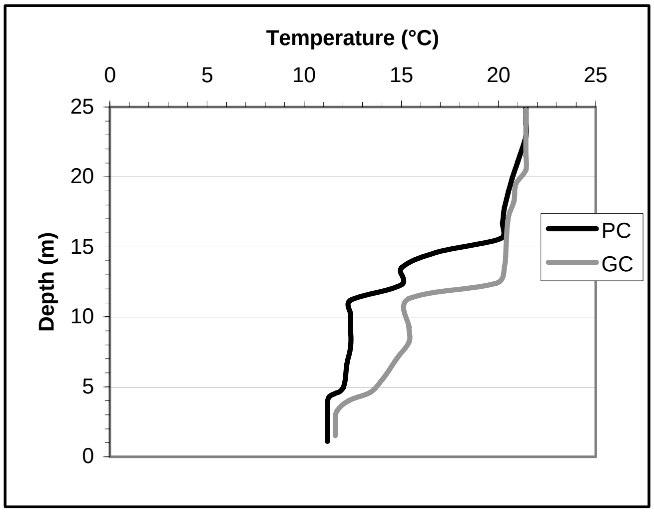
Reservoir drawn down to 31, 400 acre-feet in August and September



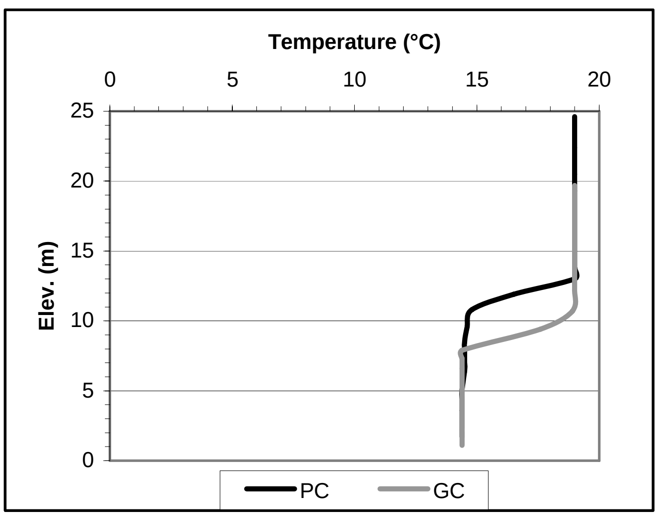
July 7, 1961



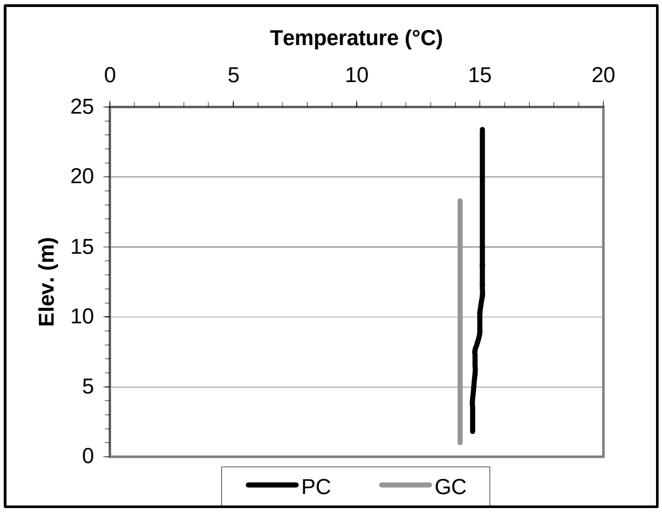
July 21, 1961



Warmest Surface Temperature – August 4, 1961



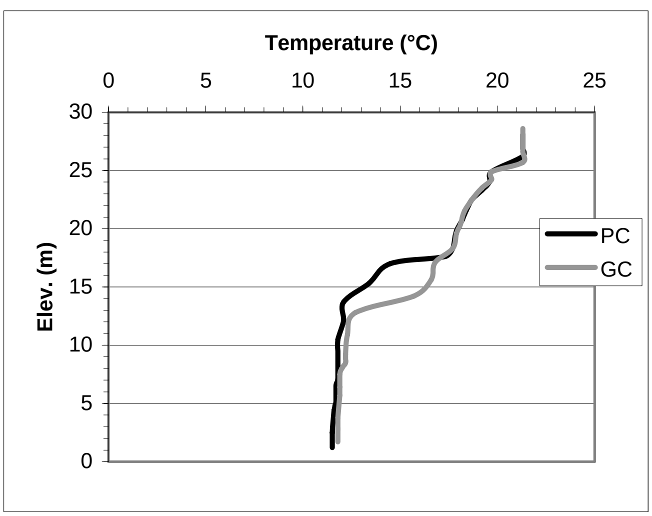
Deepening thermocline with GC Alt. due to greater withdrawal of cool water - August 25, 1961



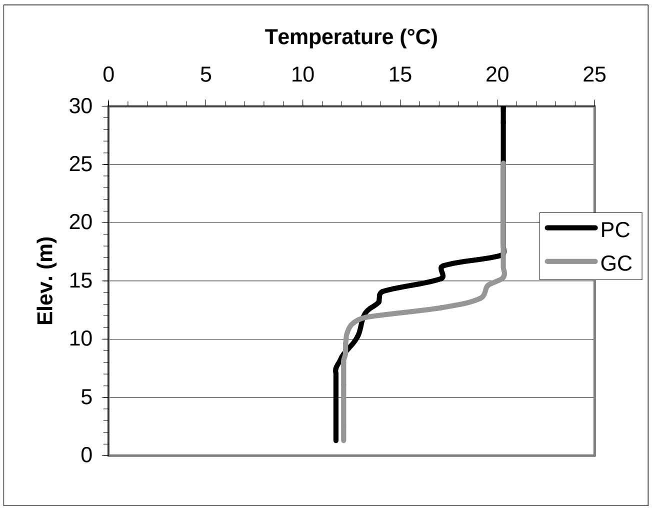
GC Alt. Isothermal Conditions – September 15, 1961

Alternatives Comparison – Critical Year 1964

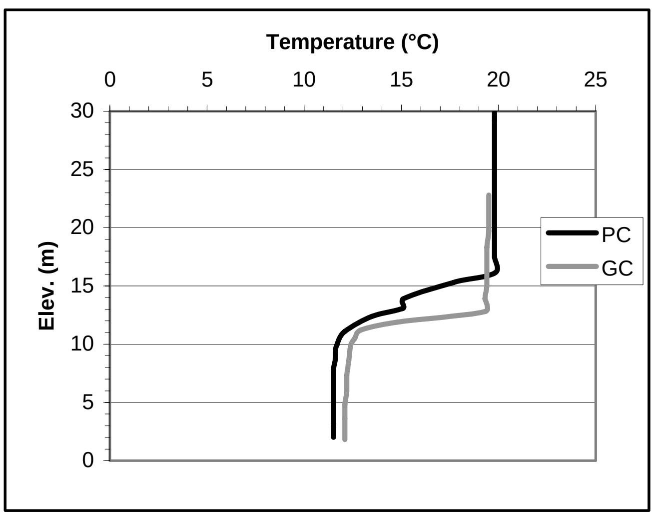
Reservoir drawn down to 31, 400 acre-feet in August and September



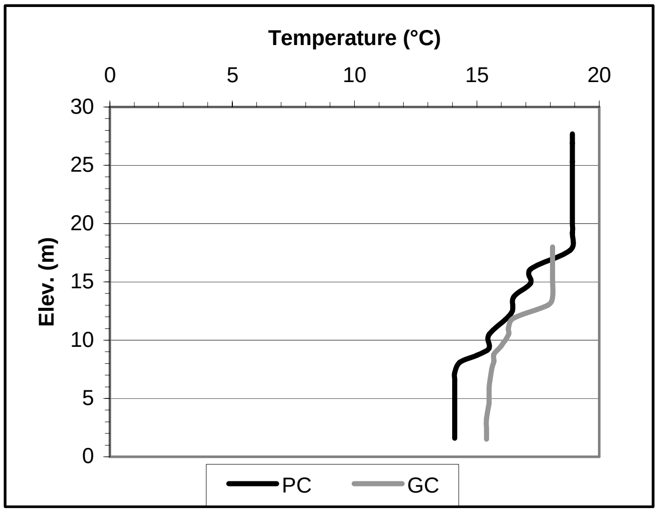
Warmest water surface – July 7, 1964



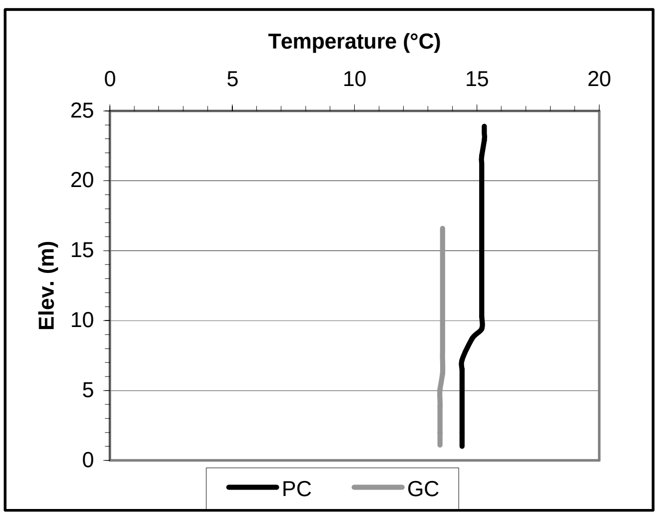
July 21, 1964



Strongest GC Alt. Stratification – July 28, 1964
7+ meters lower pool for GC Alt.



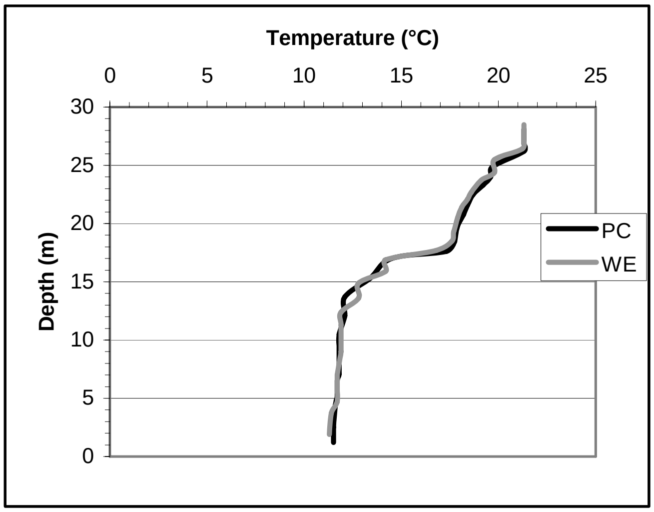
GC Alt. — 9+ meters lower pool on August 25, 1964



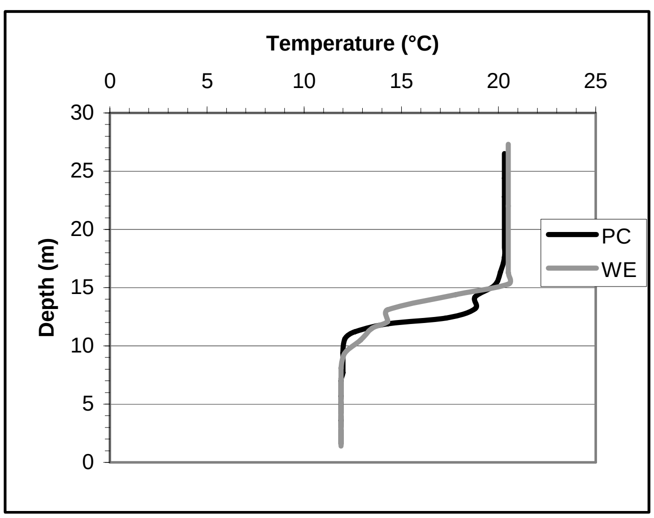
Minimum GC Alt. Reservoir Contents – September 15, 1964

2. Water Emphasis

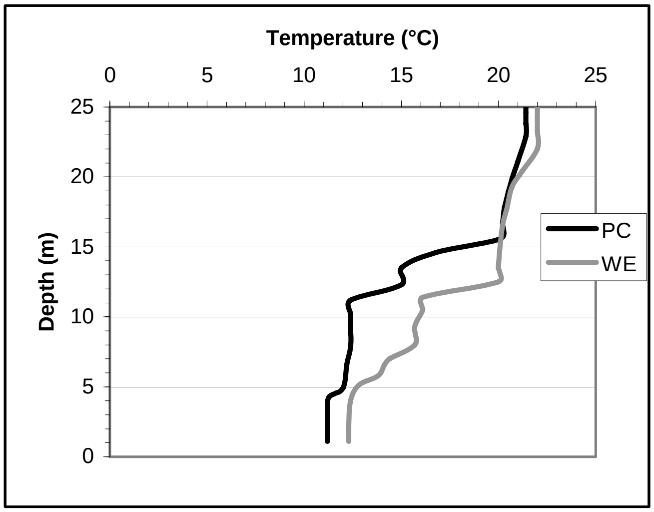
Alternatives Comparison – Critical Year 1961



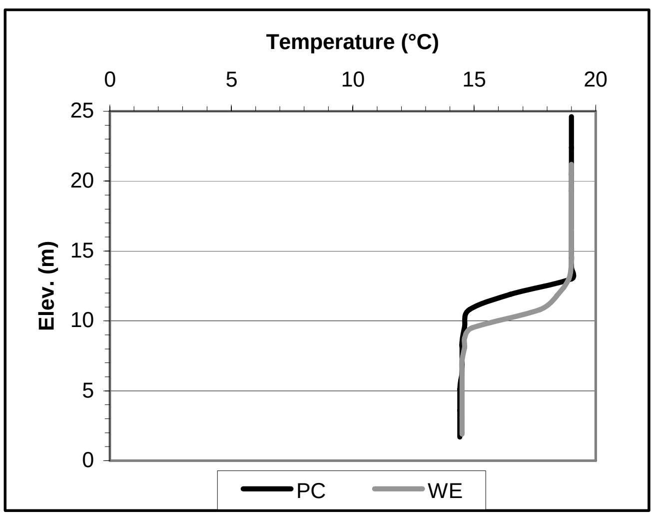
July 7, 1961



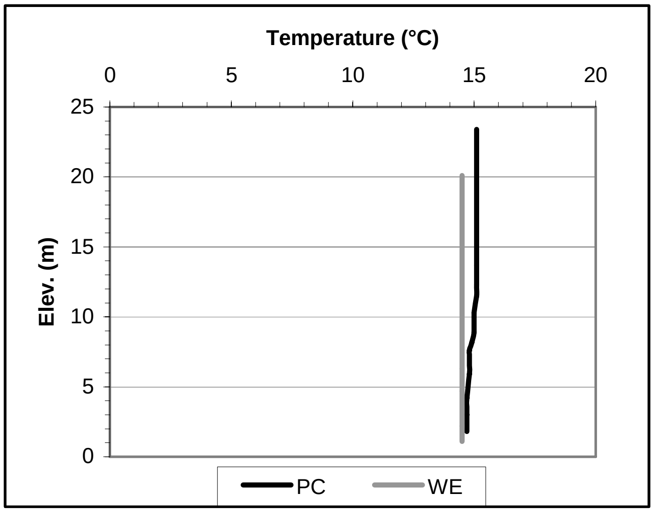
July 21, 1961



August 4, 1961

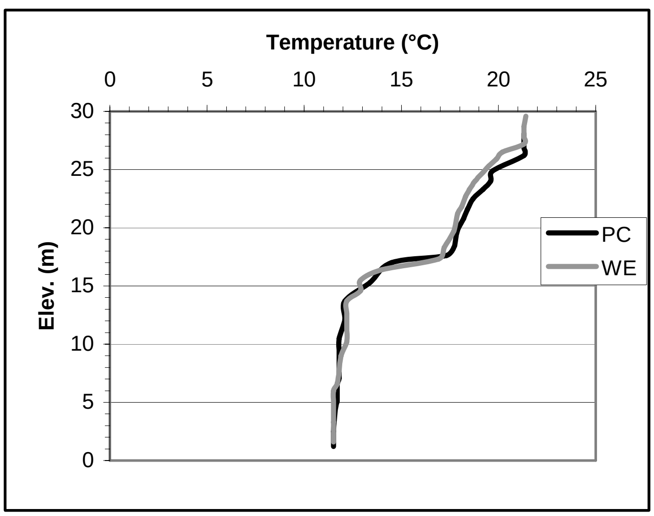


August 25, 1961

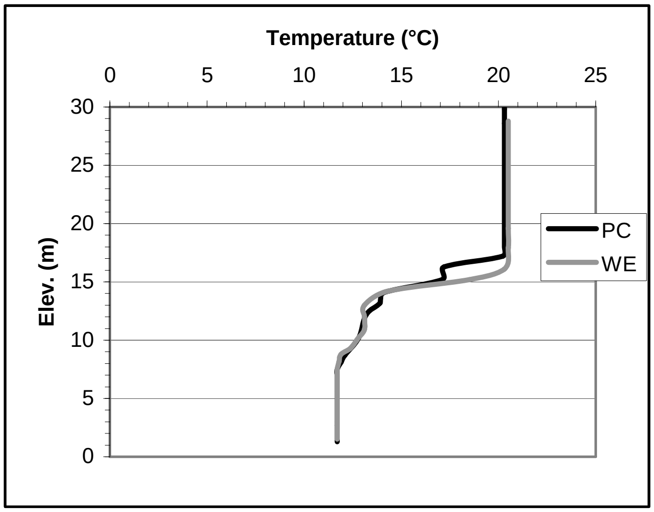


September 15, 1961 – Water Emphasis Alt. Isothermal Conditions

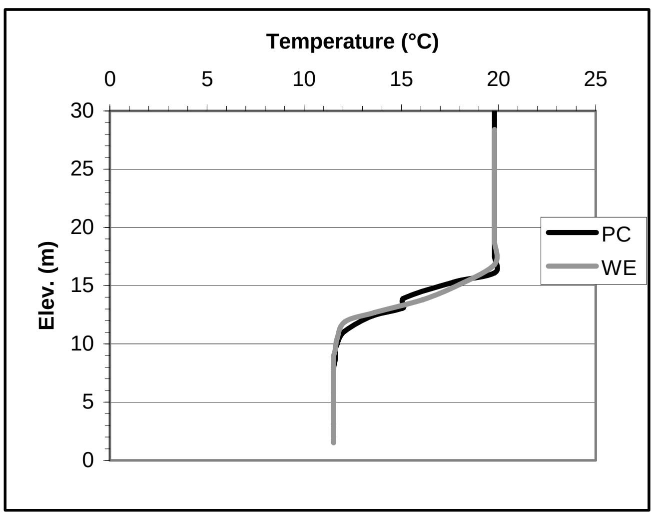
Alternatives Comparison – Critical Year 1964



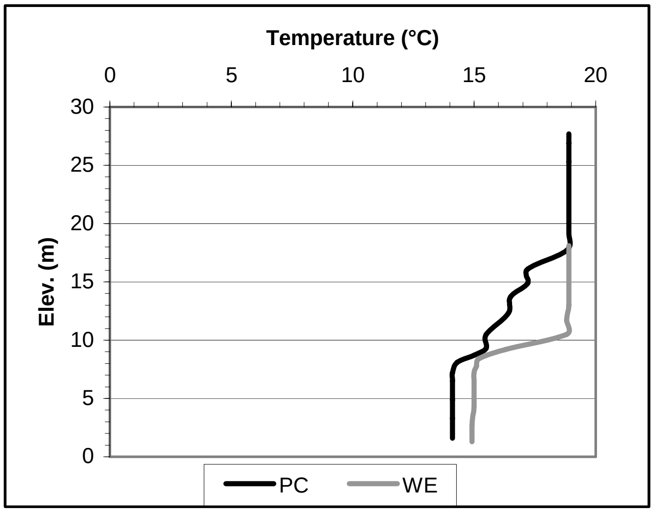
July 7, 1964



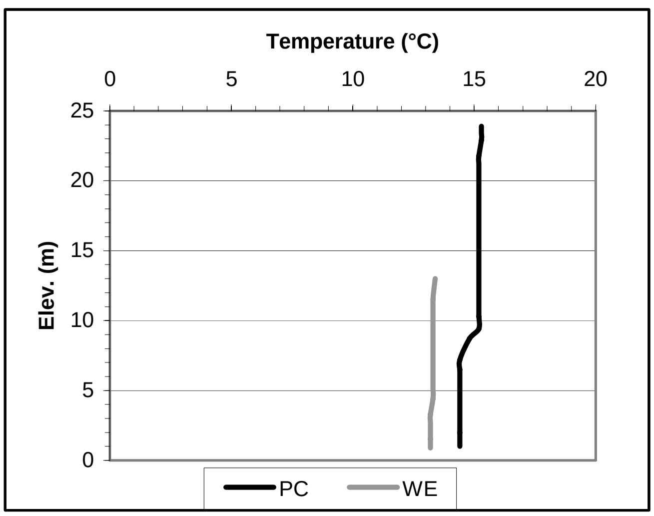
July 21, 1964



July 28, 1964



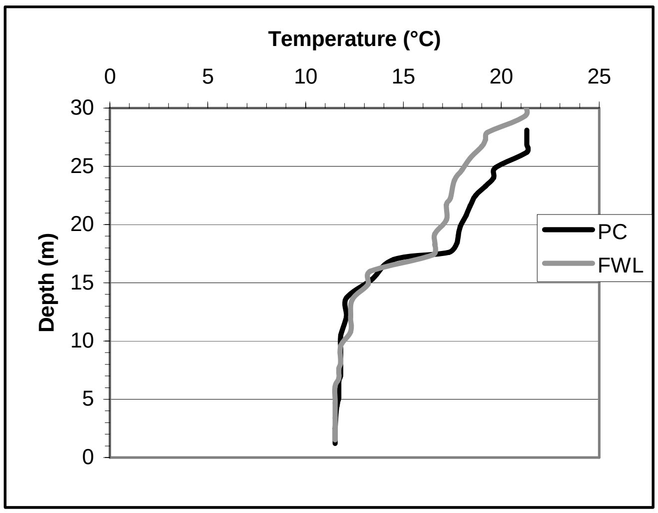
August 25, 1964 – nearly as much drawdown as GC Alt.



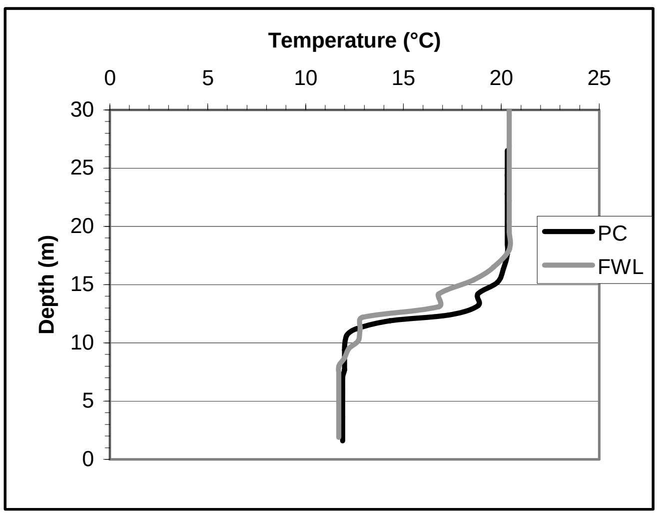
September 15, 1964 – minimum reservoir contents over 3 meters below GC Alt. pool level

3. Full Water Leasing

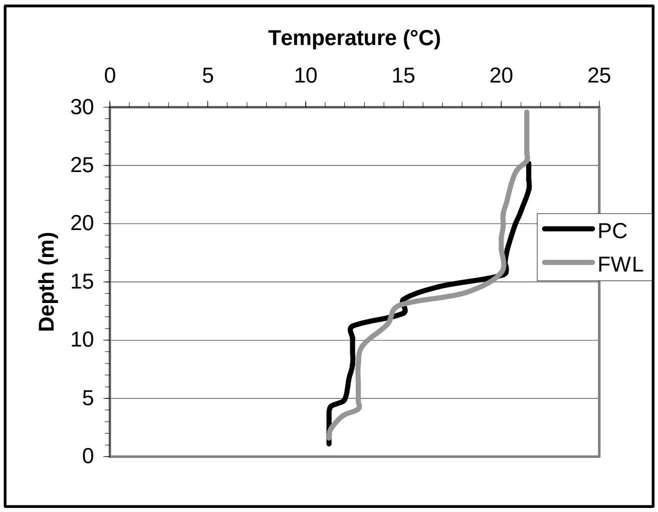
Alternatives Comparison – Critical Year 1961



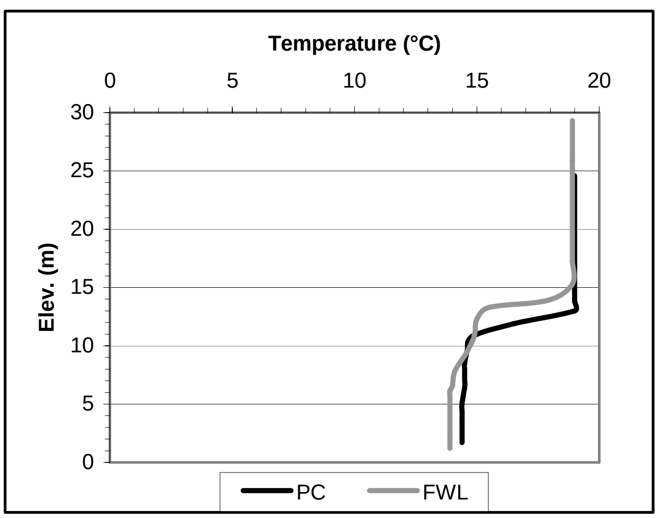
July 7, 1961



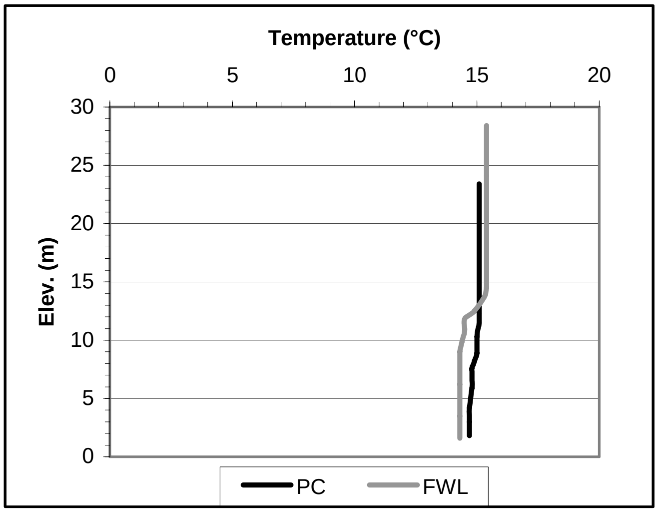
July 21, 1961



August 4, 1961

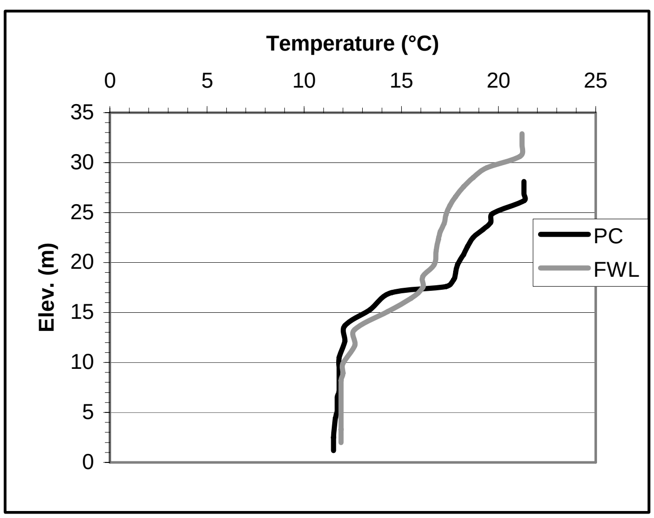


August 25, 1961

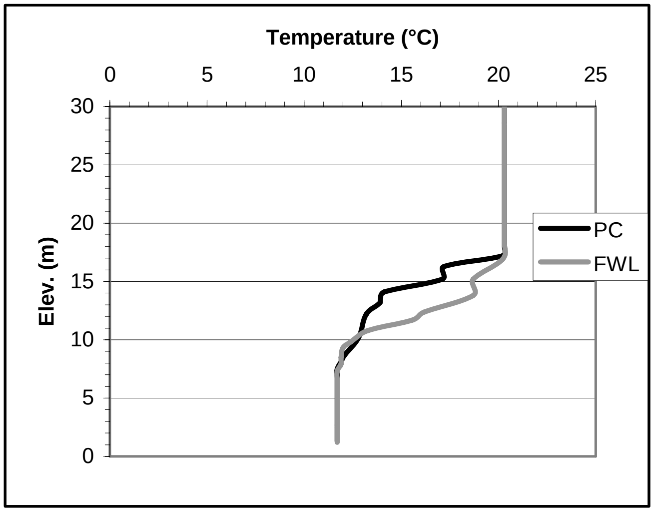


September 15,1961

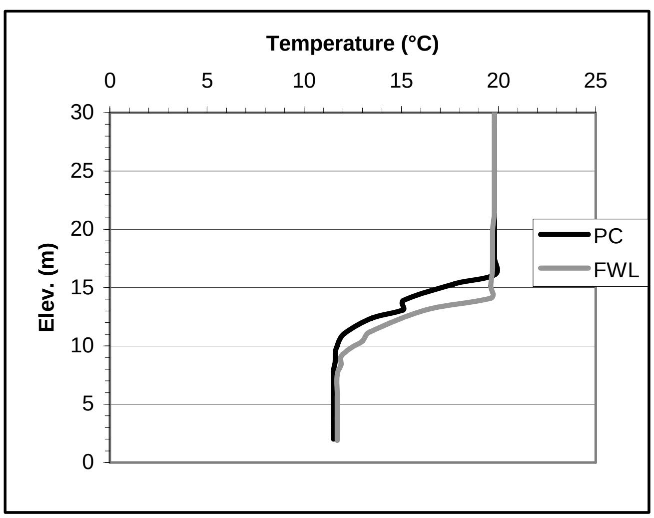
Alternatives Comparison – Critical Year 1964



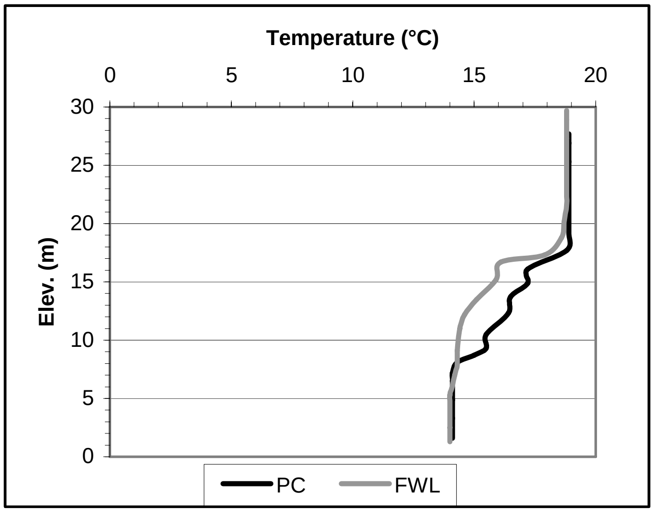
July 7, 1964



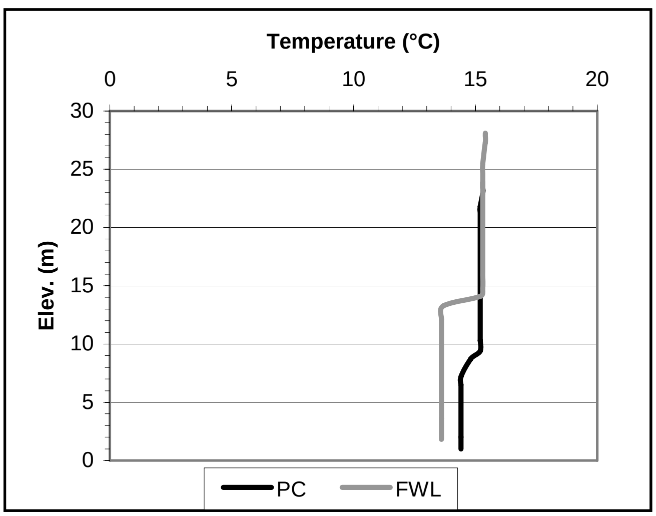
July 21, 1964



July 28, 1964



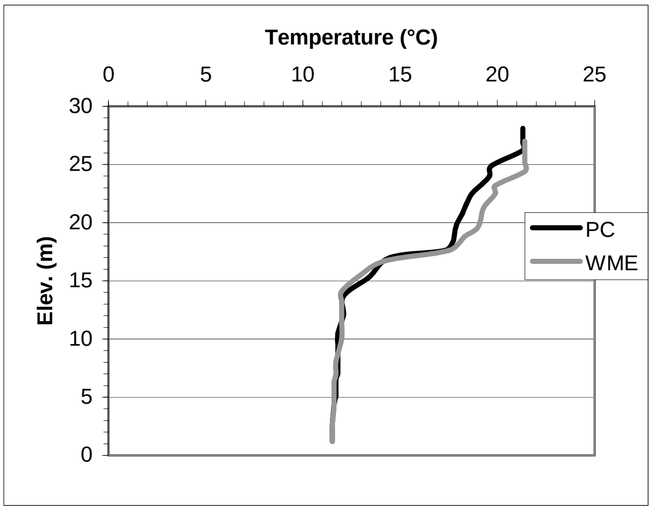
August 25, 1964



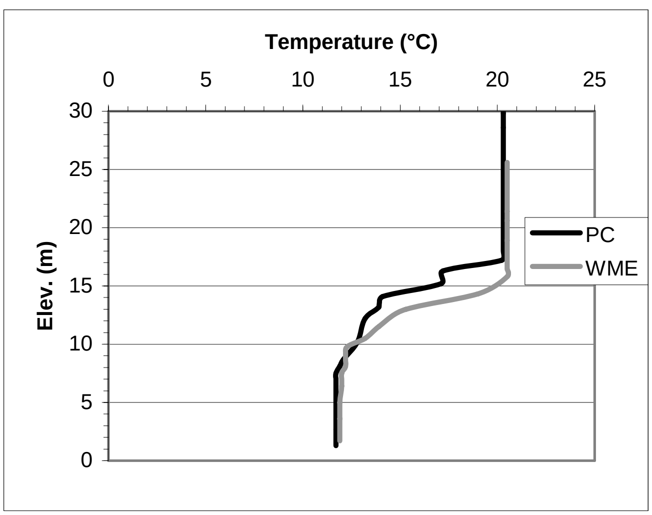
September 15, 1964

4. Wet Meadow Emphasis

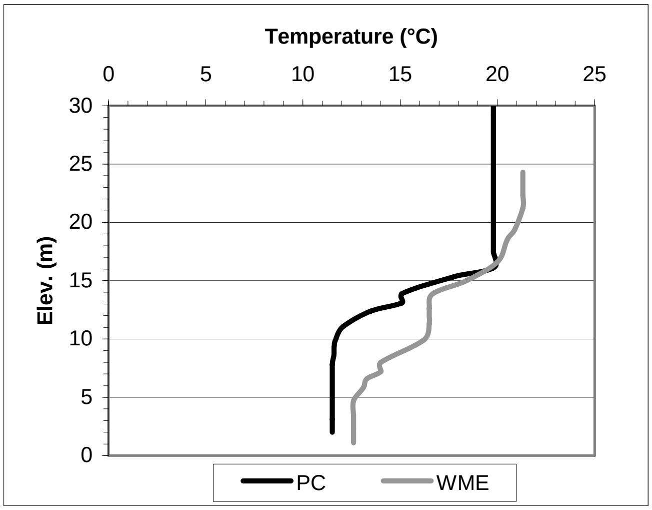
Alternatives Comparison – Critical Year 1961



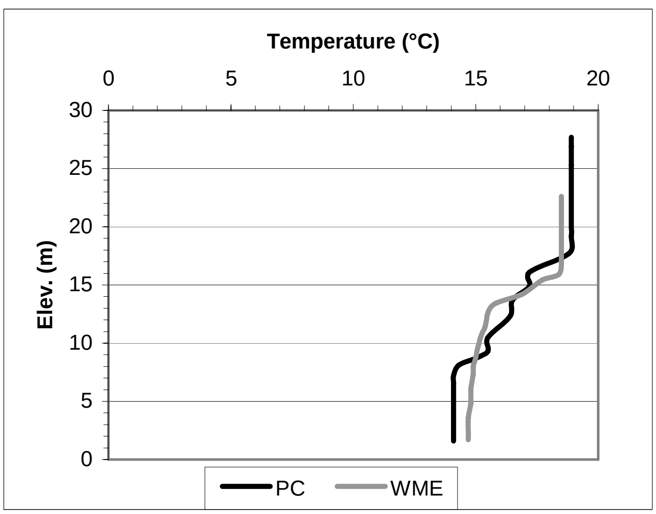
July 7, 1961



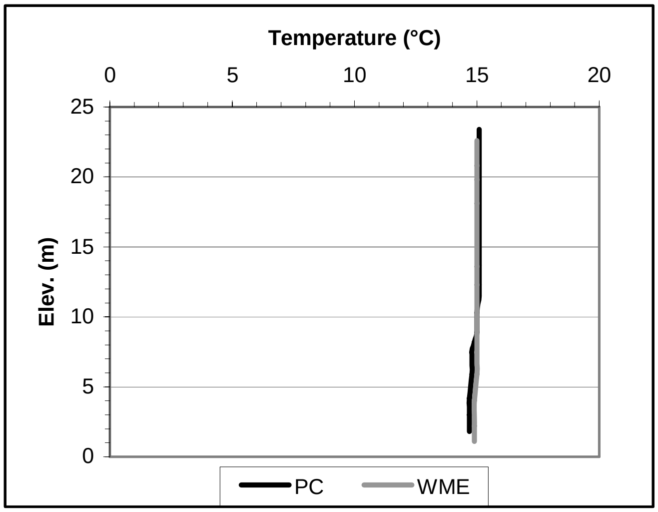
July 21, 1961



August 4, 1961

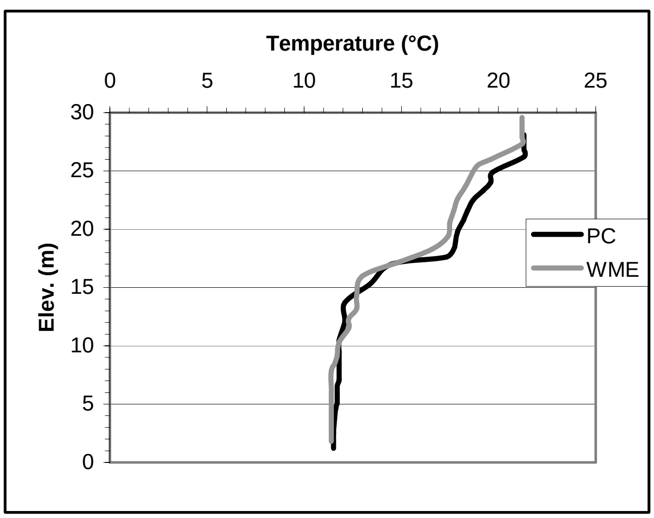


August 25, 1961

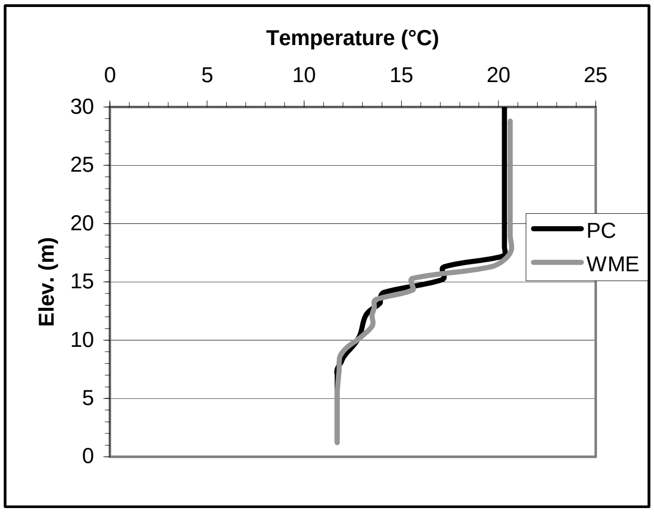


September 15, 1961

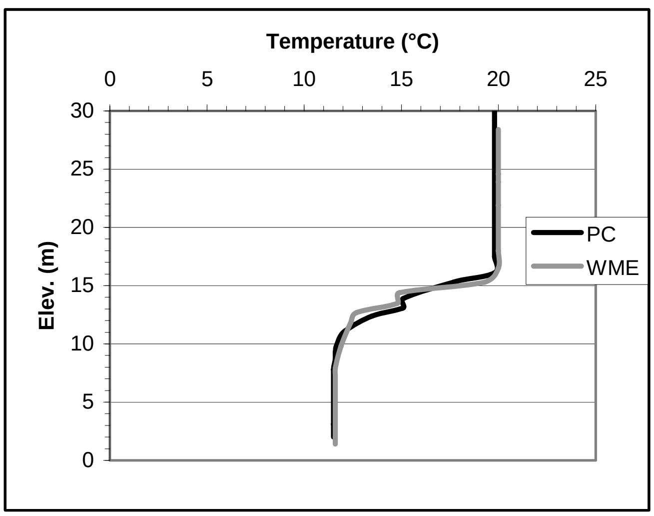
Alternatives Comparison – Critical Year 1964



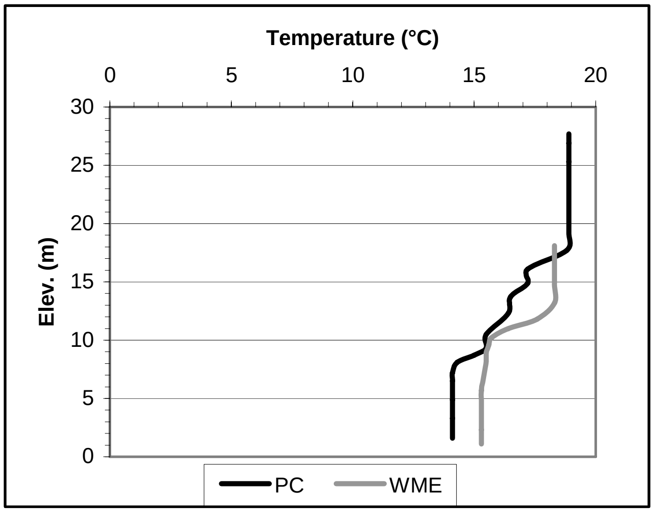
July 7, 1964



July 21, 1964



July 28, 1964



August 25, 1964