VII – CURRENT WATER CONTROL PLAN FOR THE SYSTEM

7-01. **System Water Control Plan.** In enacting the 1944 Flood Control Act, Congress adopted the recommendations contained in the underlying Pick-Sloan documents. These documents identified flood control, navigation, irrigation, hydropower, water supply, water quality, recreation, and fish and wildlife as project purposes and also provided for the protection of beneficial consumptive uses in the upper basin. Congress did not assign a priority to these purposes. Instead, it was contemplated that the Corps, in consultation with affected interests and other agencies, would balance these functions in order to obtain the optimum development and utilization of the water resources of the Missouri River basin to best serve the needs of the people. The Missouri River Master Water Control Manual Review and Update Study (Master Manual Study) was conducted without bias toward any project purpose. Therefore, no priority was assumed for any economic use or environmental resource in the conduct of that study. The result of the Master Manual Study has been the identification of the current Missouri River Mainstem Reservoir System Water Control Plan (CWCP) that is described in detail in this chapter. This chapter sets forth the detailed provisions of the selected water control plan for the System. In the event of any inconsistencies between the provisions of this Chapter VII and any other provisions of this Master Manual, this Chapter VII shall take precedence.

7-01.1. The CWCP presented in this Master Manual was developed with four objectives in mind: first, to serve the contemporary needs of the basin and the Nation; second, to serve the Congressionally authorized project purposes; third to comply with other applicable statutory and regulatory requirements including environmental laws such as the Endangered Species Act (ESA); and fourth, to fulfill the Corps' responsibilities to Federally recognized Tribes. The application of the water control plan presented in this Master Manual is designed to meet certain operational objectives during drought, flood and normal runoff periods. Many assumptions were necessary in order to effectively analyze the effects of the application of this water control plan. If these assumptions are no longer valid in the future due to changed conditions or unforeseen circumstances, the Corps will adjust the water control plan presented in this Master Manual in an attempt to continue to meet the intended operational objectives. The following paragraphs describe how the water control plan will meet the operational objectives of this Master Manual for each of the Congressionally authorized project purposes. The CWCP described in this chapter meets the objective of serving all of the Congressionally authorized project purposes of the System while considering the other short and long-term factors affecting the regulation of the System. Optimizing service to all of the Congressionally authorized purposes may be impossible at times because of conflicts between the individual authorized purposes. Therefore, optimization of benefits to individual project purposes will be pursued to the extent reasonably possible.

7-01.2. **Regulation Objectives.** As an introduction to a discussion on regulation objectives of the CWCP, the need to conform to certain basic water-in-storage provisions and basic principles of reservoir regulation of the System should be recognized, except in unusual circumstances. The Permanent Pool Zones of the System reservoirs are intended to remain permanently filled with water. This will ensure the maintenance of minimum power heads, minimum irrigation diversion levels, and minimum reservoir elevations for the water supply, recreation, and fish and wildlife purposes. Similarly, the Exclusive Flood Control Zones at the projects are provided for the regulation of the largest of floods. They will be reserved exclusively for this purpose and generally be empty. The two other storage zones that are intermediate to the Permanent Pool and the Exclusive Flood Control Zones provide active storage for project purposes. These storage zones are called the Annual Flood Control and Multiple Use and the Carryover Multiple Use Zones. These also provide storage space for the control of moderate floods and, when combined with the upper Exclusive Flood Control Zone, provide control of major floods.

7-02. **System Regulation Summary.** System regulation is, in many ways, a repetitive annual cycle. The melting of plains and mountain snow produces most of the year's runoff into the System, and spring and summer rains supplement that runoff. After reaching a peak, usually during July, the amount of water stored in the System declines until late in the winter when the cycle begins anew. A similar pattern may be found in rates of releases from the System, with the higher levels of flow from mid-March to late November, followed by low rates of winter discharge from late November until mid-March, after which the cycle repeats. The Water Control Calendar of Events, shown on Plate VII-1, presents the time sequence of many of these cyclic events.

7-02.1. Variations in runoff into the System necessitates the varied regulation plans to accommodate the multipurpose regulation objectives. The two primary high-risk flood seasons are the plains snowmelt and rainfall season extending from late February through April and the mountain snowmelt and rainfall period extending from May through July. Also, the winter ice-jam flood period extends from mid-December through February. The highest average power generation period extends from mid-April to mid-October, with high peaking loads during the winter heating season (mid-December to mid-February) and the summer air conditioning season (mid-June to mid-August). The power needs during the winter are supplied primarily with Fort Peck Dam and Garrison Dam releases and the peaking capacity of Oahe and Big Bend. During the spring and summer period, releases are normally geared to navigation and flood control requirements, and primary power loads are supplied using the four lower dams. During the fall when power needs diminish, Fort Randall is normally drawn down to permit generation during the winter period when Oahe and Big Bend peaking-power releases refill the reservoir. The major maintenance periods for the System hydropower facilities extend from March through mid-May and September through November, which normally are the lower demand and off-peak energy periods. The exception is Gavins Point, where maintenance is performed after the end of the navigation season because all three power units are normally required to provide for navigation and other downstream flow support needs. The normal 8-month navigation season extends from April 1 through December 1, during which time System releases are increased to meet downstream target flows in combination with downstream tributary inflows. Winter releases after the close of the navigation season are much lower and vary depending on the need to conserve or evacuate System storage volumes, downstream ice conditions permitting. Minimum release restrictions and pool fluctuations for fish spawning management generally occur from April 1 through July. Endangered species nesting occurs from early May through mid-August. Other factors may vary widely from year to year, such as the amount of water-in-storage and the magnitude and distribution of inflow received during the coming year. All of these factors will affect the timing and magnitude of project releases. The gain or loss in the water stored at each reservoir must also be considered in scheduling the amount of water transferred between reservoirs to achieve the desired storage levels and to generate power.

These items are continually reviewed as they occur and are appraised with respect to the expected range of regulation. The following paragraphs discuss the regulation of the individual System dams to accomplish the System reservoir regulation objectives.

7-02.2. **Fort Peck – Fort Peck Lake.** Fort Peck's primary water management functions are (1) to capture the mountain and the plains snowmelt and localized rainfall runoffs from the large drainage area above Fort Peck Dam, which are then metered out at controlled release rates to meet the System's authorized purposes while reducing flood damages in the Fort Peck Dam to Lake Sakakawea reach; (2) to serve as a secondary storage location for water accumulated in the System from reduced System releases due to major downstream flood control regulation, thus helping to alleviate large reservoir level increases in Garrison, Oahe, and Fort Randall; and (3) to provide the extra water needed to meet all of the System's Congressionally authorized project purposes that draft storage during low-water years.

7-02.3. **Garrison Dam – Lake Sakakawea.** Garrison, the largest Corps storage reservoir, is another key player in the regulation of the System. Its primary water management functions are (1) to capture the snowmelt runoff and localized rainfall runoffs from the large drainage area between Fort Peck and Garrison Dams that are then metered out at controlled release rates to meet System requirements, while reducing flood damages in the Garrison Dam to Lake Oahe reach, particularly the urban Bismarck area; (2) to serve as a secondary storage location for water accumulated in the System from reduced System releases due to major downstream flood control regulation, thus helping to alleviate large reservoir level increases in Oahe and Fort Randall; and (3) to provide the extra water needed to meet all of the System's Congressionally authorized project purposes that draft storage during low-water years.

7-02.4. **Oahe Dam – Lake Oahe.** Oahe's primary water management functions are (1) to capture plains snowmelt and localized rainfall runoffs from the large drainage area between Garrison and Oahe Dams that are then metered out at controlled release rates to meet System requirements, while reducing flood damages in the Oahe Dam to Big Bend reach, especially in the urban Pierre and Fort Pierre areas; (2) to serve as a primary storage location for water accumulated in the System from reduced System releases due to major downstream flood control regulation, thus helping to alleviate large reservoir level increases in Big Bend, Fort Randall, and Gavins Point; and (3) to provide the extra water needed to meet project purposes that draft storage during low-water years, particularly downstream water supply and navigation. In addition, hourly and daily releases from Big Bend and Oahe Dams fluctuate widely to meet varying power loads. Over the long term, their release rates are geared to back up navigation releases from Fort Randall and Gavins Point Dams in addition to providing storage space to permit a smooth transition in the scheduled annual fall drawdown of Fort Randall. Big Bend, with less than 2 MAF of storage, is primarily used for hydropower production, so releases from Oahe are generally passed directly through Big Bend.

7-02.5. **Fort Randall – Lake Francis Case.** Fort Randall's primary functions are (1) to capture plains snowmelt and localized rainfall runoffs in the drainage area from Big Bend Dam to Fort Randall Dam that are then metered out at controlled release rates to meet System requirements, while reducing flood damages in the Fort Randall reach, where several areas have homes and cabins in close proximity to the river; (2) to serve as a primary storage location, along with Oahe, for water accumulated in the System when System releases are reduced due to major downstream flood control regulation, thus helping to alleviate large pool increases in the very small Gavins Point project; (3) to provide a location to store the water necessary to provide increased winter energy to the basin by allowing an annual fall drawdown of the reservoir to occur with a winter reservoir refilling that is unique to Fort Randall; and (4) to provide the extra water needed to meet all of the System's Congressionally authorized project purposes, particularly navigation and downstream water supply, that draft storage during low-water years.

7-02.6. **Gavins Point Dam – Lewis and Clark Lake.** Gavins Point Dam, the most downstream of the System dams, is primarily used as a re-regulating dam to level out the release fluctuations from the upper System dams to better serve System requirements. With a total reservoir storage volume of only 500,000 acre-feet, it provides very little flood control and is generally maintained in a narrow reservoir elevation band between 1205 and 1207 feet msl. Due to the limited storage, releases from Gavins Point Dam must be backed up with corresponding release changes out of the upper projects. Gavins Point is the key location in the initiation of release reductions for downstream flood control. Even though it has only a small amount of storage space for flood control, this volume is usually adequate to perform downstream flood control by coordinating Gavins Point Dam release reductions with Fort Randall's. Releases greater than the powerplant capacity are passed through the spillway

7-03. **System Regulation Techniques.** The following discussion provides basic information related to the CWCP presented in this Master Manual. The concepts discussed are the division of the individual System reservoirs into regulation zones; the provision of a level of service to meet the Congressionally authorized purposes and the associated flow targets to achieve that level of service; System water-in-storage checks; and seasonal release considerations, which include regulation during the winter and regulation for endangered species. The process of implementing this CWCP is based on selecting the appropriate System regulation criteria described in this chapter for the appropriate time of year and System water in storage (storage) or water supply (System water in storage plus anticipated runoff for the remainder of the year) condition. Normal and Conservation System regulation involves a check on the amount of System water in storage on March 15 to determine if a navigation season will be provided that year, and if so, the service level to provide for the first part of the navigation season (Table VII-2). Downstream target flows at four designated locations are used to guide System releases (Table VII-1). The System water-in-storage is checked again on July 1 to determine the service level for the remainder of the navigation season (Table VII-2) and the ending date or length of the navigation season (Table VII-3). Finally the System storage is checked on September 15 (Table VII-4) to determine the System winter release rate. The above sequence is altered slightly if the System water supply is above normal or if the System is performing a major flood control action. In that case, the service level is determined as often as required (Plate VI-1) based on actual System storage and forecasted water supply so that the System release rate can be scheduled to minimize downstream flood risk and reduce flood damages. The navigation season is extended for 10 days in higher runoff years to facilitate evacuation of flood control storage space before the next flood season. Navigation Service Level is defined as "full" or "minimum." Full Service (see Table VII-7) is provided in near-normal runoff years to provide for evacuation of flood control storage before the next flood season, while serving navigation to the full capability of the authorized 9-foot downstream channel (8.5 foot draft). Minimum Service (see

Table VII-8) is usually provided in drought times to provide a minimum level of navigation service (7.5 feet of draft) while conserving water in the System in case of an extended drought. Consideration is also given to using System Replacement Flood Control Storage in cooperation with the U.S. Bureau of Reclamation (USBR), which will be discussed in greater detail later in this chapter. Also, within the framework of the overall goals stated above, there are seasonal decisions to optimize the benefits obtained for the various authorized purposes, such as fish spawning, endangered species nesting and releases during river ice formation periods.

7-03.1. **System Regulation Zones.** The storage capacity of the System has been developed to provide beneficial service to the Congressionally authorized purposes. Regulation of a particular project for one authorized purpose may be compatible, to a varying degree, with regulation for most of the other authorized purposes. For another authorized purpose, this regulation may be detrimental. For example, the vacating of storage capacity after a flood event to assure control of possible future flood events is compatible with providing releases for power, navigation, and water supply; however, it is incompatible with the objective of providing stored reserves for continuation of these purposes during a subsequent drought period. These factors made it advisable to divide the storage in individual System reservoirs into regulation zones to obtain the maximum possible service to all of the purposes consistent with the physical and authorizing limitations of the System. Totaling the storage capacity in the respective zones of the individual projects provides the total System storage capacity available in each regulation zone for use in System regulation. These values are not fixed but vary slightly over time according to changes in reservoir capacity from sediment collection in the reservoirs and shoreline erosion. For example, when the System was first considered filled in 1967, the total storage capacity was 75.2 MAF, and at this time, total storage capacity is 73.4 MAF. This change in storage capacity has been reflected in the System storage zones by adjusting the elevations of the various storage zones within the individual projects to reflect the correct amount of storage according to the change that has occurred. In some cases, the elevations have not changed but the actual System storage number has been adjusted for that zone. The regulation zones, and the guidance criteria for regulation in these zones considered necessary to achieve the multipurpose benefits and operational objectives for which the reservoirs were authorized, are described in the following paragraphs.

7-03.1.1. **Exclusive Flood Control Zone.** Flood control is the only authorized purpose that requires empty space in the reservoirs to achieve the objective. A top zone in each System reservoir is reserved for use to meet the flood control requirements. The storage space therein is used only for detention of extreme or unpredictable flood flows and is evacuated as rapidly as soon as downstream conditions permit, while still serving the overall flood control objective of protecting life and property. Considerations to achieve the flood control objective include a release limitation for each of the projects, status of storage in the other projects and the level of System or the Gavins Point Dam release being maintained, as designated by criteria discussed later in this chapter. The Exclusive Flood Control Zone represents 4.7 MAF (the upper 6 percent) of the total System storage volume, and this zone, from 73.4 MAF down to 68.7 MAF, is normally empty. The large four reservoirs, Fort Peck Lake, Lake Sakakawea, Lake Oahe, and Lake Francis Case, contain 98 percent of the total storage reserved for the Exclusive Flood Control Zone.

7-03.1.2. **Annual Flood Control and Multiple Use Zone.** An upper "normal operating zone" is reserved annually for the capture and retention of normal and flood runoff and for annual multiple-purpose regulation of this impounded water. The System storage capacity in this zone represents 11.6 MAF (16 percent) of the total System storage volume, and it extends from 68.7 MAF down to 57.1 MAF. This storage zone, located immediately below the Exclusive Flood Control Zone, will normally be evacuated to the base of this zone by about March 1 to provide adequate storage capacity for capturing runoff during the next flood season. Exceptions may occur. For example, if System Replacement Storage were requested in conjunction with regulation of the USBR reservoirs in the upper Missouri River basin. On an annual basis, water will be impounded in this zone as required to achieve the System flood control purpose and also stored in the interest of general water conservation to serve all the other Congressionally authorized System purposes. The evacuation of water from the Annual Flood Control and Multiple Use Zone is scheduled to maximize service to the authorized purposes that depend on the release of water from the System. Scheduling releases from this zone is limited by the flood control objective in that the evacuation must be completed by the beginning of the next flood season. This is normally accomplished as long as the evacuation is possible without contributing to serious downstream flooding. Evacuation is, therefore, accomplished mainly during the summer and fall because Missouri River ice formation and the potential for flooding from higher release rates limit System release rates during the December through March period.

7-03.1.3. **Carryover Multiple Use Zone.** A second lower intermediate zone provides a storage reserve for irrigation, navigation, power production, water supply, recreation, and fish and wildlife. The water stored in this zone at the three larger reservoirs (Fort Peck, Garrison, and Oahe) will maintain downstream flows through a succession of well-below-normal runoff years into the System. Serving the authorized purposes during an extended drought is an important regulation objective of the System and the primary reason the upper three System reservoirs are so large compared to other Federal water resource projects. The System storage capacity in this the largest storage zone, represents 39.0 MAF (53 percent) of the total System storage volume and extends from a volume of 57.1 MAF down to 18.1 MAF. The Carryover Multiple Use Zone is often referred to as the "bank account" for water in the System because of its role in providing assistance to the basin during critical dry periods. Water stored in the Carryover Multiple Use Zone will be used to meet project purposes in the event that the storage in the Annual Flood Control and Multiple Use Zone is exhausted. Only Fort Peck, Garrison, Oahe, and Fort Randall have this storage as a designated storage zone. The three larger projects of Fort Peck, Garrison, and Oahe serve the Missouri River basin during drought periods, and water from this zone is called upon to meet operational objectives stated in this plan. The storage space assigned to this zone in Fort Randall serves a different purpose. A portion of the Fort Randall space is normally evacuated each year during the fall season to provide recapture space for upstream winter power releases. The recapture results in complete refill of the space during the winter months. Deliberate, long-term drawdown into the Fort Randall Carryover Multiple Use Zone is not contemplated. During drought periods, the three smaller System projects (Fort Randall, Big Bend, and Gavins Point) are maintained at the same elevation they would be at if runoff conditions were normal. While a minor amount of space in Big Bend and Gavins Point was initially provided in this zone, deliberate drawdown into this zone is generally not contemplated.

7-03.1.4. **Permanent Pool Zone.** A bottom inactive zone, called the Permanent Pool Zone, provides for a minimum power head and for future sediment storage capacity. It also serves as a minimum pool for recreation, fish and wildlife, and as an assured minimum level for water access from the reservoir. A drawdown into this zone is generally not scheduled except in unusual conditions. The System storage capacity in this the lowermost storage zone represents 18.1 MAF (25 percent) of the total System storage volume (extends from 18.1 MAF down to 0 MAF). To date, this zone has been increased by the addition of storage originally in the Carryover Multiple Use Zones of Big Bend and Gavins Point. The regulation of System in the Permanent Pool Zone has been changed slightly due to the changes in the storage used in the Carryover Multiple Use Zone. The likelihood of using water stored in the Permanent Pool Zone has been reduced in the CWCP.

7-03.1.5. **Current System Storage Zone Allocations.** As of this time, the System has been regulated as an integrated system for 50 years. During this 50-year period, many regulation techniques have been evaluated. System regulation procedures have been modified to provide a plan for sustaining and balancing all of the Congressionally authorized project purposes. A basic method of evaluating proposed changes in System reservoir regulation has been the long-range System regulation study, as described in Chapter VI of this Master Manual. Numerous long-range studies have been made since 1964, and long-range study criteria have been modified so that release restrictions imposed by the flood control purpose are reflected in the studies. These many long-range studies have been supplemented by detailed examination of particularly severe flood events, which are described in detail in Appendix A of this Master Manual. The Master Manual Study included over 500 long-range studies, exceeding the total number of studies conducted prior to that time.

7-03.1.5.1. Long-term studies have also been made to investigate the effects of continued water resource development in the Missouri River basin. In general, these studies indicate that the flood control zone elevations currently used will continue being applicable well into the future. The loss of storage in the flood control zones of the System reservoirs due to sedimentation will be balanced by the reductions of flood runoff resulting from continuing water resource development, land treatment, and depletions that includes future appropriation of tribal water rights. Studies will continue to be made to determine the effects of such changes in Missouri River basin water resource development and in associated System regulation techniques. A major purpose of these studies will be the re-evaluation of System and individual System project storage zone allocations. If deemed necessary, appropriate action toward modification of System project storage zones will be initiated.

7-03.1.5.2. The current storage allocations and associated elevations in each of the zones of individual System projects, as well as for the System as a whole, is shown on Plates II-1 and II-2. Storages given in this table reflect the January 2004 elevation-storage relationships. Minor modifications from previous allocation tables are discussed below.

7-03.1.5.2.1. **Fort Peck.** The elevation of the top of the Permanent Pool Zone, or the bottom of the Carryover Multiple Use Zone, has not changed for Fort Peck; however, this updated water control plan has changed the regulation of the System during drought, or water conservation, periods. This change will result in the reservoir being approximately 22 feet higher during a drought like the 1930's; therefore, the likelihood that Fort Peck will drop to the top of its Permanent Pool Zone during its project life is reduced under this changed plan.

7-03.1.5.2.2. **Garrison.** The elevation of the top of the Permanent Pool Zone, or the bottom of the Carryover Multiple Use Zone has not changed for Garrison but it should be recognized that this updated water control plan has changed the regulation of the System during drought or water conservation periods. This change will result in the reservoir being approximately18 feet higher during a drought like the 1930's, therefore the likelihood that Garrison will drop to the top of its Permanent Pool Zone during its project life is reduced under this changed plan.

7-03.1.5.2.3. **Oahe.** The elevation of the top of the Permanent Pool Zone or the bottom of the Carryover Multiple Use Zone has not changed for Oahe but it should be recognized that this updated water control plan has changed the regulation of the System during drought or water conservation periods. This change will result in the pool being approximately 21 feet higher during a drought like the 1930's, therefore the likelihood that Oahe will drop to the top of its Permanent Pool Zone during its project life is reduced under this changed plan.

7-03.1.5.2.4. **Big Bend.** The elevation of the top of the Permanent Pool Zone or the bottom of the Carryover Multiple Use Zone has not changed for Big Bend. The Annual Flood Control and Multiple Use Zone extends between elevations 1420 and 1422 feet msl and is used for power scheduling purposes with the Exclusive Flood Control Zone extending between elevations 1422 and 1423 feet msl. The Annual Flood Control and Multiple Use Zone in Big Bend is not provided for seasonal regulation of flood inflows like the other major upstream projects, but the zone is used for day-to-day and week-to-week power operations. A settlement agreement approved in an order of dismissal by the United States District Court, District of South Dakota, in the case of Lower Brule Sioux Tribe et al. v. Rumsfeld, et al. (Civil No. 02-3014 (D.S.D.) provides that the Corps will consult with the Lower Brule Tribe and the Crow Creek Sioux Tribe during any review and revision of the Missouri River Master Water Control Manual. This agreement also provides that the Corps will coordinate the regulation of the Big Bend Project and the water level of Lake Sharp with the two Tribes to include the following: the Corps will normally strive to maintain a level at Lake Sharpe between elevation 1419 feet msl and 1421.5 feet msl; when the level of Lake Sharp drops below elevation 1419 feet msl or exceeds elevation 1421.5 feet msl, the RCC will provide notice to such persons as the Tribes shall designate in writing; when it is anticipated that the water level will drop below 1418 feet msl or rise above 1422 feet msl, or in the event the water level falls below 1418 feet msl or rises above 1422 feet msl, the Commander, Northwestern Division, or his designee, shall immediately contact the Chairpersons of the Tribes or their designees to notify them of the situation and discuss proposed actions to remedy the situation.

7-03.1.5.2.5. **Fort Randall.** The Carryover Multiple Use Zone in this project is used to recapture upstream winter power releases rather than for the maintenance of a storage reserve for long-term droughts, as is provided in the three major upstream System projects. On all reservoir regulation simulations analyzed for the Master Manual Study, Fort Randall was not drawn down below an elevation of 1337.5 feet msl. This lower limit has been a regulation objective since it was first instituted in 1972. Additional details of this change are available in an RCC report entitled, "Modification of Operation of Lake Francis Case, South Dakota." The water stored in the Fort Randall Carryover Multiple Use Zone from 1320 to 1337.5 feet msl may be used and withdrawn during a drought that is more severe than the drought of the 1930's. This storage volume remains as part of the Carryover Multiple Use Zone for this purpose.

7-03.1.5.2.6. **Gavins Point.** The Permanent Pool Zone at Gavins Point extends from 1160 to 1204.5 feet msl. The Annual Flood Control and Multiple Use Zone from 1204.5 to 1208 feet msl is the zone the project normally is regulated. The Exclusive Flood Control Zone from 1208 to 1210 is kept vacated except during flood control events. Gavins Point reservoir is normally regulated near 1206.0 feet msl in the spring and early summer with variations day to day due to rainfall runoff. The reservoir level is then increased to elevation 1207.5 feet msl following the nesting season for lake recreation enhancement.

7-03.2. **System Service Level.** To facilitate appropriate application of System multipurpose regulation criteria, a numeric "service level" has been adopted since the System was first filled in 1967. Quantitatively, this service level approximates the water volume necessary to achieve a normal 8-month navigation season with average downstream tributary flow contributions. For the "full-service" level, the numeric service level value is 35,000 cfs. For the "minimum-service" level, the numeric service level value is 29,000 cfs. This service level is used for selection of appropriate flow target values at previously established downstream control locations on the Missouri River. There are four flow target locations selected below Gavins Point to assure that the Missouri River has adequate water available for the entire downstream reach to achieve regulation objectives. Because of the fluvial nature of the bed of the Missouri River, flow targets are used rather than river stage targets at the control point locations. The discharge approach has resulted in a consistency in regulation over time as aggradation and degradation previously discussed has occurred at some of the System control point locations, which has changed river stage values for the same flow. The specific technical criteria for the relationship between service level and control point target discharge are as shown in Table VII-1. The service level determination has a range much greater than the minimum and full service discussed so far. The application of the service level concept is also used in the evacuation of flood runoff accumulated in the System by establishing service levels much greater than 35,000 cfs, as shown on Plate VI-1. The specific use of the service levels technique for System flood control evacuation is fully discussed in this chapter in Paragraph 7-04.13.4.

Table VII-1
Relation of Target Discharges to Service Level

Control Point Location	Flow Target Discharge Deviation from Service Level
Sioux City	-4,000 cfs
Omaha	-4,000 cfs
Nebraska City	+2,000 cfs
Kansas City	+6,000 cfs

7-03.2.1. **Service Level for Conservation and Normal System regulation.** A full-service level of 35,000 cfs results in target discharges of 31,000 cfs at Sioux City and Omaha, 37,000 cfs at Nebraska City and 41,000 cfs at Kansas City. Similarly, a "minimum service" level of 29,000 cfs results in target values of 6,000 cfs less than the full-service levels at the four System control points identified above. Selection of the appropriate service level to be maintained is based on the actual volume of water-in-storage in the System. The use of actual water-in-storage means that forecasting is not relied upon when the volume of water in System storage is below normal.

7-03.2.1.1. **Service Level System Water-in-Storage Checks.** The System water-in-storage checks occur on constant key dates (March 15 and July 1) of each year. The volumes selected have been derived from long-range model simulations that allow the System to function to meet authorized purposes during significant multi-year drought periods. The specific technical criteria for System service level are as shown in Table VII-2. Straight-line interpolation defines intermediate service levels between full and minimum service. These service level determinations are for conservation and normal System regulation. During years when flood evacuation is required, the service level will be calculated monthly to facilitate a smooth transition in System release rather than a stepped approach at the above-mentioned March 15 and July 1 dates. Further details related to System regulation during flood events are provided later in this chapter.

Table VII-2
Relation of Service Level to the Volume of Water in System Storage

Date	Service Level (cfs)	Water in System Storage (MAF)
March 15	35,000 cfs (full-service)	54.5 or more
March 15	29,000 cfs (minimum-service)	49.0 to 31
March 15	no service	31.0 or less
July 1	35,000 cfs (full-service)	57.0 or more
July 1	29,000 cfs (minimum-service)	50.5 or less

7-03.3. **Non-navigation Years.** As shown in Table VII-2, the CWCP presented in this revised and updated Master Manual calls for suspension of navigation service if System water-in-storage is at or below 31 MAF on March 15 of any year. It should be noted that the occurrence of System storage at or below 31 MAF would most likely coincide with a national drought emergency. If any of the reservoir regulation studies performed for the development of the AOP indicate that System storage will be at or below 31 MAF by the upcoming March 15, the Corps of Engineers will notify the Secretary of the Army. Approval from the Secretary of the Army will be required prior to suspension of Missouri River navigation for the second of two consecutive years. The Corps will ensure that basin stakeholders are promptly informed of the notification to the Secretary of the Army and of the Secretary's decision regarding suspension of navigation.

7-03.4. **Season Length Determination.** The water-in-storage check for navigation season length is taken on July 1 of each year. Assuming System water-in-storage is above 31 MAF on March 15, a navigation season will be supported. If System water-in-storage is at or above 51.5 MAF, a full 8-month navigation season would be provided, unless the season is extended to evacuate System flood control storage. However, if System water-in-storage falls below 51.5 MAF on any July 1, a shortened navigation season would be provided to conserve water stored in the System to extend availability of water-in-storage in the case of an extended drought. The specific technical criteria for season length are shown in Table VII-3. Straight-line interpolation between 51.5 and 46.8 MAF of water-in-storage on July 1 provides the closure date for a season length between 8 and 7 months. If System water-in-storage on July 1 is between 46.8 and 41.0 MAF, a 7-month navigation season is provided. A straight-line interpolation is again used between 41.0 and 36.5 MAF, providing season lengths between 7 and 6 months. For System water-in-storage on July 1 below 36.5 MAF, a 6-month season is provided.

Table VII-3
Relation of System Storage to Season Length

Date	System Storage (MAF)	Season Closure Date at Mouth of the Missouri River
March 15	31.0 or less	no season
July 1	51.5 or more	December 1 – 8-month season
July 1	46.8 through 41.0	November 1 – 7-month season
July 1	36.5 or less	October 1 – 6-month season

7-03.4.1. **Season Opening and Closing Dates**. Navigation on the Missouri River is limited to the normal ice-free season, with a full-length flow support season of 8 months. Successful commercial navigation on the Missouri River from Sioux City to the mouth is dependent upon low-flow supplementation from the System, with occasional assistance from tributary reservoirs authorized to support Missouri River navigation. Navigation is limited to the ice-free season and, based on historical records of ice formation on the Missouri River together with experience gained in System regulation to date, the opening and closing dates of a normal 8-month navigation season have been scheduled as follows:

	Opening Date	Closing Date
Sioux City	March 23	November 22
Omaha	March 25	November 24
Kansas City	March 28	November 27
Mouth	April 1	December 1

In some years, ice conditions will undoubtedly delay the opening of the season and in others may force an early end to the season.

7-03.4.2. Fall extensions of the season beyond the normal 8-month length will normally be scheduled (ice conditions permitting) in years with above-normal water supply and when such extensions will not result in a drawdown into the System's Carryover Multiple Use Zone. Based on experience to date, these season extensions will normally be limited to 10 days beyond the normal closure date, resulting in a season closing on December 11 at the mouth of the Missouri River. In addition to enhancing navigation and water supply, the 10-day extension of the navigation season also enhances hydropower production by transferring an additional block of power from the normal navigation season to the more critical (for power purposes) winter season.

7-03.5. **System Seasonal Considerations.** For a portion of some years, deviations may be made from the above stated specific technical criteria to achieve the operational objectives of the CWCP or to comply with other statutory or regulatory obligations such as the ESA. In such circumstances, the AOP will explain the deviation from the specific technical criteria and the rationale for that deviation related to the operational objectives of the CWCP or applicable statutory and regulatory requirements. Other seasonal considerations and the corresponding reservoir regulation are further discussed elsewhere, as appropriate, in this Master Manual.

7-03.5.1. **System Winter Release Determination.** Another seasonal consideration is regulation in the wintertime period, which extends from December through February, to support the Congressionally authorized project purposes of hydropower production and downstream water supply and water quality. The specific technical criteria for Gavins Point Dam winter release rate is shown in Table VII-4. The System water-in-storage check for System winter release is taken on September 1 of each year.

Table VII-4
Relation of System Winter Release Level to System Storage

September 1 System Storage in MAF	Average Winter Release from Gavins Point in cfs
58.0 or more	17,000 cfs
55.0 or less	12,000 cfs

7-03.5.2. A modification to the winter release rate from Gavins Point Dam generally occurs when the evacuation of System flood control storage cannot be accomplished by providing a full-service navigation season with a 10-day extension of the navigation season. With an excess annual water supply, the winter season Gavins Point release will be scheduled at a rate of up to 25,000 cfs to continue to evacuate the remaining excess water in System flood control storage. When extremely high runoff has not been previously evacuated due to downstream flood control regulation, consideration will be given to scheduling winter releases in the 25,000 to 30,000 cfs range to accomplish the flood control objective of evacuating the Annual Carryover and Multiple Use Zone prior to the beginning of the next flood season.

7-03.6. **Integration of Downstream Requirements.** Gavins Point Dam releases are regulated to provide service to all multiple-use purposes, while at the same time recognizing the important flood control function of the System. In years of excess water supply, Gavins Point Dam releases in excess of full-service requirements may be necessary to evacuate flood control storage space. In recognition that these higher-than-normal releases can have an adverse effect on downstream floods, should unexpected rainfall occur, the higher releases should be made, to the extent possible, when floods from downstream tributaries are less likely. Also, the magnitude of these releases during the open-water season can be reduced somewhat by scheduling winter releases at a higher rate than would be the case with a normal water supply. While this may have the effect of slightly increasing the flood risk during the winter months, it reduces the flood risk during the open-water season when the flood potential is greatest. In addition, it may also increase the service provided to the power and navigation purposes by extending the navigation season length and increasing the amount of winter energy generation. Also, flood storage evacuation releases somewhat above full-service requirements during the open-water season usually have a beneficial effect upon navigation and hydropower production.

7-03.6.1. With a normal or less-than-normal water supply, navigation and hydropower releases during the open-water season are made taking into account the existing System water-in-storage and less-than-full-service flows may be provided when water-in-storage is low. Under such conditions, winter power releases may also be reduced. Table VII-4 shows that, for a normal System water-in-storage, a winter release from Gavins Point would be approximately 17,000 cfs. This release equates to fully serving the winter System hydropower production purpose and meeting all downstream water supply requirements. If, due to a depletion in System water-in-storage reserves down to the levels identified in Table VII-3, navigation season lengths need to be reduced to less than 8 months, winter releases from Gavins Point may be reduced to the minimum necessary for water intake or water quality requirements. The minimum System release considered applicable at this time is 9,000 cfs during the non-summer open-water season (March-April and September-November), 18,000 cfs during the summer open-water season (May-August) and 12,000 cfs during the winter period (December-February).

7-03.7. **System Conservation or Drought Reservoir Regulation Considerations**. As this manual was being revised, the System was experiencing its second extended drought since the System became fully operational in 1967. In fact, the amount of water in System storage was at the lowest level since it first filled. All authorized purposes, except for flood control, are affected negatively during extended drought. The impacts range from minor to very severe. Those most severely affected are recreation in the upper three large System reservoirs and below the System; navigation; intake access on the upper three large System reservoirs and in the river reaches between the reservoirs and downstream; cold water reservoir fishery species; reservoir and river water quality including thermal powerplants; irrigation; and hydropower production.

7-04. **System Regulation for Flood Control**. The regulation of the System for flood control is provided in the following paragraphs.

7-04.1. **Objectives of Flood Control Regulation.** The System is regulated, insofar as is practical, to prevent flows originating above or within the System from contributing to damaging flows through the downstream reaches of the Missouri River. Regulation of individual System projects is integrated to successfully meet this regulation objective. In addition, each individual System project is regulated to prevent, insofar as practicable, project releases from contributing to damaging flows through the downstream reaches in which that particular project affords a significant degree of control.

7-04.2. **Method of Flood Control Regulation.** In general, the developed method of regulation of the System as described in subsequent paragraphs may be classified as Method C, as defined in EM 1110-2-3600. This represents a combination of the maximum beneficial use of the available reservoir storage space during each flood event with regulation procedures based on the control of floods of approximate reservoir design magnitude. Specific procedures for the accomplishment of flood control regulation and examples are given in the succeeding paragraphs.

7-04.3. **Mainstem System Storage Space Available for Flood Control.** During any specific major flood event, all available storage space within the System will be used to the maximum extent practicable for flood control. This control will be provided in combination with other beneficial water uses for which the System was authorized. Approximately 16.3 MAF of System storage space are allocated for flood control purposes, of which 4.7 MAF are for this purpose exclusively; the remainder combines flood control with other authorized purposes. Most of the System flood control storage space is located in the Fort Peck (Fort Peck Lake), Garrison (Lake Sakakawea), Oahe (Lake Oahe), and Fort Randall (Lake Francis Case) projects. The flood storage in the Big Bend and Gavins Point projects is relatively minor in magnitude. In addition to allocated flood control storage space, surcharge space is available in each of the System reservoirs, primarily to ensure the safety of the project, but the use of that space will provide downstream flood reductions during extreme flood events. The Carryover Multiple Use Zone storage space, when evacuated, will also serve to benefit the flood control; however, deliberate evacuation of this zone to serve flood control will not be normally scheduled. As discussed in Appendix A of this manual, determination of the current flood control storage allocation of the System is based, to a large degree, on the vacated space required to control the 1881 flood. The 1881 flood is discussed in greater detail in Appendix A of this manual. The System flood control storage allocation has been examined and confirmed as adequate by numerous long-range regulation studies and the study for this Master Manual update.

7-04.4. **Amount of Tributary Reservoir Space Available for Flood Control.** The availability of upstream tributary reservoir flood control storage space was not recognized in the early flood studies. Early long-range System regulation studies also did not consider tributary reservoirs regulated specifically for flood control along the main stem of the Missouri River. Tributary reservoir storage space upstream from the System, if regulated for that purpose, can be effective in reducing flood crests in the lower Missouri River. Certain Missouri River basin tributary reservoirs, therefore, have a portion of their available storage space allocated to flood control use on a "replacement" basis. Replacement storage is defined as tributary reservoir storage space that is regulated in close coordination with the System and, as a consequence, can replace a portion of the System's Annual Flood Control and Multiple Use Zone space. Replacement storage effectively allows for an increase in the amount of Carryover Multiple Use Zone storage that can be retained in the System projects. This greater amount of Carryover Multiple Use Zone storage results in increased multiple-use benefits while continuing the same degree of downstream flood protection that the System was designed to achieve. Past long-range regulation studies have incorporated this replacement storage concept and have demonstrated the resulting increased multiple-purpose benefits and continued flood control effectiveness of the expanded system of reservoirs. The use of replacement storage was last integrated into the System regulation in the 1980's. Basin hydrologic conditions determine if use of tributary replacement storage is warranted. Future requests for the use of tributary replacement storage are not anticipated.

7-04.4.1. **Replacement System Flood Control Storage Space.** Replacement flood control storage has been provided in three projects in the upstream basin: Clark Canyon, Canyon Ferry, and Tiber. These projects are all USBR projects controlling drainage areas upstream of Fort Peck. The Corps' NWD Commander is responsible for the flood control regulation of these projects under Section 7 of the 1944 Flood Control Act. The NWD Commander has delegated the flood control regulation of these USBR projects to the Corps' Omaha District Commander.

The drainage areas of these three projects all have relatively high runoff yields that produce significant volumes of the flood season runoff above the System. It is expected that, in years of large runoff that could conceivably tax the flood control abilities of the System, the replacement storage space in these projects would be used for the control of flooding on the Missouri River. The three USBR projects have the use of replacement System Flood Control Storage outlined in their respective tributary water control manuals. Each manual details the procedures for the Corps to follow in computing the amount of replacement storage available for each runoff season. When replacement storage for any or all of the projects is used, the actual regulation of the System proceeds as if this upstream tributary replacement storage space was a part of the System's Annual Flood Control and Multiple Use Zone. When replacement storage is used, the total System storage, or storage in a particular System project, could enter the flood season on March 1 above the base of the Annual Flood Control and Multiple Use Zone. This storage may appear to exceed the amount suggested by flood control objective criteria stated in this manual. Because the vacated space in the upstream reservoirs is being used as tributary replacement storage, what is initially seen as excess flood control storage in the System is actually consistent with criteria outlined in this manual. If replacement storage is used, the affected USBR tributary project(s) is credited with extra flood control benefits for a portion of System damages prevented on the Missouri River. The RCC is responsible for requesting, in writing, that the Omaha District water control office initiate the process to use tributary replacement storage to benefit the System. The Omaha District in turn notifies the USBR that tributary replacement storage is being requested by the RCC. The USBR must then assure that the space is evacuated in the tributary project prior to flood season in accordance with the procedures written in the tributary manuals. The volume of replacement storage space available in the USBR tributary projects, as stated in the tributary project water control manuals, is shown in Table VII-5.

Table VII-5
System Replacement Flood Control Storage

Tributary Project	System Replacement Storage
Tiber	569,468 acre-feet
Clark Canyon	106,911 acre-feet
Canyon Ferry	450,000 acre-feet
Total	1,126,379 acre-feet

7-04.4.2. **Other Tributary Reservoir Flood Control Storage Space.** In addition to the aforementioned USBR tributary projects that have assigned replacement flood control storage space, there are many other tributary reservoirs upstream from the System. Many of these tributary reservoirs have no Congressionally authorized flood control space or have flood control space assigned only for the purpose of local flood control in the immediate downstream river reach. At times, these reservoirs are drawn well below their normal full level prior to the flood season. Efficient Missouri River basin water resources management requires that the status of storage in all significant tributary reservoirs be considered and integrated into the overall regulation of the System, to the extent practical, while maintaining the overall flood control capability originally designed into the System.

7-04.5. **System Project Regulation Features.** Releases from individual System projects can be made through their respective powerplants, outlet works, and spillways. The powerplants will be used to the fullest extent possible to achieve the maximum benefit. During normal operating conditions, the greatest portion of project releases is made through the powerplants. When releases greater than the powerplant capacity or power demand are necessary, the outlet works and spillways will be used. The spillway, in combination with surcharge storage provided, ensures the safety of the dam in the case of extreme floods. Capacities of flow regulating devices at the System projects are indicated on rating curves represented on Plates II-5 through II-9 for Fort Peck, Plates II-20 through II-23 for Garrison, Plates II-34 through II-37 for Oahe, Plates II-47 through II-49 for Big Bend, Plates II-59 through II-62 for Fort Randall, and Plates II-72 through II-74 for Gavins Point. Additional information can be found in the individual System project water control manuals.

7-04.6. **System Flood Control Regulation.** Flood control regulation of the System projects, as per the objectives stated in Paragraph 7-04.1, is based on careful consideration of the following factors: river channel capacities downstream from individual System projects; observed and forecasted tributary flows to those portions of the Missouri River through which the System and individual System reservoirs afford a positive degree of flood control; observed and forecasted inflows into the System and the individual System reservoirs; amount of vacated individual System projects and total System storage space for controlling current and forecasted runoff; flood-producing potential of the drainage area both above and below the System and its relationship to individual System projects within the System; release requirements from the System and also from the individual System projects for purposes other than flood control; and available tributary reservoir flood control storage space above the System. The desired March 1 System water-in-storage is 57.1 MAF, equivalent to having each individual System reservoir at the base of its Annual Flood Control and Multiple Use Zone. When median or greater runoff occurs with System storage at 57.1 MAF or above on March 1, System releases are adjusted by computing the appropriate service level to draft storage to 57.1 MAF by March 1 of the following year. The three large reservoirs can either be balanced or unbalanced in terms of the amount of water in the Carryover Multiple Use Zone remaining on March 1 by specifying target storages; however the overall system goal is to have the system evacuated to the base of the Annual Flood Control and Multiple Use Zone (57.1 MAF) by March 1 each season to fully serve the flood control purpose.

7-04.6.1. **Use of Annual Flood Control Storage.** The flood control storage space in the System is normally evacuated prior to the start of the next flood season, which starts in March or early April. The Annual Flood Control and Multiple Use Zone will be allowed to fill or partially fill through the flood season, with the rate and amount of fill largely determined by actual and anticipated hydrologic conditions. Optimum System regulation requires the filling of a portion of this zone during the flood-runoff season to fully meet the regulation objectives of this CWCP. This is accomplished provided that inflows exceed the releases required to meet all authorized purposes.

7-04.6.2. **Use of Exclusive and Surcharge Flood Control Storage.** The Exclusive Flood Control Zone space provided in the System is reserved entirely for the control of floods and is not to be encroached on except for that specific purpose. Surcharge storage space is provided in addition to flood control space to assure project integrity and will be used only in the case of extreme floods.

7-04.7**. Individual System Project Flood Control Regulation.** Seasonal regulation of the storage within the individual System projects of the System will, to a degree, parallel that for the System, which is described in previous sections. The individual System projects have two zones designated for flood control, the Annual Flood Control and Multiple Use and the Exclusive Flood Control Zones. The Annual Flood Control and Multiple Use Zone is the zone where the projects normally operate under a wide range of runoff conditions. The zone designated as Exclusive Flood Control Zone is vacated most of the time and encroached upon only during significant runoff events. When the amount of water in an individual project or System storage is great enough to occupy this zone or the Corps' simulation models forecast the projects to rise into this zone, the projects are considered to be in a flood control state. Downstream runoff and streamflow conditions can also cause the System to be considered in a flood control state. The flood control state results in an increased frequency of forecasts and an examination of additional alternatives to return the System to a normal condition. During a flood control state, the flood control purpose is considered foremost in making release determinations.

7-04.7.1. **Fort Peck and Garrison Flood Control Considerations.** The winter season is the time period when the firm power demand from the System is the greatest. To enhance winter energy generation, winter releases from the upstream Fort Peck and Garrison reservoirs are often maintained at the maximum level possible that is consistent with downstream channel capacity. During the winter, channel capacity is reduced because of threat of flooding during river ice formation or when an established Missouri River ice cover raises Missouri River stages. Because of the somewhat unpredictable behavior of a downstream ice cover, the exact potential volume of winter releases from these upstream projects cannot be estimated accurately. Pre-winter System reservoir storage levels are scheduled on the basis that the established winter release rate will be made most of the time through these upstream powerplants. If channel conditions during the winter are such that the established winter release rate assumed in pre-winter scheduling is not possible, a release deviation will be implemented. The changed release rate may result in some imbalance in the amount of water-in-storage in individual System reservoirs by the following spring. This storage imbalance will favor the downstream flood control purpose, with additional evacuated storage space located in the largest downstream System project, Oahe. This is not a matter of great concern because open-water channel capacities below Fort Peck and Garrison are sufficient to allow a relatively fast restoration of System storage balance following the ice breakup if attaining a balance in the amount of water-in-storage at the large upper three reservoirs is still a goal at that time of the season.

7-04.7.2. **Fort Randall Flood Control Considerations.** The early spring flood potential is defined by the amount of accumulation of plains snow and the ground conditions in the incremental areas above and between the System reservoirs. Manipulation of the Fort Randall reservoir level prior to the flood season is based on the spring flood potential. In years when the early-spring flood potential between Oahe and Fort Randall is high because of plains snow accumulation or the flooding potential below Fort Randall is high, the Fort Randall reservoir level may be held below its base of the Annual Flood Control and Multiple Use Zone prior to the onset of spring runoff. This reservoir level manipulation is achieved by reducing late winter power releases from the Oahe and Big Bend projects. The additional vacated storage space in

Fort Randall allows for the capture of flood flows with a less severe disruption of power releases from upstream projects through the spring runoff period. During normal runoff situations, the reservoir will be maintained at the base of flood control, 1350 feet msl. During those years that the flood potential below Oahe is low, it may be desirable to raise Fort Randall reservoir level above the base of the Annual Flood Control and Multiple Use Zone prior to March 1. This allows for an increased amount of energy to be generated during the high demand winter period. Additionally, the higher reservoir level provides a reserve of additional water that may be used to satisfy short-term demands for increased System releases during the following navigation season for downstream flow support. Experience has indicated that a Fort Randall reservoir level of about 1355 feet msl, 5 feet above the base of the Annual Flood Control and Multiple Use Zone, is satisfactory for meeting the short-term downstream flow support demands. Experience has also indicated that maintaining a minimum pool elevation of 1353.0 feet msl will meet the recreational and irrigation purposes during the April to September timeframe. Consequently, any deliberate fill of the Fort Randall reservoir, based on low flood potential prior to March 1, will normally be limited to an elevation of 1355.0 feet msl.

7-04.7.3. **Gavins Point Flood Control Considerations.** Consideration of the early spring flood potential in the drainage area between Fort Randall Dam and Gavins Point Dam is similar to that outlined in Paragraph 7-04.7.2 for the area between the Oahe and Fort Randall projects. Because it is possible to manipulate the Gavins Point reservoir level in a relatively short period of time, the reservoir level at the start of the flood season will be somewhat dependent on this spring flood potential. When the spring flood potential between Fort Randall Dam and Gavins Point Dam is high, the Gavins Point reservoir level will be drawn down well below the base of Annual Flood Control and Multiple Use Zone immediately prior to the start of the snowmelt period and allowed to refill from the snowmelt runoff. The limit of this drawdown will be dependent on the potential for flooding based on the forecasted runoff in the Fort Randall Dam to Gavins Point Dam reach. When the runoff potential between Fort Randall and Gavins Point Dam is very low, as evidenced by the lack of a plains snow cover or by a lack of antecedent rainfall over the incremental drainage area, complete evacuation of the Annual Flood Control and Multiple Use Zone may not be necessary. Continued surveillance of the runoff potential in this incremental area is required. If the runoff potential increases during the March through July flood season, appropriate measures will be taken to lower the level of the Gavins Point reservoir to near the base of the Annual Flood Control and Multiple Use Zone, which is 1204.5 feet msl; however, consideration of the state of tern and plover nesting must be made prior to lowering the reservoir. The potential effects on the recreational use of the Gavins Point project will be a consideration in any decision made to reduce the elevation of Gavins Point to capture additional runoff. In this area, there is continued pressure from recreation specific interests to maintain Gavins Point reservoir levels at the highest practical level consistent with the flood runoff potential. Additionally, keeping the Gavins Point reservoir level high, along with a corresponding storage decrease in upstream reservoirs, increases System power production because the small size of Gavins Point provides a greater amount of power per unit of storage than any of the other System projects. Because releases from this downstream project are normally greater than from other System projects, the additional head is more effective for increased energy production than a corresponding head increase at another System project. The Gavins Point reservoir level following the March through July flood season and the completion of tern and plover nesting season will normally be maintained at 1207.5 feet msl to enhance both recreation and power. The base of the Exclusive Flood Control Zone is 1208.0 feet msl. Manipulation of the Gavins

Point and Fort Randall reservoir levels, as described in this and the preceding sections, has no effect on the overall availability of evacuated flood control storage space in the System prior to early spring floods. This is because desired reservoir levels are realized by scheduling releases from upstream projects. Downstream System release rates are also not affected by any System reservoir level manipulations discussed in the subparagraphs of 7-04.7.

7-04.8**. System Flood Control Regulation Criteria.** In order to conduct System flood control regulation in an optimum manner, while at the same time providing the maximum possible service to the other multiple-use purposes of the System, storage space allocated for flood control in the downstream System reservoirs of Big Bend, Fort Randall, and Gavins Point should be maintained as near to the base of their Annual Flood Control and Multiple Use Zones as possible, which is consistent with the discussion in Paragraph 7-04.7. The basis for this type of System regulation is explained in the following subparagraphs.

7-04.8.1. Vacant space in the three smaller downstream System projects provides an additional measure of flood control for the large urban damage centers below the System than the same amount of vacated space in the upper three, larger System projects.

7-04.8.2. When the levels of the Big Bend and Fort Randall reservoirs are near the base of their respective Annual Flood Control and Multiple Use Zones, tailwater levels at the immediately upstream Oahe and Big Bend projects will provide maximum power heads. This will result in improved hydropower production.

7-04.8.3. In the case of heavy runoff originating below the System, vacant Annual Flood Control and Multiple Use Zone space in the downstream three smaller System projects helps both flood control and power generation. These smaller projects then have the space to store the upstream project releases necessary to maintain the optimum System power generation from the upstream three larger System projects, while releases can be reduced from the smaller downstream projects to provide the maximum practical flood reductions.

7-04.8.4. Flood control releases from the System will be made in such a manner as to satisfy the following general requirement. When allocated flood control storage space in Fort Randall is available to capture existing or forecasted flood events, maximum System releases will normally be limited to a rate that will not contribute to flows that exceed 120,000 cfs at Sioux City, Iowa. If insufficient storage is available in Fort Randall reservoir for controlling the existing or forecasted runoff, System releases will be increased as necessary to ensure project safety while at the same time providing significant downstream flood reductions.

7-04.9. **System Regulation Considerations During Winter Ice Season.** The maximum flow that may be passed without damage varies through the length of the Missouri River and is dependent on channel dimensions, the degree of encroachment onto the floodplain, and improvements such as levees and channel modifications. Capacities at specific locations also vary from season to season, especially in the middle and upper river reaches, where a decrease in capacity due to the formation of an ice cover is common through the winter and early spring months. Like with most streams, the capacity of the Missouri River channel usually increases progressively downstream, although instances occur where this trend is reversed.

7-04.9.1. Above Sioux City, the Missouri River and its tributaries can be expected to freeze over each year. An intermittent ice cover will also usually form on the Missouri River as far downstream as St. Joseph. In the downstream reaches of the river below St. Joseph, an ice cover may occasionally form as a result of severe and extended cold temperatures. The time of formation and breakup of the ice cover varies widely from year to year, but an ice cover may be expected over some reaches from early December to about mid-March. RCC Technical Report No. SS-N-71, "Missouri River Freeze and Breakup," November 1971, presents detailed historical data on this subject.

7-04.9.2. An ice cover greatly decreases the river conveyance at any given stage and, consequently, the channel capacities are significantly reduced. The formation and breakup of the ice cover through any reach or series of reaches often causes ice jams. Substantial volumes of water are stored temporarily by these ice jams or by a solid ice cover due to flow restriction by the ice. This phenomenon has a marked effect upon streamflow and river stages. Downstream flows and accompanying stages may be markedly reduced at the onset of the jam, while stages just upstream or in the upstream portions of ice-covered sections of the river may rise to damaging levels. The volume of ice in any particular reach of the river that may contribute to jamming is a function of the thickness of ice, the width of the river, and the length of the reach. With low stages, the river width, and the ice volume within the reach are reduced from what they would have been with higher stages. Most of the maximum stages of record in the upper Missouri River resulted from ice jams and occurred prior to regulation provided by the System. The System projects tend to act as a trap to flowing ice and reduce the possibility of severe ice jam formation in downstream areas, both during the period of ice formation and ice breakup.

7-04.9.3. In the downstream portions of the Missouri River, ice jamming or ice bridging is likely to occur during periods of extremely cold weather. Large cakes of ice form and float downstream to a restricted reach where they lodge. The resulting blockages are fed by additional floating ice. Usually, such blockages in the downstream reaches are temporary in nature and continue until such time that temperatures moderate. On several occasions, blockages have formed in the Nebraska City to St. Joseph reach of the Missouri River and have caused stages to exceed established flood stage, in spite of low releases from Gavins Point. In recent years, the Missouri River normally freezes first below Gavins Point Dam in the Ponca area above Sioux City; below Decatur, Nebraska; below Fort Calhoun, Nebraska; below the Platte River confluence with the Missouri River and near Leavenworth, Kansas. During severely cold Midwest winters, over 400 miles of the Missouri River have been covered by ice below Gavins Point Dam. Generally, the long travel times to most locations prevent the Corps from making significant changes in Gavins Point releases to correct stage fluctuations from ice jam events below the System.

7-04.9.4. Ice cover forming on the Missouri River below Fort Peck, Garrison, and Oahe Dams has a marked effect on the winter regulation of these projects. At the time the ice cover first forms below Fort Peck and Garrison Dams, the downstream channel capacities are at a minimum. As the river ice cover stabilizes, flows are normally slowly increased followed by a progressive increase in the channel capacity that continues until just prior to the end of the winter season. It is often possible to increase releases while maintaining relatively constant downstream stages. This phenomenon is discussed in more detail in two RCC Technical Reports, "Freezing of the Missouri River Below Garrison Dam," February 1973, and "Freezing of the Missouri River Below Fort Peck Dam," July 1973.

7-04.9.5. Ice cover forming on the Missouri River below the Oahe Dam also has a marked effect upon the winter regulation of this project. As discussed previously, Federal funds are currently being used to acquire the properties most susceptible to ice-affected flooding in Pierre and Fort Pierre, South Dakota.

7-04.9.6. **System Winter Season Flood Control Releases.** Due to restricted channel capacities under ice conditions, releases from specific projects during the winter river ice-cover period will be limited at all six System projects.

7-04.9.6.1. **Fort Peck.** At the time when active downstream river ice formation is anticipated or occurring in the reach between Fort Peck Dam and the mouth of the Yellowstone River, mean daily releases from Fort Peck are limited to a maximum of 10,000 cfs unless higher releases are needed for flood control evacuation. After a river ice-cover has formed, releases will be limited to prevent Missouri River stages from exceeding 11 feet at Wolf Point or 13 feet at Culbertson unless higher release rates are required for flood control evacuation. Experience indicates that, after the downstream ice cover has formed and stabilized, mean daily releases can be increased up to 15,000 cfs, which is the Fort Peck powerplant capacity. However, increases in releases from the normal freeze-in level to the maximum winter ice-covered level should normally be made in gradual increments. Additionally, tributary runoff between Fort Peck and the downstream Wolf Point and Culbertson gages due to plains snowmelt prior to the time the river becomes ice-free are a consideration in release scheduling.

7-04.9.6.2. **Garrison.** Garrison releases are normally not scheduled above 20,000 cfs in December to prevent the river at the Bismarck gage from exceeding a 13-foot stage during the winter freeze-in period. Releases have been reduced to as low as 16,000 cfs in past years as the head of ice advanced upstream from the upper end of Lake Oahe. This action is taken to prevent flooding of housing developments adjacent to the river in Bismarck and Mandan, North Dakota. Releases can be safely increased without increasing the river stage after an ice cover is established. After the river ice cover has stabilized in the downstream Missouri River reach around Bismarck, releases from Garrison can be gradually increased without increasing the river stage. Experience has shown that approximately 1 month after the initial freeze-in at Bismarck, releases approaching 27,000 cfs are possible. Tributary runoff between Garrison Dam and Bismarck prior to the time the Missouri River becomes ice-free must be considered in scheduling Garrison releases. The 27,000 cfs winter release rate is a reduction from the original Garrison powerplant capacity winter release rate of 35,000 cfs. This reduction is attributed to aggradation in the upper end of Oahe, which has caused a reduction in channel capacity.

7-04.9.6.3. **Oahe.** Experience has indicated that the normal powerplant peaking at Oahe maintains the 7-mile reach between Oahe Dam and the head of Lake Sharpe largely in an ice-free condition under all but the most severe weather conditions. Therefore, the channel capacity available requires no restrictions on winter discharges through the Oahe powerplant except during the most severely cold conditions. Several times since 1979, minimum and maximum restrictions have been placed on Oahe generation when extremely cold weather results in ice formation and high stages in the Pierre and Fort Pierre area. The formation of this ice cover at times has resulted in street flooding. The Bad River delta, which has raised the water surface for both open-water and ice-affected flows, exacerbates this problem. As a result, powerplant release restrictions have been imposed during critically cold periods. The previously discussed Corps project will reduce flood damage potential, which will allow for some reduction in these restrictions.

7-04.9.6.4. **Big Bend.** Big Bend discharges directly into Lake Francis Case, consequently, no restrictions on winter releases are necessary.

7-04.9.6.5. **Fort Randall.** Although the ice-covered Missouri River channel between Fort Randall Dam and the head of Lewis and Clark Lake could sustain higher discharges without resulting in damages, the average winter season release from Fort Randall is normally limited to about 15,000 cfs. This release restriction is due to the restricted ice-covered channel capacity below Gavins Point Dam combined with the small amount of storage space available in Gavins Point reservoir to re-regulate flows in this downstream project. Additionally, System regulation associated with an average winter release of 15,000 cfs from Fort Randall represents full winter service to the power function of the System. Winter release rates when the channel is ice covered may be increased gradually to average 25,000 cfs or slightly more when it is deemed necessary to evacuate accumulated flood storage.

7-04.9.6.6. **Gavins Point.** In the reach of the Missouri River from Gavins Point Dam to Kansas City, Missouri, ice jams can and have caused flood damage. This reach is particularly vulnerable due to intermittent freeze-ups and breakups of Missouri River ice cover throughout the winter. This reach of the river valley is also highly developed relative to the rest of the basin; therefore, there is a high flood damage potential related to serious ice jams. There has been ice-jam-related flooding during extremely cold winters when much of the Missouri River below the System is ice covered. The long travel time to this reach of the river makes river-icing problems particularly difficult, if not impossible, to resolve with System release changes. Normally, any attempt to modify the result of the river icing this far downstream, results in a risk to upstream ice cover and potential flooding. Experience has demonstrated that the icing situation normally resolves itself before the System release change arrives at the problem location. The travel times during open-water periods are 5 to 10 days to this reach, and, when ice cover is present, these times are extended considerably. Additional degradation of the Missouri River in the Sioux City vicinity has permitted the maximum Gavins Point winter release rate to be increased from 20,000 cfs up to 30,000 cfs. Open-water stages corresponding to a release of 30,000 cfs today are essentially the same as they were previously with a 20,000 cfs release. At times, reductions below the 25,000 cfs level may be necessary due to the formation of severe ice blockages in the Gavins Point to Sioux City reach.

7-04.9.6.6.1. During periods of extended drought, recent experience indicates an average winter release of 12,000 cfs with increases up to 18,000 cfs during river ice formation periods is required to meet winter water supply needs downstream of Gavins Point Dam extending as far as the Kansas City metropolitan area. When the System was first filled, the downstream reach of concern during the winter was much shorter, mostly confined to the Missouri River reach from Gavins Point Dam to Omaha, Nebraska. Additional years of degradation have, however, resulted in moving the most affected area downstream to at least Kansas City. It should be noted that most of these winter water supply problems are related to intake access problems that need to be corrected by the intake owners; however, a large number of problem areas may be an indication that it is more than just an access problem. The Corps updates a Missouri River Stage Trends Report each year that discusses the degradation and aggradation that is occurring on the Missouri River. The report shows graphically the effects of degradation or aggradation during the past several years for specific Missouri River locations at various levels of flow. Some intake owners have used this report in planning for adequate water supply access.

7-04.10. **System Flood Control Considerations During the Open-Water Season.** Maximum releases during the open-water season are based on downstream channel capacities at all times that flood control storage space is available to control existing or forecasted inflows.

7-04.10.1. **Use of Upper Three Reservoirs.** To the extent reasonably possible, the available flood control storage space available in the three upper System reservoirs, Fort Peck, Garrison, and Oahe, will be used for the control of floods in preference to the flood control storage space available in the three lower System reservoirs. The allocated flood control space in the downstream Big Bend, Fort Randall, and Gavins Point projects will be used to the degree necessary to re-regulate upstream System reservoir releases and to control runoff originating below the Oahe Dam drainage area.

7.04.10.2. **Balancing Available Flood Control Space.** To the extent reasonably possible, a balance of the vacant storage space (in terms of percent of allocated space) within both the Annual Flood Control and Multiple Use Zones and Exclusive Flood Control Zones will be maintained between the three larger upper; Fort Peck, Garrison, and Oahe projects when the flood control storage in the System is taxed or expected to be taxed by forecasted inflows. When flood control storage zones are more than able to contain forecasted inflows, departures from storage balance criteria will be permitted in the interest of enhancing other Congressionally authorized purposes. It should be recognized that, in the event of extreme deviations in expected runoff at individual System projects, some time will be required to achieve a storage balance in the upper three reservoirs without causing downstream damaging flows.

7-04.10.3. **System Flood Control Evacuation Priority.** Evacuation of System flood control storage immediately following the capture of flood runoff will be accomplished, insofar as practical, on the basis of established priorities in the order as follows:

1st Surcharge Storage from all of the System reservoirs.

2nd Exclusive Flood Control Storage Zones in the three lower reservoirs (Big Bend, Fort Randall and Gavins Point).

3rd Exclusive Flood Control Storage Zones in the three upper larger reservoirs (Fort Peck, Garrison, and Oahe).

4th Annual Flood Control and Multiple Use Zone in Gavins Point and in Fort Randall above elevation 1360.0 feet msl. Evacuation of Fort Randall storage below elevation 1360.0 feet msl is greatly influenced by power loads and the required power generation at Oahe and Big Bend

5th Annual Flood Control and Multiple Use Zones in the three upper projects (Fort Peck, Garrison, and Oahe). In general, evacuation of at least the upper portions of the Annual Flood Control and Multiple Use Zones in the three upper reservoirs should be conducted in such a manner as to maintain a balance of available allocated space within all three of the large reservoirs. Due to the restricted channel capacity below Fort Peck, it may be necessary, depending on conditions, to distort this balance to assure the evacuation of that System project.

6th Evacuation of the Annual Flood Control and Multiple Use Zone storage space will be made in a manner that, to the extent reasonably possible, will assure complete evacuation of this space prior to the beginning of the next flood runoff season while achieving the maximum beneficial conservation use of the stored water based on the operational objectives stated in this manual. The serious hazard of downstream flood damages in the case of late fall or winter ice conditions may make complete evacuation of Annual Flood Control and Multiple Use Zone prior to the next flood season inadvisable. In certain extreme high water years, there being a lesser risk associated with leaving some water in the Annual Flood Control and Multiple Use Zones as opposed to continuing the evacuation and, possibly, contributing to downstream flood damages during the late fall and winter months. Even in these high water years, a major portion of the Annual Flood Control and Multiple Use Zone will be evacuated prior to the next runoff season.

7-04.11. **Scheduling of System Releases.** The flood control purpose of the System continues to be a major consideration in scheduling System releases, irrespective of the amount of water contained in the System or the character of inflows to the System. Multipurpose regulation techniques described in this Master Manual are consistent with the flood control objectives. During the winter months, multipurpose releases are restricted due to the possibility of ice formation and consequent severe loss of channel capacity. Downstream flow support releases during the open-water season are based on maintaining specified target flows at downstream control points. This type of multipurpose regulation serves flood control and the other downstream purposes most of the time.

7-04.11.1. There are times, however, when the service provided to other purposes must be modified in the interest of the flood control objective. During winter months, severe ice jams can form on the Missouri River below Gavins Point Dam, even with the restrictions to System releases that are imposed during the winter season. Because this is the non-crop season, flood damages associated with the resultant high Missouri River stages are, fortunately, usually much less than would occur if similar stages were experienced during the summer season. Particularly severe ice jamming could result in flooding of property susceptible to flood damage; therefore, when severe ice jamming is occurring at downstream locations, a reduction in System releases may be warranted. While past experience indicates that those release reductions will have very little effect on stages associated with the jams, action by the Corps will indicate awareness of the problem and the desire to alleviate the adverse conditions. Such release reductions will usually be only temporary, extending, at the most, for a week or two. The overall level of service to other System purposes can usually be maintained by increasing releases after the river ice cover stabilizes. At other times, it is prudent to increase System releases prior to the onset of expected river ice buildup or even during a significant ice jam. Experience during recent years indicates that increasing System releases speeds the recovery of the Missouri River to more normal stages and assures that the downstream water intakes are operational sooner or affected less by the icing condition. The Corps will evaluate each ice-jam situation on a case-by-case basis and make a determination regarding the appropriate release.

7-04.12. **System Service Level.** Because the ability to evacuate System storage is severely restricted during the winter months, the necessary increases in System release rates for storage evacuation purposes above the rates necessary for navigation and other authorized purposes will largely be made during the navigation season. The methodology to determine releases to evacuate flood storage and reduced System releases during periods of downstream flood events is an extension of the "service level" and "target flow" concepts described in Paragraphs 7-03.2 through 7-03.2.1.1 of this chapter. Basic to use of the "service level" concept is a definition of the minimum and maximum service levels that can be maintained while meeting the other regulation objectives.

7-04.12.1. **Flood Control Considerations for the System Minimum Service Level.** As discussed earlier in this chapter, the minimum open-water level that will sustain the navigation purpose throughout the Missouri River navigation project is the 29,000 cfs service level. Target flows for this service level are 25,000 (29,000 - 4,000) cfs at Sioux City, Iowa and Omaha, Nebraska, 31,000 (29,000 + 2,000) cfs at Nebraska City, Nebraska and 35,000 (29,000 + 6,000) cfs at Kansas City, Missouri. Making release reductions below this service level for flood control purposes could have serious adverse effects on navigation, downstream recreation, and water supply. Adverse effects on power production are also quite probable with sharply reduced System releases. Release reductions to below the minimum navigation service level should, therefore, be made only when it is reasonably assured that the reductions will be of significant benefit from the flood control standpoint. Reductions below the minimum service level will not be made without consideration of the effects on other project purposes.

7-04.12.2. **Flood Control Considerations for the System Full-Service Level.** The full-service level of downstream open-water flows is 35,000 cfs. This is the flow necessary to meet the navigation channel requirements along with all other Congressionally authorized project purposes, such as water supply and recreation, served below the System. Missouri River target flows for this service level are 31,000 cfs at Sioux City and Omaha, 37,000 cfs at Nebraska City and 41,000 cfs at Kansas City. Navigation and some other authorized purposes are enhanced to some extent by flows in excess of those provided by this full-service level. Powerplant capacities of the downstream powerplants are also generally sufficient to use System release rates somewhat in excess of those necessary for full-service flows. Any enhancement to navigation and power production would be negligible for service levels increased beyond the 45,000 cfs service level. System releases above 45,000 cfs may, however, be necessary for flood storage evacuation purposes.

7-04.12.2.1. During the winter season, a 5,000 cfs or higher release level from Fort Randall Dam can be sustained during all past hydrologic conditions since 1898 with the present level of water resource development. Reductions below this level will not be made. The full-service winter level corresponds to a 15,000 cfs average winter release from Fort Randall Dam. Past experience has indicated that the winter release level can be increased to 25,000 cfs from Gavins Point Dam with only a modest increase in the potential for downstream ice-jam flooding. This increased potential is held to a minimum by selective release scheduling through the winter season, based on temperature forecasts and observations of current or forecasted ice conditions. In high runoff years when complete evacuation of the accumulated flood control storage during an extended navigation season would result in release rates that are substantially above normal, consideration will be given to scheduling winter System releases in the 25,000 to 30,000 cfs range to provide the most effective overall System flood control regulation.

7-04.13. **System Service Level Selection for Flood Control Evacuation.** Selection of the appropriate service level for flood storage evacuation purposes in excess of the full-service level is dependent on anticipated runoff from the Missouri River drainage area above the System; depletions to this runoff that can be expected to occur prior to the time this runoff appears as inflows to the System reservoirs; current storage conditions in the System and in the major tributary reservoirs located above the System; and evaporation from the System reservoirs. Plate VI-1 was developed to determine the service level at any time during the year. This plate relates the annual water supply and time of year to the appropriate System service level. If a significant growth in depletions occurs, appropriate revisions should be made to Plate VI-1. The revisions would be necessary because the water supply necessary to maintain the indicated service level is based on depletions expected. Determination of water supply is made based on a combination of (a) forecasted runoff above Gavins Point Dam from the current date through December, (b) current amount of water in System storage, and (c) the tributary reservoir storage deficiency.

7-04.13.1. **Forecasted Runoff.** The forecasted runoff for the remainder of the current calendar year is developed by procedures described in Paragraph 6-04.1.1 of this Master Manual, with specific forecast techniques described in detail in MRD-RCC Technical Study MH-73.

7-04.13.2. **Tributary Storage Deficiency.** The current tributary water-in-storage deficiency is developed by first accumulating the current reservoir water-in-storage in each of the 10 tributary USBR reservoirs listed in Table VII-6. All of these reservoirs are located above the System. These reservoirs, when filled to levels that can be expected during years of excess runoff, have a storage capacity of over 6 MAF. For the purpose of determining an appropriate System service level, a 5.5 MAF level of tributary reservoir storage was selected as the base level for computation of an acceptable water-in-storage level condition by March 1 of the next year. If there is currently more water than 5.5 MAF, the difference is subtracted from the water supply value computed for use in Plate VI-1, and vice versa, as a second step in the computation.

Table VII-6
USBR Projects Used for Calculating Tributary Storage Deficiency for the Water Supply Computation

Lima	Tiber
Clark Canyon	Bull Lake
Hebgen	Boysen
Canyon Ferry	Buffalo Bill
Gibson	Yellowtail

7-04.13.3. **Future Adjustments to Service Level.** It can be expected that future adjustments to Plate VI-1 may be required. Several factors and past history indicate that changes in tributary reservoir storage and in System storage due to sedimentation and other factors may require some adjustment when they become significant. Also significant Missouri River basin depletion changes may require adjustment. A significant change in release patterns for any reason may require the information provided on Plate VI-1 to be adjusted since it assumes a steady flow will be provided throughout the remainder of the period.

7-04.13.4. **Determining the Service Level for Flood Control Evacuation.** Plate VI-1 presents water supply (System water-in-storage plus anticipated runoff into the System for the remainder of the year) evacuation curves. Releases based on the curves can be expected to result in the evacuation of the System to the base of the Annual Flood Control and Multiple Use Zone, provided scheduled winter releases can also be maintained, by the following March 1. Determination of the appropriate service level is accomplished by computing the current tributary reservoir water-in-storage excess or deficiency and adding or subtracting it from the current actual System water-in-storage. The resulting water-in-storage is then added to the forecasted remaining calendar year runoff into the System to obtain the current water supply value. The water supply value, which is computed as described above, is then used to enter Plate VI-1. By following the water supply value horizontally to the current date, the appropriate service level on which System releases should be based is determined. Forecasted runoff is an essential (Plate VI-7 shows an example of the calendar year forecast) component to determining the service level. Because forecasts of future runoff (which may not materialize) are basic to the use of this plate, and because the potential for downstream tributary flood runoff is greater during the spring and early summer months, the service level provided should not be increased above the 35,000 cfs, full-service level prior to July 1 unless an indicated service level of 40,000 cfs or greater is identified by using Plate VI-1. This limitation provides a factor of safety in favor of the flood control purpose. For service level determinations below full-service, release rates are computed based on actual water-in-storage checks discussed in this chapter and on Plate VI-1. The March 1 date indicators on the curves are consistent with the service level definitions defined in this chapter.

7-04.14. **System Expanded Full-Service Level.** The 35,000 cfs service level is considered to be the full-service level for meeting all authorized purposes of the System. The initial increase above this full-service level has been designated as the "expanded full-service level" and consists of extending the navigation season 10 days beyond its normal closing data of December 1 at the mouth of the Missouri River. Additionally, as a storage evacuation measure, winter releases averaging 20,000 cfs will be scheduled from Gavins Point Dam. While a primary purpose of this expanded full-service is for the evacuation of storage space in the System, it also benefits the other authorized purposes. An additional 10 days of navigation service also results in the transfer of a substantial block of power from the normal fall navigation season, when power is relatively abundant, to the winter season. In some years, ice conditions may preclude this extension, and, if such occurs, it may be necessary to carry a minor amount of excess water over to the succeeding flood season. In recognition of ice problems that may occur, releases during the 10-day extension of the navigation season will be made at the full-service level unless storage evacuation requirements are such that higher releases are deemed necessary. The announcement of this expanded service should be made as soon as it is determined to allow the downstream users to take full advantage of the 10 days of higher flows.

7-04.15. **System Reservoir System – Missouri River Flood Target Flows.** Normally, the difference between the selected service level and target flows at control points below the System will be the same for evacuation of flood storage as for normal navigation or downstream flow support releases. This results in Missouri River flow targets located at Sioux City and Omaha of 4,000 cfs less than the current service level, at Nebraska City of 2,000 cfs greater than the current service level, and at Kansas City of 6,000 cfs greater than the current service level. Similar to navigation or downstream flow support targets, storage evacuation targets are for minimum flows at the controlling flow target location. For example, with a 40,000 cfs service level, a target flow of 42,000 cfs at Nebraska City might be controlling with Sioux City, Omaha, and Kansas City forecasted flows in excess of their respective targets of 36,000, 36,000, and 46,000 cfs, respectively. When target flows at the non-controlling locations approach critical levels from a flood damage standpoint, the service level-target flow concept is modified to emphasize System regulation for downstream flood control instead of navigation support or System storage evacuation.

7-04.16. **Missouri River Flood Target Flows – Full-Service Provided.** As a flood control measure, the normal relationship between service levels and target flow levels may be modified when large amounts of tributary inflow are forecasted between Gavins Point Dam and the downstream flow target control points. Criteria for these modifications are presented in Table VII-7. For example, if the current service level were 40,000 cfs, System releases would be reduced consistent with the full-service level if it were deemed necessary to maintain flows at or below 46,000 cfs at Omaha, 52,000 cfs at Nebraska City, or 76,000 cfs at Kansas City. These target flows may be modified by up to 5,000 cfs after consideration is given to antecedent, current, and projected hydrometeorological conditions. Modification of target flows to the full-service levels provides a safety margin for the inability to accurately forecast downstream tributary runoff and from unexpected rainfall. There are, however, conditions during large runoff years similar to 1997, when the above criteria must be replaced with a System regulation approach that will result in the best flood control for the lower river. Repeated reductions in System releases early in the runoff season will likely result in the need to make higher System releases to evacuate accumulated floodwater later in the season. The progressive increase in System releases must be evaluated against the approach of taking some small flood risk over a longer period of time and providing a slightly higher System release initially.

Table VII-7
Criteria for Modifying Target Flows – Full Service

Target flows will be reduced to those consistent with the full-service level of 35,000 cfs when one or more of the anticipated downstream flows exceed the current service level flow values by more than:	
6,000 cfs at Omaha	(target flow plus 10,000 cfs)
12,000 cfs at Nebraska City	(target flow plus 10,000 cfs)
36,000 cfs at Kansas City	(target flow plus 30,000 cfs)

7-04.17. **Missouri River Flood Target Flows – Minimum Service Provided.** As an additional flood control measure for the lower Missouri River, the normal relationship between minimum service levels and target flow levels will be modified when large amounts of tributary runoff are forecasted or occurring between Gavins Point Dam and the downstream flow target control points. Selected criteria for these modifications are noted in Table VII-8. These target flows may also be modified by up to 5,000 cfs after consideration is given to antecedent, current, and projected hydrometeorological conditions. Modification of target flows to the minimum service levels provides even a greater safety margin (than to the full-service level) for the inability to accurately forecast downstream tributary runoff and from unexpected rainfall. There are, however, conditions during large runoff years similar to 1997, when the above criteria must sometimes be replaced with a System reservoir regulation approach that will result in the best flood control for the downstream reach for the entire flood runoff season. Repeated reductions in System releases early in the runoff season will result in the need, later in the season, to make higher System releases to evacuate accumulated floodwater. The progressive increase in System releases must be evaluated against the approach of taking some small flood risk over a longer period of time. This System flood control approach is accomplished by providing a slightly higher System release initially or earlier in the flood runoff season and, therefore, lower flows are provided later in the year. This flood control reservoir regulation approach is at times the preferred option when it is known the flood runoff season will be extended because of the large volume of runoff expected.

Table VII-8
Criteria for Modifying Target Flows – Minimum Service

Target flows will be reduced to those consistent with the minimum service level of 29,000 cfs in order that one or more of the anticipated resultant downstream flows exceed the current service level flow value by more than:	
11,000 cfs at Omaha	(target flow plus 15,000 cfs)
22,000 cfs at Nebraska City	(target flow plus 20,000 cfs)
66,000 cfs at Kansas City	(target flow plus 60,000 cfs)

7-04.18. **Coordination of System and Tributary Reservoir Flood Control Releases.** At Kansas City, the farthest downstream control point used for scheduling System releases, control of streamflow is also provided by tributary reservoirs located in the Kansas River basin. Flood control regulation criteria and techniques applicable to the Kansas River basin reservoir projects when this competition does not exist are described in the Kansas River Basin Master Manual and in the project manuals for individual Kansas River basin reservoirs. At times, however, competition will exist between the two reservoir systems for use of the available Missouri River channel capacity at Kansas City and downstream. When storage evacuation is required from the Kansas basin reservoirs, coordinated regulation of the two systems of reservoirs will proceed as follows.

7-04.18.1. If the System water supply is such that a service level of 35,000 cfs or less is applicable, Kansas River basin reservoirs will have priority for the Missouri River channel capacity below Kansas City. Target flows on the Missouri River upstream from Kansas City will be reduced up to the minimum service level (if required) so that System releases do not contribute to forecasted Kansas City flows in excess of the current System service level flow value plus 66,000 cfs.

7-04.18.2. Releases from Kansas River basin reservoirs with accumulated flood control storage in Phase II or higher will have priority over System releases for the available channel capacity, irrespective of the current System service level. System releases will be scheduled as described in Paragraphs 7-04.16 or 7-04.17 after consideration is made of the effects of Phase II and Phase III releases from Kansas River basin reservoirs on Kansas City target flows.

7-04.18.3. If System storage evacuation requires a service level greater than the 35,000 cfs level, the System release requirements will have priority over releases from Kansas River basin reservoirs with accumulated flood control storage in the Phase I zone. Releases from the Phase I zone of Kansas basin reservoirs will be scheduled on the basis of System releases made in accordance with criteria given in Paragraphs 7-04.16 or 7-04.17.

7-04.18.4. During the period of flood storage evacuation from the Kansas River basin reservoirs, close coordination between the Corps' Kansas City District water control office and the RCC is required for the development of release schedules. This coordination consists of the following actions.

7-04.18.4.1. The Kansas City District water control office will develop release schedules for their tributary reservoirs with storage levels in Phase II or higher and furnish the resultant forecasted flows of the Kansas River at Desoto, Kansas to the RCC in a timely fashion so that it can be integrated into the RCC's daily Missouri River streamflow forecast. Based on the above, the RCC will schedule releases from the System and furnish this schedule to the Kansas City District in the form of the RCC's Missouri River streamflow forecast. The Kansas City District will then take advantage of any remaining Missouri River channel capacity available at Kansas City and downstream Missouri River locations to schedule releases from reservoirs in the Phase I zone.

7-04.19. **Lower Missouri River Flood Flows.** Because the water travel time to Missouri River locations below Kansas City is over 6 days from Gavins Point Dam, the Kansas City flow target location is the most downstream location for which System releases will normally be scheduled based on a forecast. Experience has shown that predicted hydrologic conditions that could produce large rainfalls are only mildly accurate for periods 3 to 6 days in advance and are not accurate for periods more than 6 days in advance. If System release reductions will not result in missing flow targets and hydrologic forecasts indicate that System release reductions will result in flood damage reductions below Kansas City, a reduction in System releases will be scheduled. This should not be attempted if it will significantly impact System or tributary reservoir flood storage evacuation. Due to the long-range forecasts required and the current state-of-the-art forecasting technology, such System release reductions for this purpose will seldom be necessary except during severe, prolonged downstream flooding periods. Requests for coordinated flood storage evacuation from the System due to flooding on the Mississippi River have occurred in the past. This regulation has been requested even though there are no flood control targets below Kansas City or on the Mississippi River. These requests are rare and difficult to achieve because of the travel time involved. If System regulation changes can be accomplished without significant adverse affects, they should be attempted. There have been times when the RCC has also been requested to coordinate tributary reservoir releases from Corps' projects located in the

Kansas City District to minimize flood crests on the Mississippi River. These actions have proven beneficial to preventing or reducing flood damages on the Mississippi River.

7-04.20. **Individual System Project Reservoir Regulation Techniques.** Volumes 2 through 7 of the Mainstem Reservoir Regulation Manual series present the details necessary for integrating regulation of the individual System reservoirs with System regulation described in this volume. Paragraph 1-02.1.in this manual presents an explanation of the Mainstem Reservoir Regulation Manual series. While regulation of many of the tributary reservoirs in the Missouri River basin is independent of System regulation, integrated regulation will, at times, be required. Paragraph 7-04.18 describes the coordination necessary in regulating Kansas River basin reservoirs. Individual System project manuals describe coordinated regulation with those tributary reservoirs that are most closely related with each individual System project, particularly those tributary reservoirs that have System replacement flood control storage, as described in Paragraph 7-04.4.1.of this manual.

7-04.20.1. During extreme floods approaching the magnitude of the greatest floods of historical record, it is quite probable that surcharge regulation will be required of one or more of the System projects. If such an event were to occur, System regulation would be conducted largely on a reservoir-by-reservoir basis and would be based on techniques described in the individual project manuals. System releases would be as defined by the Gavins Point procedures. In the event of a prolonged communications failure between the RCC and individual projects, System release rates would be scheduled according to the emergency procedures outlined in the individual System project manuals.

7-04.21. **Responsibility for Application of System Reservoir Regulation Techniques.** Due to the necessity for integrated regulation to secure the maximum degree of beneficial use from all System storage, the RCC will be responsible for, and will direct, the regulation of all the System reservoirs in accordance with the relationship between the RCC and District offices outlined in Chapter VIII of this manual. Such direction will normally be in the form of regulation orders to the System projects that specify releases to be maintained, the permissible fluctuations in this release rate, and the period through which the order will be applicable. The respective District offices provide personnel for operation and maintenance of the projects and are responsible for the physical manipulations necessary to carry out the directives.

7-04.22**. Responsibility for System Dam Safety and Emergency Regulation.** Although regulation procedures for the System and individual System reservoirs are normally developed in the RCC, it is the responsibility of the District to maintain adequate provisions for maintaining the integrity of the System dams at all times. The RCC will be informed, and a specific method of System or individual reservoir regulation may be recommended by the District at any time it is believed that any part of a project's dam structure may be endangered by existing or anticipated conditions. In addition, the RCC will be advised when local flood conditions are such that improved conditions may result by specific methods of System reservoir regulation. The RCC will consider this information and field recommendations in conjunction with other known existing conditions in the basin prior to issuing System project regulation instructions. If Corps staff believes that the integrity of a dam is endangered and communications with the RCC are not possible, the project office and/or the District office may modify instructions (regulation orders) to ensure the safety of the structure. When communication with the RCC is impossible and the project/s are under emergency conditions, the District or project is entirely responsible for application of emergency regulation techniques. Paragraph 7-16 of this chapter contains a more detailed discussion regarding System emergency regulation procedures.

7-04.23. **Responsibility for Flood Control Reservoir Regulation Coordination in Missouri River Basin.** Normally, tributary reservoir regulation is a function of the Districts with pertinent reservoir regulation information furnished to the RCC. When tributary reservoir regulation affects Missouri River flood flows or navigation on the Missouri River, tributary reservoir regulation will, however, become a direct concern of the RCC. During such periods, the RCC will issue pertinent tributary reservoir regulating instructions so that flood damages may be held to a minimum through integrated regulation of all flood control reservoirs in the Missouri River basin. The appropriate District, with only nominal Division supervision, will direct tributary reservoir regulation during periods of tributary floods not extending to the Missouri River. The provisions of Paragraph 7-04.22 of this manual regarding safety of the project and conflicts between local and general flood protection will also apply to tributary reservoirs during periods when they are regulated as directed by the RCC. The Corps' Guidance Memorandum entitled, "Reservoir Control Center (RCC)", dated March 1972, serves as the document that details the role and responsibilities of the RCC in managing and regulating the System, including the coordination responsibilities for the regulation of tributary reservoirs during major flood control events.

7-04.24. **Reporting of System Flood Control Operations.** Status reports regarding System flood control operations are prepared by the RCC and provided to key Division and District offices on an immediate basis. The reports are normally distributed by email and/or posted to the internal Corps website. The Power Plant Control System (PPCS) allows RCC staff access to all System projects to obtain real-time System data such as instantaneous releases from each power unit, spillway releases, outlet tunnel flows, and reservoir elevations. This information is transmitted automatically to the RCC database on an hourly basis. Once these data are received in the RCC, reservoir storages and inflows are calculated. Even with all the project data available to the RCC, it is sometimes necessary and prudent for RCC staff to speak directly to the project staff to assess any potential problems with the project, its major features, or any matter that could affect future project release decisions. During severe flood periods, daily summaries of hydrologic conditions and reservoir regulation will be furnished to Office of the Chief of Engineers by the District Engineer. Various types of information relative to floods are required in the flood control operations status reports including reservoir name, reservoir elevation, forecasted maximum elevation and associated date, current and forecasted rates of inflow and outflow in cfs, percent of flood control storage used to date, and any other specific information pertinent to the flood situation. Coordination is required with the RCC prior to the Districts furnishing this information relating to the System to the Chief of Engineers.

7-04.25. **Monthly System and Tributary Reservoir Reports.** Each month, the RCC prepares a reservoir summary report, also referred to as an MRD 0168 Report, for each System project, indicating daily reservoir elevation, storage, inflow, release, and estimated evaporation. The appropriate District office prepares the same report for each of the Corps' tributary reservoirs and all USBR tributary reservoir projects having flood control as an authorized purpose. The District reports are either provided to the RCC electronically or the data to create the report is available in the RCC database.

7-04.26. **Historical Examples of System Regulation During Major Floods.** Although Fort Peck was placed in operation in 1937, additional projects on the System were not operable prior to the 1950's and early 1960's. Limited System regulation was initiated in 1953, following the closure of the Fort Randall embankment in 1952 and Garrison in 1953. Gavins Point was closed in 1955, Oahe in 1958, and Big Bend in 1963. Although this completed the embankment closures on the System, regulation of the System was somewhat limited in the early years of regulation by project construction and the completion of real estate activities. In July 1966, installation of all of the present power units was completed, and the following summer the System reservoirs reached their base of the Annual Flood Control and Multiple Use Zones for the first time. Only since that time, have the individual System reservoirs, therefore, been regulated as a completely integrated System. Appendix A contains the historical examples of flood since the system was completed in 1967.

7-04.26.1. **System Storage Accumulation.** Initial fill of the System was accompanied during a period of below-normal runoff from the Missouri River drainage area above the System. Runoff was well below normal during each year of the 8-year period, extending from 1954 through 1961. The cumulative effect of these low-runoff years resulted in the second most severe drought period for the Missouri River basin since 1898. Runoff above the System averaged somewhat above normal from 1962 through the mid-1980's with well-above-normal amounts occurring in some years. The 6-year drought extending from 1987 through 1992, represented a particularly challenging System regulation period. The 1990's represent the highest runoff decade of the past century. As of the writing of this manual (March 2004), the System has been experiencing drought conditions since 2000. Plate VII-2 illustrates month-by-month accumulation of water in the System and its distribution in the individual System reservoirs. As shown on Plate VII-2, the Carryover Multiple Use Zone was first filled in 1967. Since 1967, the volume of water in System storage has generally remained within the Annual Flood Control and Multiple Use Zone that extends from 57.1 MAF to 68.7 MAF. The typical annual variation of the amount of water in System storage shown on Plate VII-2 reflects the normal accumulation of water-in-storage during the March through July flood season and normal evacuation of accumulated water to regain this space during the remainder of the year.

7-04.26.2. **System Regulation Effects on Streamflow.** The accumulation and evacuation of water in System storage has had a major effect on streamflow below the System. Plate VII-3 presents hydrographs of mean monthly flows at Yankton, South Dakota, which is immediately below Gavins Point Dam, since the System has been fully operational. The flows at Sioux City consist primarily of Gavins Point Dam releases. Unregulated flows are determined at various sites for the purpose of calculating flood damages prevented. Unregulated daily flows are determined by representing the regulated flows adjusted for upstream reservoir effects. The upstream reservoir effects include storage of runoff, evaporation from the reservoir surface, and precipitation directly on the reservoirs. The reservoir effects used in the development of unregulated flows include those from major tributary reservoirs and the System projects. The major portion of the reservoir effects results from regulation provided by the System. Unregulated flow development was on a mean daily basis, and only the mean monthly flows are shown on Plate VII-3.

7-04.26.3. The 1967, 1972, 1975, 1978, 1993, and 1997 hydrographs illustrate the effects of System regulation on substantial flood inflows. Plates VII-4 through VII-9 also illustrate characteristic patterns of releases from the System. Data to produce similar hydrographs that indicate System regulated versus unregulated flows are stored on the RCC database. The data are available for all years of regulation since 1950 and for other locations within and below the System. Complete write-ups for each year are on file as separate reports in the RCC.

7-04.27. **Regulation During Extreme Floods and During Emergencies.** The following paragraphs briefly describe the System flood control regulation procedures for extreme floods and during emergencies.

7-04.27.1. **System Regulation During Extreme Floods.** During extremely large foods that may use all of the flood control storage zone capacity provided in any of the individual System projects, regulation will primarily be based on conditions affecting that particular project rather than the System as a whole. Examples of regulation during this type of flood are, consequently, not included in this manual. Individual System project water control manuals address this subject with the Gavins Point manual providing the best example of System releases that could be expected to occur during such events. The effects from individual project regulation will be integrated into a System model to balance the effects throughout the System and afford greater flood control downstream than that provided by any one project. Paragraph 7-04.10.3 of this Master Manual describes the flood storage evacuation priority order for the System and individual projects. The System daily and long-range study simulation models discussed in Chapter VI include this evacuation priority as a normal regulation procedure. Further model refinement is provided by manually adjusting individual project and System releases to achieve the desired result.

7-04.28. **Emergency Procedures.** Regulation criteria in the event of a communications failure with the RCC are detailed in individual project manuals and their associated instructions to project personnel for such events. Examples of their application are contained in individual System project water control manuals.

7-04.29**. System Flood Control Storage Analysis.** This manual presents a new CWCP primarily making changes to the drought conservation measures used for System regulation. Normal and flood control System reservoir regulation procedures have not been changed, but they have been updated to reflect current conditions. The amount of System flood control storage space required has been analyzed in depth for the Master Manual Study. Results indicate that very little additional flood control benefit could be obtained from additional flood control storage space in the System. In general, much of the basin lies below the System. That fact has prevented, and will continue to prevent, the System from controlling all flooding along the Missouri River. Normally, enough vacant space exists in the System prior to the runoff season to control the significant floods that occur above the System, as demonstrated by the 200-percent-of-normal event that occurred in 1997. This storage normally provides the additional space needed to provide for an extensive reduction in System releases to control downstream flooding. The decade of the 1990's provided four of the top seven basin runoffs that occurred in the 106-year Missouri River basin historic runoff record (1898-2003). Regulation of these runoffs has refined the System flood control techniques described in this chapter and provided many examples of successful System flood control regulation. Study and refinement of System flood regulation techniques will continue along with research and development to improve the long-range forecasting of expected runoff in the Missouri River basin.

7-05. **Multipurpose Regulation Plans.** In the course of the planning, design, construction, and regulation of the System, many long-range regulation studies have been made to establish and demonstrate the capabilities of the System to meet the many project purposes and to establish criteria for planning, design and regulation purposes. Other shorter-term studies, on a continuing basis, lead to AOPs, 5-year projections, and many other special purpose plans. These studies provide a sufficient volume of predetermined vacant storage capacity at each of the System reservoirs at the beginning of the flood season; therefore, they recognize the flood control purpose. The daily routing model (DRM), which uses a daily time-step, serves as a useful tool in the examination of detailed flood control regulation criteria and the other project purposes.

7-05.1. **Long-Range Regulation Studies.** Long-range regulation studies of the System encompassing the hydrologic period from 1898 to the time of the study have been referred to previously in this manual, particularly in Chapter VI, Hydrologic Forecasts, Paragraph 6-04. Long-Range Forecasts, where some of the limitations of these studies were discussed. Major studies have been published and distributed to interested Corps offices, USBR, Western, and others. The RCC has a list of the major studies performed in the past and pertinent data as to the basic conditions assumed in their performance. Future studies by the RCC will be needed to evaluate proposed Adaptive Management actions and other regulation considerations as the System matures under this updated water control plan.

7-05.2. **Service to System Authorized Purposes.** The long-range regulation studies demonstrate the service (e.g., flows, reservoir levels, and power generation values) that the System is expected to provide for the basic purposes under various scenarios with differing levels of basin development and conditions of water supply. They also serve to examine variations in regulation criteria and in this manner keep criteria consistent with changing emphasis upon specific purposes through the years. The latest studies reflect current conditions (or near-term anticipated future conditions) and the service to purposes provided by the System under current criteria included in the Master Manual.

7-06. **Emergency Regulation Procedures (Standing Instructions to Dam Tender).** The Standing Instructions to the dam tender that would be used in the event that communication is lost with the RCC are contained in the individual System project water control manuals and are not repeated in this document. Those instructions are to be used only in the event of a significant communication failure over an extended period of time that results from a catastrophic event. The RCC uses real-time simulation modeling to effectively regulate the System and this cannot be replicated in the instructions to the dam tenders. These orders serve only as a temporary way of bridging the time period between not having orders and until RCC staff can run their models and issue new orders. The RCC normally schedules each of the System projects for more than 1 day into the future, many as long as the next week. It is unlikely, even in a significant communications failure, that the System projects would not have Power Production and Reservoir Regulation orders with which to regulate the project.

7-07. **Flood Control Purpose System Regulation.** The discussion of the planning and subsequent regulation for the flood control purpose of the System constitutes a major portion of this Master Manual. The planning of the sizing of the individual Mainstem project flood control zones is described above and in Appendix A. The reservoir regulation of the System for flood control is detailed in the paragraphs above. Storage of large runoffs in the System for multiple purpose use later by releasing during low-flow periods is consistent with the Congressionally authorized flood control purpose. Similarly, storage of water for the control of floods is also compatible, to a great extent, with multiple purpose regulation of the System. The flood control purpose of the System will be given the highest System priority during periods of significant runoff when loss of life and property could occur. Regulation efforts will be made to minimize these losses. The flood damage prevention provided by the System has been greater than originally envisioned because of the protection provided to the critical urban areas in the basin during the 1993 and 1997 flood events. Plate VI-2 identifies the flood damages prevented to date by the System. The $24.8 billion in accumulative damages prevented by the System exceeds the cost of building the entire System in today's dollars. Several specific years (1993, 1995, 1996, 1997, and 1999) have resulted in more than 60 percent of the total damages prevented, primarily due the protection of downstream urban areas located below the System. The unpredictability of these major flood events means that, to fulfill the flood control operational objective of the System, the Exclusive Flood Zone should be kept empty except during major flood events. This unpredictability also means that the System should normally be at the base of the Annual Flood Control and Multiple Use Zone (57.1 MAF) prior to the beginning of the flood season. The use of Plate VI-1 as a guide in determining the service level for evacuation of water captured in the Exclusive Flood Control and the Annual Flood Control and Multiple Use Zones and for normal and conservation regulation is discussed in Chapter VI and above. This plan was developed with the intent of fully meeting the Congressionally authorized flood control purpose.

7-07.1. **Flood Control Regulation Problems Associated with Stage–Discharge Variation and Channel Capacity Deterioration.** The following paragraphs discuss the problems associated with System regulation during flooding with regard to variation in the stage-discharge relationship on a seasonal basis and channel degradation.

7-07.1.1. **Seasonal Variations in the Stage-Discharge Relationships.** The Missouri River is an alluvial stream with a movable sand bed; consequently, marked variations in the relationship between stages and corresponding discharges occur. While some of these variations may be more or less permanent in nature due to changes in channel regimen, there is a seasonal shift in this relationship, particularly in the reach extending from Sioux City to Kansas City. Investigation indicates that this shift is related to water temperature and consequent bed form configuration. In essence, the typical seasonal shift results in higher stages during the mid-summer months than during the early spring and fall months for similar rates of flow. Stage variations of approximately 1 foot may occur as a result of these seasonal rating curve shifts. Gavins Point Dam releases are made to meet a downstream level of service (target flows) at Sioux City, Omaha, Nebraska City, and Kansas City. Evaluation of these service level requirements is based on the stage-discharge relationship at the above USGS gaging station locations. Accurate determination of flow based on observed stage at the gaging stations is difficult during the spring and fall water temperature rating curve shift period, requiring more frequent Missouri River discharge measurements and database corrections.

7-07.1.2. **River Channel Deterioration.** Evidence exists of a permanent shift in the stage-discharge relationship at numerous locations along the Missouri. This shift generally is in the direction of reduced channel capacity for higher flows and has been very significant at some locations. For example, below Fort Randall Dam and just upstream from the mouth of the Niobrara River, land areas adjacent to the river channel are now being inundated with flows less than 50,000 cfs that were dry with flows of over 150,000 cfs prior to the time that System reservoir regulation began. By the mid 1970's, the bankfull capacity was reduced to 60,000 cfs, and further reductions continued to 44,000 cfs in 1985 and 35,000 cfs in 1994. The high releases in 1997 resulted in an improvement in channel capacity when some deposits were scoured from the channel. Many similar instances could be cited, although generally not as extreme as the above example. The effects of these channel changes have been to reduce capacity and can be partly attributed to the control by the System of flood flows and their scouring. Some deterioration in channel capacity at some locations may have, however, resulted from bank stabilization measures that have been constructed for navigation or streambank erosion control purposes.

7-07.1.2.1. Conversely, in some Missouri River reaches, evidence exists of significant degradation, or lowering, of the Missouri River channel. As expected, degradation has occurred downstream of the System powerplants. In these cases, degradation has been considered beneficial, as increased power heads result that allow a greater amount of power production. On the Missouri River below the System, particularly in the Missouri River reach from Gavins Point Dam to Omaha, river stages have decreased markedly since System regulation first began in 1954. This degradation has had adverse effects on; recreation facilities, water intakes, well fields, navigation docks, tributary channel stability, and wetland habitat. The degradation has had a positive effect on flood control, as channel capacity has improved and areas that were once subject to flooding are now high and dry during significant release increases. For example, the flood control situation has been significantly improved for moderate floods in both the Dakota Dunes area near Sioux City and the Kansas City urban area because of additional channel degradation during the 1990's.

7-07.1.3. **Flood Control Regulation Problems Associated with Interior Drainage and Groundwater.** Also of concern is the effect of higher System releases during prolonged flood evacuation periods on interior drainage and groundwater tables in the reach of the Missouri River below the System. Higher Missouri River levels below the System make the draining of runoff that falls on cropland difficult, if not impossible, especially because the levee system constructed generally depends on draining into the Missouri River. Higher Missouri River levels also result in higher groundwater levels that make planting and harvesting crops difficult or impossible for farmland located just adjacent to the Missouri River. This is especially true in the aggradation reach just below the confluence of the Platte River with the Missouri River in Nebraska. Consideration is given to the effects of interior drainage and high groundwater levels in any prolonged flood control System regulation event.

7-07.1.3.1. Development of flood damageable property in flood-prone areas has been general and extensive throughout the entire reach of the Missouri River, especially in the areas downstream of the System projects. When higher-than-normal releases are required from System projects, flooding of floodplain lands and developments can, and should be, expected. The capture and metering of flood flows during the remainder of the year can also result in higher releases during late summer and fall. This period is normally not a high-runoff period, but, for those low-lying areas immediately adjacent to the Missouri River, poor drainage conditions are a continual concern.

7-07.2. **Other Flood Control Regulation Challenges.** The regulation of the System during years when the annual runoff is approximately equal to or greater than 30 MAF has occurred many times since the System became operational in 1967. The most significant flood runoff years are 1975, 1978, 1984, 1986, 1993, 1995, 1996, 1997 and 1999, all of which are documented in detail in the flood history of Appendix A. The 1975, 1978, and 1997 years stand apart from the others in the severity of the events. Most of the concerns arose from high pool elevations and passing the large volumes of water through the existing outlet works and into limited downstream channels to evacuate flood storage. The following should be recognized in a typical flood control situation.

7-07.2.1. System releases will be reduced to a minimum level to protect and minimize the loss of life and property downstream in all river reaches during significant flood events. The releases are never reduced to zero, because this would have significant negative impacts for just a small improvement in downstream flood control. Over reaction in the form of reducing releases to extremely low levels early in the runoff season may result in significantly less capability to control flooding, should a significant flood event or a succession of lesser flood events occur later. The System has a finite amount of storage available for flood control, and it should be used judiciously.

7-07.2.2. All reasonable attempts will be made to evacuate all of the water that is captured or retained in the System above the base of the Annual Flood Control and Multiple Use Zone prior to the following March 1. Most of this volume will be evacuated by December 1, prior to the onset of winter release restrictions due to expected limited winter releases because of river icing.

7-07.2.3. The System does not guarantee a flood-free zone in the Missouri River reaches between the System reservoirs and below the System. Downstream flooding will occur even if releases are reduced to minimums from the System dams because enough uncontrolled area exists downstream from several of the dams to cause major flooding if significant rainfall occurs. The potential extent and amount of damage caused by this runoff varies. Lack of floodplain zoning to discourage development in flood-prone areas will result in higher flood damage in the future even with the flood protection provided by the System.

7-07.2.4. If a flood occurs below the System, the damages are likely to be greater than if the same volume of flood occurs in reaches within the System because the major urban centers that exist below the System have a greater potential for very high flood damages. Two Missouri River reaches within the system below Garrison and Oahe, also have large cities on the floodplain, and the potential flood damage in these reaches is also very significant.

7-07.2.5. During past major flood events, a concern has developed that the upper three System reservoirs rise too high into their Annual Flood Control and Multiple Use and Exclusive Flood Control Zones. In 1975, a large rainfall event occurred in eastern Montana, and Fort Peck reached a maximum elevation that was 1.6 feet above its maximum operating level, or 1.6 feet into the surcharge zone provided for the control of extraordinary floods. Only Federal lands acquired for project purposes were inundated. Also in 1975, Garrison's maximum level reached elevation 1854.8 feet msl, or 0.8 foot into the surcharge zone but below the 1855-foot msl guide taking line for land acquisition. The majority of the concerns relating to high reservoir levels were received from the headwaters' area of the Garrison project. Lands affected were Federally-purchased lands affected by the backwater effects of both high reservoir levels and large inflow rates. These were lands leased to private individuals, subject to flooding if required for project regulation. Concerns were also voiced over flooding on the Missouri River near the mouth of the Yellowstone, upstream of the taking line; however, this land was flooded by high river flows, rather than by Lake Sakakawea. During the large plains and mountain snowmelt flood of 1997, Garrison again exceeded the maximum normal operating level following a large, local rainfall event after it had successfully captured snowmelt runoff. Oahe has been in its Exclusive Flood Control Zone several times during the 1990's, prompting concerns about high, prolonged reservoir levels at this System project. The RCC recognizes that encroachment has occurred into the surcharge zone of some System projects. This, however, has not reduced the effectiveness of these projects to control flood inflows. All studies to date have indicated that there is no long-term problem associated with having the large System projects in their Exclusive Flood Control Zones. This zone is designed to store water during major flood events and the maximum project benefits cannot be obtained unless this zone is used, when appropriate. Releases from System projects with water in their Exclusive Flood Control Zones should be increased to the maximum practical in order to use downstream channel capacity so that the Exclusive Flood Control and the Surcharge Zones are vacated as soon as possible to allow storage space for subsequent runoff, should it occur.

7-07.2.6. A question has arisen in recent years whether or not project releases should be increased to higher levels earlier in the season to lower maximum release rates and reservoir levels. This is a common practice for snowmelt-type flood events; however, this approach does not apply to rainfall events that cannot be predicted. With snowmelt events, the actual conditions during the melt heavily influence the amount of runoff volume produced. Unfortunately, the temperatures and associated rainfall during snowmelt, the most significant variables, cannot be reliably predicted. This results in a wide range of potential runoff volume for the same amount of accumulated snow. Releasing at higher-than-normal rates early in the season that cannot be supported by runoff forecasting techniques is inconsistent with all System purposes other than flood control. All of the other authorized purposes depend upon the accumulation of water in the System rather than the availability of vacant storage space. Unnecessary drawdown of water in the System would not achieve the regulation objective of optimizing service to all authorized purposes.

7-07.2.7. Bank erosion along the unstabilized portion of the Missouri River channel has been a past concern. Data available to the Corps indicate that average erosion rates through the unprotected areas since full System regulation began in 1967 are less than during pre-project conditions, although this improvement is small in some Missouri River reaches.

7-07.3. **Missouri River Open-Water Channel Capacities.** A brief summary of present open-water channel capacities for specific Missouri River reaches is given below. Discussion of ice-affected channel capacities is presented in 7.04-9.

7-07.3.1. **Fort Peck Dam to the Mouth of the Yellowstone River.** Damages in this reach begin with open-water flows of 30,000 cfs; however, with flows ranging from 50,000 cfs in the upper portion to 70,000 cfs in the lower portion of the reach, damages are relatively minor and limited mainly to pasture and other unimproved lands.

7-07.3.2. **Garrison Dam to Lake Oahe.** The main damage center in this reach is Bismarck. If Bismarck stages are not allowed to rise significantly above 13 feet, few flood damages are observed. Flood stage at the Bismarck gage is 16 feet. At the time Garrison Dam was constructed, this represented an open-water channel capacity of about 90,000 cfs; however, in 1975, after 20 years of reservoir regulation, the channel had deteriorated to the extent that open-water flows of about 50,000 cfs resulted in a stage of 13 feet. This is due in part to the Oahe delta affect just downstream of Bismarck. A substantial amount of floodplain development has occurred at low levels in the Bismarck/Mandan vicinity.

7-07.3.3. **Big Bend Dam to Lake Francis Case.** During the 1991 fall drawdown of Fort Randall, it was observed that the White River delta, which extends across Lake Francis Case, was having a damming effect that created different lake elevations upstream and downstream of the delta. In recent times, the upper reservoir elevation has been as much as 6 feet higher than that for the reservoir downstream from the delta. The Corps has published a revised elevation capacity table for Lake Francis Case reflecting the effect of this sedimentation near elevation 1347 feet msl and below.

7-07.3.4. **Fort Randall Dam to Lewis and Clark Lake.** Since System regulation began, a delta has formed at the mouth of the Niobrara River, a stream that enters the Missouri River just upstream from Lewis and Clark Lake. Prior to System regulation, large flood flows periodically removed the delta material; however, these large floods are now eliminated by upstream System control. While this reach of the Missouri River was capable of passing flows in excess of 150,000 cfs prior to construction of the System projects, Fort Randall Dam open-water releases of 40,000 to 50,000 cfs now result in flood problems to adjacent property owners.

7-07.3.5. **Gavins Point Dam to Sioux City.** Prior to construction of the System, the open-water channel capacity through this reach of the Missouri River was well in excess of 100,000 cfs. There is evidence of channel deterioration due largely to encroachment in backwater areas and along old river meander chutes; however, this is partially offset by channel degradation. In 1997, sustained flows of 70,000 cfs in this reach caused some damage. The channel capacity has increased in this reach since 1995 by the additional degradation of approximately 3 feet in this reach, based on the estimated stage change at flows near 100,000 cfs.

7-07.3.6. **Sioux City to Omaha.** Open-water channel capacity in this reach prior to construction of the System was in excess of 100,000 cfs. During recent years, there has been considerable encroachment on the channel area. Fixed boat docks have been constructed in numerous locations through this reach, and low areas are now being farmed. Much of this development is on or adjacent to river stabilization structures and takes advantage of sediment deposition encouraged by this stabilization. Adversely affecting the channel and floodplain developmental encroachment is the channel degradation in this reach. Degradation, while increasing the channel flood capacity, has adversely impacted marinas, water intakes, and tributary channel stability.

7-07.3.7. **Omaha to St. Joseph.** Deterioration of the channel capacity has occurred through this reach. Recent experience indicates that mid-summer flows exceeding 90,000 cfs will result in river levels above flood stage at Nebraska City and Rulo, Nebraska and St. Joseph, Missouri. Damage due to high groundwater and interior drainage behind levees in cultivated fields begins at stages 2 or more feet below flood stage.

7-07.3.8. **St. Joseph to the Mouth of Missouri River Near St. Louis.** Open-water flows of about 150,000 cfs will cause only relatively minor agricultural damages in this reach; however, the established flood stage at Waverly, Missouri, has been exceeded when flows were greater than 115,000 cfs during recent years.

7-08. **Recreation Purpose System Regulation.** Historic System regulation to serve the recreation purpose is detailed in Appendix B of this Master Manual. Numerous adjustments of both a temporary and a relatively permanent nature have been made to the regulation of individual System projects to enhance recreational activities. For example, a limitation is placed on power peaking during particular periods in order that downstream boating or fishing tournaments may be facilitated. Recreational use of the System has increased through the years, with the visitor-hour attendance approaching or slightly exceeding 60 million visitor hours during the past 7 years.

7-08.1. Reservoir levels in the upper three, larger System reservoirs during drought were a main focus of the Master Manual Study that was the basis for the selection of the CWCP presented in this document. Application of the specific technical criteria for the CWCP discussed previously in this chapter would improve benefits provided to lake recreation as compared to the former water control plan.

7-08.2. The three smaller System projects are not affected to any significant degree by extended drought because their levels are basically unaffected by changes in the annual water supply and total System storage. Only if a drought were more severe than that experienced in the 1930's, would the elevation in Lake Francis Case be reduced to levels lower than the normal annual cycle.

7-09. **Water Quality Purpose System Regulation.** Historic System regulation to serve the water quality purpose is detailed in Appendix C of this Master Manual. Water quality characteristics that are of greatest concern in the basin are chemical constituents, which affect human health, plant and animal life, and the various uses of water by man (irrigation, domestic, and industrial uses); temperatures, which affect fisheries and the aquatic environment; biological organisms, which affect human health; and taste, odor, and floating materials, which affect the water's potability and the aesthetic quality of the environment. The level of dissolved solids concentrations has been a concern historically. Biologic quality and dissolved-oxygen quality have not been considered problems within the basin until recent years. As a result, there has not been a long-term watershed approach in obtaining area-wide data, but it is known that problems exist below several of the major cities and below industrialized areas on some of the smaller tributary streams. High ambient air temperatures, solar radiation, water depth, and thermal discharges from point sources can also affect thermal water quality conditions. Low releases could impact the operation of downstream powerplants.

7-09.1. **System Downstream Release Requirements for Water Quality.** Generally, System project release levels necessary to meet the downstream water supply purposes exceed the minimum release levels necessary to meet minimum downstream water quality requirements. Tentative flow requirements for satisfactory water quality were first established by the U.S. Public Health Service and presented in the 1951 Missouri Basin Inter-Agency Committee Report on Adequacy of Flows in the Missouri River. These requirements were used in System regulation until revisions were made in 1969 by the Federal Water Pollution Control Administration. The Missouri River minimum daily flow requirements for water quality that are given in Table VII-9 were initially established by the Federal Water Pollution Control Administration in 1969. They were reaffirmed by the Environmental Protection Agency in 1974 after consideration of (1) the current status of PL 92-500 programs for managing both point and non-point waste sources discharging into the river, and (2) the satisfactory adherence to the dissolved-oxygen concentration of 5.0 parts per million (ppm). The minimum daily flow requirements listed in Table VII-9 will be used for System regulation purposes. The intent of this CWCP is to fully meet applicable water quality requirements and to continue to monitor the reservoirs and releases from the System to assure that this occurs.

Table VII-9
Minimum Daily Flow Requirements Below the System
for Adequate Dissolved Oxygen
(cfs)

Urban Area	December January February	March April	May	June July August September	October November
Sioux City	1,800	1,350	1,800	3,000	1,350
Omaha	4,500	3,375	4,500	7,500	3,375
Kansas City	5,400	4,050	5,400	9,000	4,050

7-09.2. **Other Water Quality Considerations.** The System and its regulation have significantly improved water quality in the river reaches between the reservoirs and downstream of the System, compared to the water quality in the Missouri River before the System was constructed. Downstream flow support from the System for the authorized purposes other than water quality more than meets the minimum flow requirements for Missouri River water quality. Water quality, therefore, has more than enough flow during all periods of the year in all of the Missouri River reaches with the CWCP. Water quality in the System reservoirs has been deteriorating for some time, essentially since the reservoirs were first filled. The dissolved-oxygen levels in the lower levels of the System reservoirs do not provide water quality conditions conducive to support some types of fish. The number of algae blooms has increased during the life of the System. Water quality has deteriorated in some arms of the large reservoirs for short periods so that the water in these locations is not potable, but these situations have been rare. In general, the water quality in the System reservoirs is considered good and is expected to remain so. Low flows in the reaches downstream from Garrison and Gavins Point Dams directly affect the ability of thermal powerplants in these two reaches to meet National Pollutant

Discharge Elimination System (NPDES) permit standards for discharging cooling water back into the Missouri River. Low reservoir levels and river stages may increase the sediment content in water supplies.

7-10. **Fish and Wildlife Purpose System Regulation.** Historic System regulation to serve the fish and wildlife purpose is detailed in Appendix D of this Master Manual. Declining water levels of the reservoirs are a concern to many project users interested in the reservoir fishery; however, some fluctuation in the reservoir levels is unavoidable if the reservoirs are to serve all of the authorized purposes. A continuing objective in the regulation of the System is to minimize the departures in reservoir levels from normal, full multipurpose levels to the maximum practical extent consistent with regulation for other authorized project purposes. The partial elimination of the annual drawdown of Lake Francis Case, which was previously discussed, is a good example of limiting reservoir level fluctuations while continuing to meet authorized purposes.

7-10.1. The maintenance of relatively uniform release rates during certain times of the year is also an environmental objective to benefit certain riverine species during their spawning period. Minimum releases are also required from some of the projects for downstream fisheries. System regulation has reduced high flows and supplementing low flows that still naturally occur on the Missouri River, which allows requests by State game and fish agencies to be met. Relatively constant releases, however, are not desirable for all fish species. Some fluctuations in release rates continue to be unavoidable if all of the authorized System project purposes are to be served. Additionally, access to the river may be more difficult at times, fishing success may be affected, the sediment load in the river may be increased, and use of fixed boat docks may be inconvenienced. To the extent practical, considering release requirements for other authorized purposes, release fluctuations are being minimized.

7-10.2. **Minimum System Releases for Fish and Wildlife.** Establishment of minimum releases and steady-to-rising pools during the spring months have been recognized since the 1950's as beneficial for successful fish spawning and hatching. An ad-hoc committee of the American Fisheries Society first made recommendations to the former Missouri River Division Reservoir Control Center in 1972 regarding regulation activities beneficial for the fishery. This committee was replaced with the MRNRC, which was established in 1987 to provide the Corps with a coordinated recommendation for fishery enhancement. The MRNRC is comprised of representatives from fish and game agencies from the seven states bordering the Missouri River.

7-10.2.1. **Fort Peck Minimum Release.** Minimum hourly releases, particularly during fish spawning, have been requested from Fort Peck, Garrison and Fort Randall Dams for many years. These requests are implemented if other project purposes are not affected. A year-round instantaneous minimum release of 3,000 cfs was established at Fort Peck in 1992 for the trout fishery located in the dredge cuts immediately below Fort Peck Dam. This minimum was raised to 4,000 cfs in 1995 and has been in place since, except in the spring of 1997 when releases were lowered to 3,000 cfs as part of a System flood control operation to reduce inflows to a rapidly rising Lake Sakakawea.

7-10.2.2. **Garrison Minimum Release.** Garrison Dam minimum releases are established by standing orders that call for a minimum generation over a specified number of hours depending on a range of daily average project releases. In most years, the minimum hourly generation resulting from release patterns for least terns and piping plovers is higher than the minimum specified in the standing orders. The minimum daily average Garrison Dam release is 9,000 cfs to avoid excessively low stages at downstream water intakes.

7-10.2.3. **Oahe Minimum Release.** A 3,000 cfs minimum Oahe Dam release during daylight hours is normally established in early April to enhance downstream fishing and boating use during the recreation season.

7-10.2.4. **Fort Randall Minimum Release.** Minimum releases from Fort Randall Dam are imposed for fish spawning below the project in years when daily average releases are sufficiently high. The most recent MRNRC recommendation is a minimum of 9,000 cfs from April through June.

7-10.2.5. **Gavins Point Minimum Release.** The minimums under the CWCP for other purposes exceed current fishery minimum requirements.

7-10.3. **Modified System Regulation for Threatened and Endangered Species.** Releases from all projects except Oahe and Big Bend have been modified to accommodate endangered interior least tern and threatened piping plover nesting since 1986. Daily hydropower peaking patterns are developed prior to nest initiation in early to mid-May and are provided to Western. Fort Peck and Garrison peaking is limited to 4 of 5 units for no more than 6 hours each day. Fort Randall peaking is limited to 7 of 8 units for no more than 6 hours per day. Deviations from this CWCP to address ESA requirements will normally be provided in the AOP.

7-10.3.1. **Gavins Point Cycling.** During the early years of operating for endangered species, a technique of increasing project releases every third day by 8,000 to 10,000 cfs was used to encourage terns and plovers to build their nests high so that these nests would not be inundated later when increases were required to meet the regulation objectives of the System. This pattern of increasing releases every third day was referred to as "cycling." Cycling has not been used in recent years because of the potential harm to native fish and the risk of stranding chicks. Every third day "cycling" of Gavins Point Dam releases during release reductions for downstream flood control has continued to be used to keep birds nesting at sufficiently high elevations to maintain room for release increases when downstream flooding has subsided. The variation in releases is normally limited to 8,000 cfs to minimize adverse affects on downstream river users and fish.

7-10.3.2. **Gavins Point Steady Release.** Another technique, called "steady release," is to increase the Gavins Point Dam release by early to mid-May when the terns and plovers begin to initiate nesting activities to the amount expected to be needed in August when downstream tributary flows are typically lower. This uses an additional amount of water stored in the System but usually preserves the ability to support downstream flow objectives and meet endangered species objectives as well. This type of release from Gavins Point Dam has been successfully used many times since system regulation for threatened and endangered species nesting began.

7-10.3.3. **Gavins Point Flow-to-Target Release.** Prior to the System regulating for endangered species, a "flow-to-target" approach was taken where releases from the System were increased as needed to provide downstream flow support. While this approach preserved the most habitat during the initial nesting phase, it normally resulted in the inundation of nests as downstream tributary flows fell off and Gavins Point Dam releases were increased to meet downstream target flows.

7-10.3.4. **Gavins Point Steady Release – Flow to Target.** During the 2003 nesting season, a new procedure, called "steady release – flow to target" was used to set the Gavins Point Dam release. This procedure combined features of the original "flow-to-target" method with the "steady release" plan. It called for an initial steady release high enough to inundate low-lying habitat that would likely be subject to inundation later in the season. As downstream tributary flows declined through the summer, releases could be increased as needed, within the limits of the Incidental Take Statement provided by the Service in its Supplemental BiOp prepared for the 2003 AOP, to meet downstream flow support for navigation and other authorized purposes.

7-11. **Water Supply and Irrigation Purpose System Regulation.** Historic System regulation to serve the water supply and irrigation purpose as well as intake locations are detailed in Appendix E of this Master Manual. Tribal intakes are presented as well in Appendix E. Numerous water intakes are located along the Missouri River, both within and below the System. These intakes are primarily for the purposes of municipal water supplies, nuclear and thermal powerplant cooling, and irrigation supplies withdrawn directly from the Missouri River. Historically, water access problems have been associated with several of these intakes; however, the problems have been primarily a matter of sandbars or sediment deposition at the intake restricting access to the river rather than insufficient water supply. Other water supply problems can occur during the winter months due to ice jamming on the river. Floating or frazil ice can also block the water intake facilities directly, which can reduce flow to unacceptable rates.

7-11.1. **System Water Supply Considerations.** The minimum daily flow requirements established for water supply are designed to prevent operational problems at municipal and thermal powerplant intakes at numerous locations along the Missouri River below the System. The lower Missouri River is significant with regard to water supply because 94 percent of the population served and 75 percent of the thermal power generating capacity using the Missouri River for once-through cooling are located below the System. Problems that have been experienced within the System are related primarily to intake elevations or river access rather than inadequate water supply. Evaluations are continuing by appropriate State agencies in coordination with water plant operators to determine the minimum stage and flow requirements at each intake location for satisfactory hydraulic operation. During drought, downstream water supply and water quality (thermal effects) will be a major consideration if the service level is dropped below minimum service from April through November to further conserve water in the System (navigation purpose not served). The minimum required summer release below minimum service rates to fully meet the water supply and water quality needs has not been established because this release has not been tested. In 2003, a 21,000 cfs release for only a few days resulted in downstream water supply problems. It is not known if these facilities could be modified to function at lower levels. An 18,000 cfs release rate was modeled during the development of this CWCP as a potential minimum Gavins Point Dam release rate in the summer months, which may result in some adverse impacts to power generation to comply with the water quality requirements for temperature. Lower releases of 9,000 cfs are included in the non-summer, open-water-season months, and these releases may not be adequate to meet water supply needs below the System on the Missouri River without modifications to some intakes, particularly those in the degradation reaches at Sioux City and Kansas City.

7-11.2. **Water Supply.** The growth in the use of the Missouri River for water supply as an authorized purpose has, like recreation, exceeded all original expectations. The RCC recognizes the importance to regulate the System in a manner to provide sufficient streamflow in intervening reaches between the System reservoirs and in the lower Missouri River reach from Gavins Point Dam to the mouth near St. Louis, Missouri, to sustain public water supplies of the numerous communities along the banks of the Missouri River. More than 1,600 intakes and intake facilities have been identified on the reservoirs and in the river reaches (Table E-1). Of these, 302 intakes and intake facilities are identified for American Indian Tribes. Appendix E and Section 2-10 discuss water supply intakes using the Missouri River. These intakes are primarily for municipal, industrial, and individual water supplies; fossil and nuclear-fueled powerplant cooling; and irrigation withdrawals directly from the Missouri River. In recent years, problems have been associated with several of these intakes; however, the problems have been a matter of intake access to the water rather than insufficient water to supply or meet requirements. The lower river reach is very reliant on the river for water supply because 94 percent of the population served, as shown in Table E-1, is located downstream of the System. In addition, 75 percent of the generation by thermal powerplants using the Missouri River, as shown in Table E-2, is located below the System. The following paragraphs discuss water supply for the reaches between the System projects and below the System. The purpose of this plan is to fully meet these water supply requirements to the extent reasonably possible. The Corps will continue to obtain the necessary data and make adjustments to the System to assure that this occurs; however, the intake access associated with obtaining Missouri River water is the responsibility of the entity choosing to use this source of water for its supply. Intake access problems are the responsibility of the intake owner, and the Corps will not guarantee access only that the supply of water in the Missouri River is adequate to meet this project purpose.

7-11.3. **Minimum System Release Requirements for Water Supply and Irrigation – Open-Water Season.**

7-11.3.1. **Fort Peck.** Historic regulating experience indicates that a minimum daily average release of 3,000 cfs from Fort Peck Dam is satisfactory for municipal water supply. During the spring and fall, instantaneous releases of no less than 4,000 cfs are normally scheduled for a downstream fishery. The irrigation demands below Fort Peck Dam during the irrigation season currently call for a flow of 6,000 cfs as a minimum; however, the formation of sandbars has at times restricted flows to some intakes in this reach. The Fort Peck Dam minimum release rate is, therefore, greater than the minimum water supply release requirement for this reach.

7-11.3.2. **Garrison.** At Garrison Dam, a minimum average daily release of at least 9,000 cfs during both the open-water and ice-cover seasons is desirable to provide sufficient river depths for satisfactory operation of municipal, irrigation, and powerplant water intakes in North Dakota.

In this reach of the river, fluctuations in release levels at times require the resetting of irrigation pumping facilities to achieve access to available water or to prevent inundation of pumps.

7-11.3.3. **Oahe and Big Bend.** No restriction on minimum releases from Oahe and Big Bend is necessary for adequate service to water intakes because the headwaters of downstream reservoirs may extend to near the upstream dam sites. Minimum flows from Oahe of at least 3,000 cfs are normally made during the daylight hours during the recreation season.

7-11.3.4. **Fort Randall.** Mean daily releases of 1,000 cfs are considered to be adequate to meet all of the water supply requirements below Fort Randall Dam except for the city of Pickstown, South Dakota. This city has, in the past, needed a minimum of 12,000 cfs for 12 hours every third day to fill its water supply storage tanks. The city has recently connected to a rural water supply system that should eliminate this requirement in the future.

7-11.3.5. **Below Gavins Point.** When the water-in-storage in the System is at normal or higher levels, releases for the navigation and power production purposes and to evacuate flood control storage during the navigation season and winter period will normally be at levels that are deemed to be sufficient for the downstream water supply needs. During extended droughts, Gavins Point Dam releases are reduced. Some intakes require more than 9,000 cfs (minimum release required in the early 1990's) during the open-water season for effective operation. These intakes should be modified as soon as possible to ensure that they can remain operational as the Corps continues to pursue lowering the Gavins Point Dam release in the non-navigation months during drought periods to this rate. A winter Gavins Point Dam minimum release rate of 12,000 cfs has been established as the guide in meeting downstream water supply requirements during this period. Intakes typically have higher requirements during the winter period because of the effects of river ice in reducing the capacity of their intakes. If Gavins Point Dam release rates are reduced below 12,000 cfs for water conservation, continued surveillance of these intakes will be required, and, if appropriate, additional releases may be required to assure adequate water levels for uninterrupted intake operation. During the critical and more difficult winter period, release rates may be adjusted according to river icing conditions to assure that the water supply service is provided downstream. During drought years when System storage is low enough to reduce or eliminate the navigation season, a Gavins Point Dam release of 18,000 cfs has been established as meeting the summer water supply requirement. Intake owners should modify their intakes as soon as possible if a summer Gavins Point Dam release rate of 18,000 cfs will not be adequate to meet their needs.

7-11.4. **Irrigation Purpose System Regulation.** Federally-developed irrigation projects served directly from the System were envisioned and the pumping plants to support these irrigation projects from Garrison and Oahe were constructed. The Federal irrigation projects have not been constructed. The Oahe Diversion project was deauthorized, and the Garrison Diversion project has been significantly scaled back. No acres are currently irrigated with the Garrison Diversion project. Current plans for water resource development in the Missouri River basin do not include significant Federal irrigation development from the System. Releases from the reservoirs are used by numerous private irrigators and by Federally-financed projects. Private irrigation directly from the reservoirs is also continuing to develop. While the minimum releases established for water quality or for satisfactory operation of Missouri River water supply intakes are usually ample to meet the needs of irrigators, low reservoir levels and low river stages, with their associated exposure of sandbars and drying up of secondary channels, make access to the available supply difficult or inconvenient to obtain. Instances of such occurrences are discussed in the individual System project water control manuals. The System will continue to regulate for this Congressionally authorized project purpose and adjust releases to meet needs. As previously discussed, access is the major problem for all types of intakes along the Missouri River and on the System reservoirs. Generally speaking, access to Missouri River water for irrigation is the responsibility of the entity owning the intake.

7-12. **Hydropower Purpose System Regulation.** Historic System regulation to serve the hydropower purpose is detailed in Appendix F of this Master Manual. Since completion of the power installations at the System projects, most System project releases have been made through the respective powerplants. When release requirements were exceptionally high due to flood control storage evacuation, spillway releases were necessary at Gavins Point Dam. Some spills have also been required at Fort Peck, Garrison and Fort Randall Dams for this purpose; however, in most years releases from all projects are made through the powerplants at all times. The six System dams support 36 hydropower units with a combined plant capacity of 2,436 megawatts (MW) of potential power generation. These units provide an average of 10 million MWh of energy per year, which is marketed by Western. Power generation at the six System dams generally must follow the seasonal pattern of water movement through the System; however, adjustments are made, when possible, to provide maximum power production during the summer and winter when demand and value of this authorized purpose is highest. Hydropower is the only Congressionally authorized purpose of the System that actually returns money to the Federal Treasury

7-12.1. Realization of the maximum power potential provided by the water passing through the dams of the System requires that hydropower operations be carefully integrated into regulation of the overall System. This requires consideration of many factors, including generating capacity at each plant, marketability and current market price of generated power, necessary peaking capability, anticipated long-range storage balance requirements, regional power emergencies, and others. Regulation of the System projects is scheduled to develop the maximum power benefits to the extent reasonably possible. .

7-12.2. **Hydropower Modifications for Transmission Loading Relief.** Pursuant to the Federal Energy Regulatory Commission's open access transmission law, Western was requested to reduce generation on the System hydropower system during the spring and summer of 1997 to preserve transmission capability. This "transmission loading relief" (TLR) is accomplished on a very short notice at any time of the day and is performed by reducing the load at one or more System hydropower plants for an unforeseen duration, although usually for just a few hours. TLR was normally accomplished at Oahe in 1997 but also occurred at Fort Randall and Garrison. The relief involved shedding anywhere from a few MW to a few hundred MW with an accompanying reduction in System project release. Corps project personnel were then pressed into service to initiate supplemental releases through outlet works other than the powerplants to compensate for the reduced powerplant releases. During 1997, the volume of runoff was twice that in a normal year, and even a few hours of reduced releases could have become critical. Evacuation of the record runoff in 1997 caused releases to exceed powerplant capacity at all projects except Big Bend. TLR has been frequently provided by the System powerplants, particularly Oahe, since 1997. Lower runoff associated with the current drought has resulted in reduced generation since the record high set in 1997, and TLR requirements have eased due to lighter loading of the generating units. When high runoff years return, TLR is expected to be a consideration in regulation of the System.

7-12.3. **Hydropower Considerations – Annual Fort Randall Drawdown.** A disparity exists between summer power generation, when releases from four of the six System projects are relatively high to provide Missouri River downstream flow support, and winter generation, when System releases to the lower river must be restricted due to the limited ice-covered channel capacity. The effect of this disparity may be eased by another aspect of System regulation, the draft and refill of a portion of the Fort Randall Carryover Multiple Use Zone storage space. During this regulation, Oahe and Big Bend releases are reduced several weeks before the end of the navigation season. This leaves the water in Fort Randall as the primary source for downstream release requirements for the remainder of the fall season, a process that results in evacuation of a portion of its Carryover Multiple Use Zone storage space. This vacated storage space is then refilled with Oahe and Big Bend releases following the navigation season through the winter period. Whereas, the volume of winter releases from Oahe and Big Bend, in the absence of this recapture, would be about equal to those from Fort Randall, the refill of the evacuated Fort Randall space allows winter releases from these upstream projects to substantially exceed those from Fort Randall Dam.

7-12.3.1. During the period of initial fill and the regulation of the System in years prior to 1971, as much as 2 MAF of storage below the base of the Annual Flood Control Multiple Use Zone were drawn out of Fort Randall. The recapture of the evacuated storage space allowed Oahe and Big Bend releases to exceed Fort Randall releases by an average of 8,000 cfs for the winter. This regulation resulted in substantially more winter energy generation, exceeding 300,000 MWhs, when Oahe was at its normal level. Offsetting this gain in System generation, the generating capability at Fort Randall Dam was reduced by 60 to 70 MW in early December because of the lower reservoir level; however, this negatively impacted other System authorized purposes. A lowered Lake Francis Case has an adverse effect on recreation in and around the reservoir area while the exposed reservoir floor becomes undesirable in an esthetic sense. Mud flats in the reservoir headwaters spawned blowing dust storms near Chamberlain, and boat ramps were out of the water. The effects of this drawdown on the surrounding environment became an increasing concern, particularly when this drawdown proceeded below elevation 1340 feet msl. Studies conducted in 1971 and 1972 resulted in a compromise being accepted that limited the drawdown of Fort Randall to elevation 1337.5 feet msl in most years. The drawdown to this level was also delayed as late as possible in the year so that any negative impacts were felt for the shortest possible period of time. This drawdown was also scheduled to coincide with the period during which there is a marked decline in the recreational usage of the reservoir. Fort Randall, at a reservoir level of elevation 1337.5 feet msl, makes available about 900 MAF of storage space below the base of the Annual Flood Control and Multiple Use Zone for recapture of winter power releases from Oahe and Big Bend Dams. During droughts greater than that of the 1930's, when System storage reserves and System releases are reduced, an additional drawdown of Fort Randall to as low as 1320 feet msl may be scheduled to permit Oahe and Big Bend Dam releases to be maintained near a 15,000 cfs rate during the winter period.

7-12.4. **Other Hydropower Considerations – Annual Oahe Drawdown.** While not as significant (in terms of pool level fluctuation) as the Fort Randall recapture, a similar recapture can occur at Oahe. This recapture is coordinated with upstream Fort Peck and Garrison Dam releases. Oahe recapture may also significantly increase the amount of winter energy generation. During the 4-month winter period, Garrison Dam releases normally are scheduled to be at least 1 MAF more than Oahe releases. The recapture of these upstream releases results in a rise of up to 5 feet or more in Lake Oahe elevation during the winter months.

7-12.5. **System Hydropower Coordination.** Daily, real-time regulation of the System for hydropower purposes is closely coordinated with Western and with regulation of the System for non-hydropower purposes. Detailed advance planning is essential so that releases from each of the System projects for any of the other authorized project purposes may be used to the fullest extent practicable for optimum power production. Daily schedules of power production for each System powerplant are prepared and furnished to Western. Western, in turn, makes such daily changes in the power marketing arrangements as are necessary. Power production orders, which include the scheduled daily generation as well as limits of powerplant loading, are issued directly by the RCC to individual System powerplants. Within the limits of the daily schedules, Western controls the actual hourly loadings of the plants, subject to the limitations imposed by load limits in the power production orders and discharge limits imposed by concurrent reservoir regulation orders schedule by the RCC.

7-12.5.1. The Big Bend and Oahe powerplants are used primarily to follow daily load patterns. In the summer cooling season, Big Bend and Oahe generation is patterned to meet peak electricity demands, which generally occur around 6 p.m. In the winter heating season, their generation is patterned to meet morning and evening peak demands. The Fort Randall, Garrison, and Fort Peck powerplants are also used for peaking, but to a lesser degree. The relative role of each powerplant in meeting required peaking patterns varies with relative water supply available to each powerplant and other regulation factors. The peaking patterns vary through time, primarily in response to such factors as the demand for power and the average release rate through the System. At individual dams, daily power releases are normally adjusted for other project purposes, taking into account; flood control, water conservation, environmental objectives, physical and seasonal constraints, and other factors.

7-13. **Navigation Purpose System Regulation.** Historic System regulation to serve the navigation purpose is detailed in Appendix G of this Master Manual. Service was provided to navigation on the lower Missouri River during the years that Fort Peck was regulated as an individual project. With the construction and filling of additional System projects, this service was expanded. Full-length (8-month) seasons were first initiated in 1962 and have continued except in years when flow reductions were required during extended droughts. Navigation service flows have been provided since June 1967. Navigation on the Missouri River occurs from Sioux City to the mouth near St. Louis. Commercial traffic has ranged from as high as 3.3 million tons in 1978 but has declined in recent years to less than 2 million tons. In 1999, total commercial traffic moved by barge reached a record peak of 9.25 million tons. Commercial tonnage, not including sand, gravel, and waterway materials, accounted for 1.58 million tons. The Missouri River Bank Stabilization and Navigation Project is authorized to provide a 9-foot-deep by a minimum of 300-foot-wide navigation channel. Downstream flow support is provided to meet many of the Congressionally authorized purposes, which includes navigation. Navigation flow support is provided to maintain an 8 to 9-foot depth in the navigation channel depending on the amount of water stored in the System, according to the criteria presented in Table VII-2.

7-13.1. **Navigation and Other Downstream Support Considerations.** Frequent groundings are often experienced during the early portion of the navigation season. These are believed to be due to a combination of cold water temperatures and the requirement for the channel dimensions to adjust from the lower winter flows to the higher navigation and downstream support flows. To alleviate this situation, when appropriate, based on water supply, downstream flow support releases at the beginning of the season may be scheduled for a short period at a level of up to 5,000 cfs higher than the service level requires, to provide channel conditioning provided System storage levels at the time are adequate.

7-13.1.1. Day-by-day regulation of the System to support navigation requires forecasts of inflow to various reaches of the Missouri River below the System. From these forecasts and current flow targets, the control point (either Sioux City, Omaha, Nebraska City, or Kansas City) is determined daily. Anticipated traffic or the absence of traffic at the control points will also have a bearing on the control point selection. For this reason, the RCC will continuously monitor traffic movement on the Missouri River. After selection of the control point, releases from the System are adjusted so that, in combination with the anticipated inflows between the System and the control point, they will meet the target flow at the control point.

7-13.2. **System Downstream Flow Support.** The System releases required to meet the minimum and full-service targets vary by month in response to downstream tributary flow, as shown on Table VII-10. These values will be updated as additional data are accumulated and when a significant change in these values occurs. A reanalysis of the average monthly Gavins Point Dam releases needed to meet navigation service requirements was completed in 1999. As part of this study, the relationship between annual runoff upstream of Sioux City and the average Gavins Point Dam release required for the navigation season was analyzed. That study showed that generally more water was needed downstream to support navigation during years with below-normal upper basin runoff than during years with higher upper basin runoff. Regulation studies performed since 1999, therefore, use two levels of System release requirements, one for Median, Upper Quartile, and Upper Decile runoff scenarios and another for Lower Quartile and Lower Decile scenarios. An examination of the data presented in Table VII-10 reflects that, early in the season, the flow target is at Sioux City with adequate downstream tributary flows to meet flow targets. Normally, as the runoff season progresses, downstream tributary flows recede or cease during the summer, and the flow target moves from Sioux City to Nebraska City and eventually Kansas City. This requires higher flow support as the season progresses through the summer. Often the target moves upstream during the fall, when higher downstream tributary flows return. This seasonal tributary flow pattern is reflected in the Gavins Point Dam release data presented below. These releases are the average monthly values during the period studied for the various runoff conditions and do not reflect the maximum and minimums required during that month to meet flow targets. Actual regulation, therefore, requires daily adjustments to fully serve the Congressionally authorized project purpose of navigation. Studies conducted for the ESA consultation in the spring of 2003 concluded that 30,000 cfs would be needed to provide a

90 percent assurance of meeting minimum service flow targets in July and August. That study used all runoff data from the period of analysis (1898 through 1997).

Table VII-10
Gavins Point Releases Needed to Meet
Downstream Target Flows for Indicated Service Level
1950 to 1996 Data
(Discharges in 1,000 cfs)

Median, Upper Quartile, Upper Decile Runoff

	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
Full-Service	26.7	28.0	27.9	31.6	33.2	32.6	32.0	31.1
Minimum-Service	20.7	22.0	21.9	25.6	27.2	26.6	26.0	25.1

Lower Quartile, Lower Decile Runoff

	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
Full-Service	29.8	31.3	31.2	34.3	34.0	33.5	33.1	31.2
Minimum-Service	23.8	25.3	25.2	28.3	28.0	27.5	27.1	25.2

7-13.3. **Navigation Service Disruptions.** The level of service to navigation can be affected by release restrictions at Gavins Point Dam for the tern and plover nesting season. Release restrictions were first implemented in 1986 to preserve nesting habitat and not inundate nests or birds that could not yet fly. At times during the release restriction period, navigation target flows could not be met because tributary flows are declining in July and August and flows cannot be augmented by increased releases from Gavins Point Dam beyond the maximum release established prior to tern and plover nesting. Generally, release restrictions to protect the birds are lifted in mid-August when the young birds are able to fly and leave the area. Beginning in 1995, releases from Gavins Point Dam were adjusted in early May, when the terns and plovers began to initiate nesting. The release rate was based on an assessment of flows needed to support navigation in July and August. The resulting release prevented the inundation of nests and chicks by not requiring increased downstream support later in the summer.

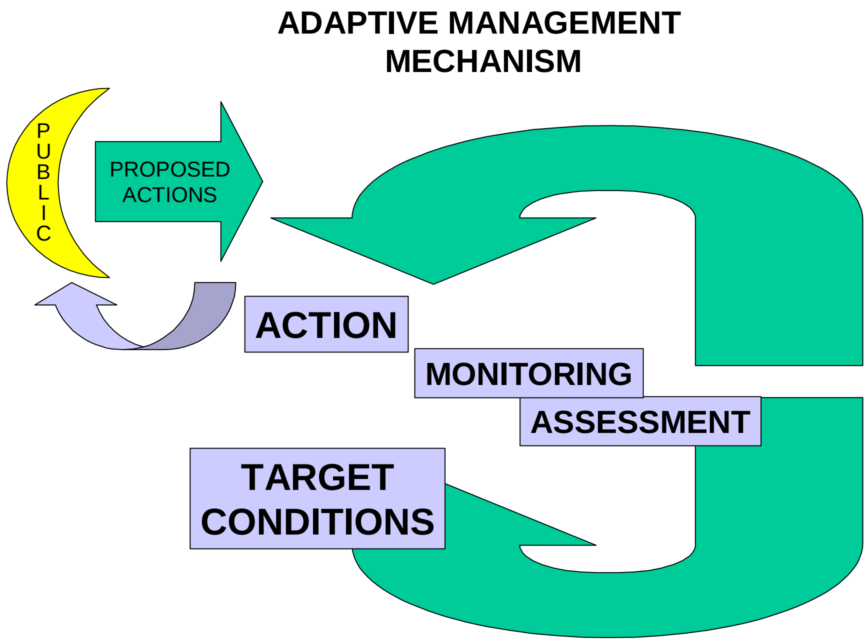
7-13.3.1. High lower Missouri River flows can also disrupt navigation. The river is generally closed to navigation when stages become so high that towboat prop wash and the wake from the tows can damage the Missouri River levees. In the flood of 1993, the Missouri River was closed for navigation for 7 weeks by high flows between Kansas City and St. Louis. The U.S. Coast Guard has the responsibility of officially closing the Missouri River. The Corps and the Coast Guard coordinate this closing and reopening so that significant impacts can be minimized both to the levee system and to the navigation industry. During both the 1987-93 drought and the current drought, navigators experienced hardships and lost revenues due to both reduced Gavins Point Dam releases and shortened navigation seasons, including disruptions caused by court-ordered actions and threatened and endangered species operations. Table G-3 provides the season lengths and tonnage on the Missouri River since the System filled in 1967.

Guard coordinate this closing and reopening so that significant impacts can be minimized both to the levee system and to the navigation industry. During both the 1987-93 drought and the current drought, navigators experienced hardships and lost revenues due to both reduced Gavins Point Dam releases and shortened navigation seasons, including disruptions caused by court-ordered actions and threatened and endangered species operations. Table G-3 provides the season lengths and tonnage on the Missouri River since the System filled in 1967.

7-14. **Adaptive Management.** The Corps has implemented some System regulation changes via an Adaptive Management process for many years. The Corps, in implementing the CWCP described in this manual, will continue the use of the Adaptive Management process. Adaptive Management is not a new concept; but rather, commonly used throughout the world to help shape resource management decisions, policies, and approaches. The process involves recognition that all is not known about the impacts, both positive and negative, of changes in System regulation. It also recognizes the likelihood that physical conditions may change in the future, and allows flexibility to meet the challenges of those changed conditions. For example, the database of information on the complete life cycles and behaviors of the threatened and endangered species or their requisite habitat needs throughout their life cycles grows constantly. Adaptive Management is an overall strategy for dealing with change and scientific uncertainty. It promotes an environment that allows testing of hypotheses and pursuit of promising change based on sound scientific data and analyses followed by critical monitoring and evaluation.

7-14.1. The Corps recognizes that changes in the operation of the System may impact many river uses and is committed to ensuring that the public is actively involved and well informed of potential changes in System regulation and has the opportunity to comment on those proposed changes prior to any decision on implementation. The adaptive management process will be used to implement changes designed to improve the benefits provided by the System, including benefits to the threatened and endangered species. Decisions regarding actions proposed through the adaptive management process will meet the Corps' treaty and trust responsibilities to the Tribes and conform to all of the applicable requirements of Federal laws including the National Environmental Policy Act, Endangered Species Act and the Flood Control Act of 1944. Adaptive management measures implemented as part of the water control plan are described and explained in Appendix I.

7-14.2. **Adaptive Management Process Diagram.** A conceptual diagram of an Adaptive Management strategy is provided below.



7-15. **Drought Contingency Plan.** Regulation of the System during drought was a significant consideration in the development of this CWCP. The System is the largest reservoir system in the United States serving all authorized project purposes during an extended drought like the 1930's was part of the original objectives of the System. This resulted in the construction of the System with an enormous amount of water normally retained in System storage in anticipation of the onset of extended drought. For this reason, the three upper reservoirs are extremely large compared to other Corps reservoirs, which makes the System so unique. The System was designed to use this stored water during extended drought periods to meet a diminished level of service to all Congressionally authorized purposes except flood control. As such, no separate Drought Contingency Plan is needed or required for the System, as it is included as part of the CWCP presented in this Master Manual.

7-16. **Flood Emergency Action Plans.** The Omaha District is responsible for the development of Flood Emergency Action Plans for the System. The Omaha District has developed a Contingency Plan for Emergencies for each of the System dams, and these plans are presented as Appendix E of the Operations and Maintenance Manuals for each System project. The action plans were all developed for individual projects and were last updated in 1984. These action plans are available to the RCC and project staff for use should a catastrophic failure be imminent or occur. These action plans are contained in large documents and, as such, are not provided as part of this Master Manual. In addition, the Omaha District has conducted full Emergency Dam Safety Exercises involving all of the larger System dams with expected emergency management partners. The RCC was a participant in these exercises and provided modeling support for System regulation during the exercises. The Fort Peck Dam Safety Exercise was conducted in July 1985, and it simulated an earthquake-related event that involved Federal, State, and local participation. The Garrison Dam Safety Exercise was conducted in August 1987, and it was a flood-related event that involved Federal, State, and local participation. The Oahe Dam Safety Exercise was conducted in September 1992, and it was also a flood-related event with Federal, State, and local participation. These full-scale Dam Safety Exercises have also been augmented by tabletop exercises to train and prepare the staff for emergency situations.

7-17. **Other Considerations.** Other considerations than just serving the authorized System purposes must be served from the System, as needed. Adjustments are made to System regulation at times for downstream construction and to aid in recovering bodies from drowning accidents. Recently, adjustments in reservoir levels or dam release rates to help reintur cultural artifacts and human remains at Tribal burial sites have occurred. Special regulation to determine the effectiveness of moving accumulated sediment below the System projects has also occurred.

7-18. **Deviations from the CWCP.** The deviations from the operational objectives presented in this Master Manual or the following year's AOP final plan are discussed during the AOP process. All significant deviations from this CWCP will be coordinated and approved by the Northwestern Division Commander, who may also coordinate with higher authority. All deviations of significance are modeled and presented to the public through the normal coordination procedures involving public press releases and World Wide Web dissemination. Minor deviations are accomplished by the RCC through coordination directly with the affected parties.

7-19. **Rate of Change in Release.** Releases from the System are generally scheduled on a mean daily basis. A gradual change is important when releases are being decreased and downstream conditions are very wet, resulting in saturated riverbank conditions. The RCC staff is aware that a significant reduction in System releases over a short period can result in some bank sloughing, and release changes are scheduled accordingly when a slower rate of change does not significantly impact downstream flood risk. Overall, the effect of System regulation on streambank erosion has been reduced by the regulation of the System because higher peak-runoff flows into the System are captured and metered out more slowly. Increasing System project releases can be changed more significantly than reductions because streambank erosion due to sloughing is not an issue. Many years of regulation experience have also indicated that a simple transition of releases is normally desirable, when possible.

7-19.1. Two sets of criteria are used that are related to the rate of release change for the System dams. The rate of release change criteria is adjusted from that for a normal situation if a flood control regulation objective is initiated to protect life and property in downstream areas or to respond if an emergency exists either at the project or in the project vicinity that requires rapid release changes. Table VII-11 lists the normal and flood control daily rate of release change criteria for each System project. If a situation presents itself that has not been contemplated or a change greater than that described below is required to meet the operational objectives of this plan, the appropriate change will be made. A rate of release change guideline at Oahe and Big Bend does not apply because the tailwaters empty into either a very short river reach or the downstream reservoir, respectively. Also Oahe and Big Bend experience daily changes of releases in the range of full powerplant capacity as required for System hydropower generation to meet this authorized project purpose.

Table VII-11
Mainstem Project
Maximum Daily Rate of Release Change

Mainstem Project	Normal Increase cfs	Normal Decrease cfs	Flood Control Increase cfs	Flood Control Decrease cfs
Fort Peck	6,000	3,000	9,000	12,000
Garrison	6,000	3,000	9,000	12,000
Oahe	N.A.	N.A.	N.A.	N.A.
Big Bend	N.A.	N.A.	N.A.	N.A.
Fort Randall	10,000	6,000	12,000	17,000
Gavins Point	8,000	4,000	10,000	15,000

7-19.2. While Table VII-11 shows the maximum daily decrease is 4,000 cfs per day at Gavins Point Dam during a normal situation, this assumes no change in tributary flows downstream. If tributary flows in the reach just downstream of a System project are increasing or decreasing, the actual project release increase or decrease can be based on the combination of tributary flow change and release change to provide the same result downstream. For example, if reach increase of tributary flows of 5,000 cfs were forecasted or experienced at gaging locations in the reach just below Gavins Point Dam and the System were in a normal situation, Gavins Point Dam releases could be reduced by 9,000 cfs per day (5,000 cfs more than the 4,000 cfs shown in Table VII-11) to obtain the same downstream result on the Missouri River as would occur with no tributary flow changes and a release change of 4,000 cfs.

7-20. **Mainstem System Physical Constraints.** The physical constraints of the System are relatively minor with a few exceptions. These constraints are discussed in the following paragraphs.

7-20.1. **Fort Peck – Emergency Flood Tunnels.** The three largest System projects have flood control tunnels that served as outlets when the project embankments were constructed. The flood control tunnels at Fort Peck Dam consist of two 24’ 8” diameter concrete-lined tunnels. The regulation of flow through these tunnels is provided by the operation of a cylinder gate in the tunnels, which also have upstream emergency gates. The use of the flood control tunnels has revealed many operational problems and resulted in high maintenance costs. The operational problems consist of entrained air, cavitation, gate vibration, violent surging, loud noises, and gate icing. The flood tunnels are considered unreliable for the prolonged discharge of water from Fort Peck Dam. The emergency gates consist of cable-suspended, tractor gates, which have never been tested under full flow emergency gate closure conditions. A high probability exists that the emergency gates would not close under full flow conditions, and considerable risk would be associated with any attempt to close these gates under design conditions.

7-20.2. **Fort Peck – Emergency Spillway.** The emergency spillway consists of a gated, overflow weir, with a net crest length of 640 feet; a 5,000-foot-long, trapezoidal-shaped, concrete-lined chute; and a 70-foot deep, downstream cutoff wall. The spillway was not provided with an energy dissipation structure. Concerns over the use of the emergency spillway under higher flows consist of the potential for uplifting of the concrete slabs on the spillway and enlargement of the downstream scour hole and its impact on the integrity of the adjacent cutoff wall.

7-20.3. **Fort Peck – Spillway Vertical Lift Gates.** Recent engineering analyses have shown that there should not be any continuous overtopping of the vertical lift gates at Fort Peck Dam other than the wind-induced effects of run-up and setup. A System constraint task item was established following the 1997 flood to evaluate this concern, but the studies have yet to be completed.

7-20.4. **Garrison – Floodplain Development.** The primary regulation constraint for releases from Garrison Dam is an increased water surface at Bismarck and Mandan due to aggradation in the upper reaches of Lake Oahe. The past two decades have resulted in a considerable amount of residential development along both sides of the Missouri River floodplain in the Bismarck, North Dakota area. Flows at and above flood stage will result in a considerable amount of flood damage. The natural Missouri River flows prior to the construction of Garrison Dam were high enough, and the flooding frequent enough, to discourage such floodplain development. When high releases from Garrison are required for flood storage evacuation, local interests will likely express their desires to keep flows through Bismarck below flood stage to reduce the amount of damage in the floodplain near Bismarck. A Federal Emergency Management Agency (FEMA) Flood Insurance Study (FIS) for the Bismarck area has been completed, but the report has not yet been finalized. The Federal Government does not hold the authority to control local floodplain development.

7-20.5. **Garrison – Spillway Tainter Gates.** Recent engineering analyses have shown that there should not be any continuous overtopping of the tainter gates at Garrison Dam other than wind-induced effects of run-up and setup. This has been an issue when the reservoir nears the top of the Exclusive Flood Control Zone, as it has two times in the past. A System constraint task item was established following the 1997 flood to evaluate this concern, but the studies have yet to be completed.

7-20.6. **Garrison – Spillway Slab.** Use of the Garrison Dam spillway is a concern because of the associated spillway structure uplift pressures. An engineering analysis was completed in 1999 that indicates satisfactory factors of safety are achieved up to a reservoir elevation of 1859 feet msl. Due to the limited amount of data for analysis, a cautious approach should, however, be taken when spillway releases are required. Instrumentation has been installed, and evaluation under higher pools is required to complete the analysis.

7-20.7. **Oahe – Spillway.** The Oahe spillway empties into a downstream earth channel, therefore, when used, it will incur significant downstream erosion and flood damages. There will be some local resistance to using this project feature whenever it is first used.

7-20.8. **Oahe – Spillway Tainter Gates.** Recent engineering analyses have shown that there should not be any continuous overtopping of the tainter gates at Oahe Dam other than wind-induced effects of run-up and setup. A System constraint task item was established in 1998 to evaluate this concern, but the studies have yet to be completed.

7-20.9. **Oahe – High Pool Levels.** There has been considerable concern in recent years regarding the use of the Oahe Exclusive Flood Control Zone for controlling major floods (reservoir level above 1617 feet msl). A Board of Consultants was convened to evaluate the Oahe embankment stability for maximum design pool levels. The primary conclusion of the Board was that *"The dam has sufficient global resistance to operate without restriction to the maximum surcharge pool of elevation 1645 feet. The required safety is provided by the reserve resistance of the potential break-out zone and the three-dimensional restraints.*"

7-20.10. **Oahe – Winter Release Rates.** Winter release rates in past years during river ice formation have resulted in minor street flooding in the cities of Pierre and Fort Pierre, South Dakota. This flooding has prompted the application of a restriction on releases from Oahe Dam during a period when river ice formation is occurring, which usually coincides with high demands for hydropower production. A project is currently underway to provide a solution to this problem via a combination of purchasing and/or flood proofing homes and/or the purchase of flooding easements for the affected property in Pierre and Fort Pierre floodplains. The completion of this project will allow for more flexibility for winter regulation of Oahe. Completing this Federal project will take several more years.

7-20.11. **Big Bend – Spillway.** The Big Bend project has never used the spillway, however, this is not considered an operational constraint during periods of large flood evacuations. The powerplant can normally pass the expected flows, but a powerplant failure for more than a short period of time could disrupt the transfer of water downstream requiring supplemental spillway flows.

7-20.12. **Fort Randall – Low Pool Levels.** The fall drawdown and winter refill at Fort Randall permits increased energy generation from the System during the winter. Complaints during the late 1960's about the fall regulation of Fort Randall reduced the amount of the normal fall drawdown from 1320 to 1337.5 feet msl. This change in regulation in the early 1970's has reduced overall power benefits. During a very severe drought, Fort Randall reservoir can be drawn down to 1320 feet msl to augment water provided by the upper three, larger System reservoirs.

7-20.13. **Fort Randall – Flood Tunnel Fine Regulating Gate.** The fine regulating gate at Fort Randall was destroyed in 1975 and has never been replaced. Two gates in Flood Tunnel No. 11 have been modified to dampen gate vibrations and can be used to make fine regulating releases, either individually or in combination with each other.

7-20.14. **Fort Randall – Reduced Channel Capacity.** There has been significant loss of channel capacity in the downstream Fort Randall river reach, such that releases to evacuate accumulated flood storage in 1997 caused flooding to some property located adjacent to the Missouri River. The Niobrara River has been depositing sediments at its mouth (near the upper end of Lewis and Clark Lake), which is causing a loss of conveyance capacity in the river channel in this reach. Restricted downstream channel capacity because of aggradation remains a concern. Also some cabins and residences have encroached onto the floodplain in this reach and were, in some cases, flooded by the 1997 flood evacuation releases.

7-20.15. **Gavins Point – Spillway Tainter Gates.** Steady winter releases from Gavins Point Dam are required to meet minimum downstream flow support targets. The spillway is used to ensure steady releases in the case of a planned or forced hydropower unit outage. In the case of a forced hydropower unit outage, spillway releases are initiated immediately to ensure that a reduction in flows below target levels does not occur downstream. In the winter, lower than planned downstream flows could cause disruption of established downstream river ice cover by a sudden reduction in flows, which could result in an ice jam. Winter operation of the spillway tainter gates has been hindered by ice formation along the tainter gate seals and the backside of the gates from water spraying over the spillway and freezing. Sidewall heater plates have been installed to alleviate the gate seal problem. These have not been tested to date during a significantly cold winter to determine effectiveness of this solution.

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