PROPOSED REVISION
TO THE INTERIM OPERATIONS PLAN FOR JIM WOODRUFF LOCK AND DAM FOR THE IMPLMENTATION OF "REASONABLE AND PRUDENT MEASURE #3"

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Prepared for
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by

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ATTACHMENTS

1. Daniel P. Sheer, *Analyzing the Risk of Drought: The Occoquan Experience*, 72 Journal of the American Water Works Association 246-253 (May 1980).

2. Robert M. Hirsch, *Stochastic Hydrologic Model for Drought Management*, 107 Journal of the Water Resources and Management Division, ASCE 303-313 (October 1981).

3. CD Containing Input and Output files for MSRR Model Results.

(Attachments available upon request)

1. EXECUTIVE SUMMARY

The Atlanta Regional Commission is pleased to propose the following revision to the Interim Operations Plan ("IOP") for Jim Woodruff Lock and Dam ("JWLD") for implementation of Reasonable and Prudent Measure #3 ("RPM3") in accordance with the Biological Opinion issued by the Fish and Wildlife Service ("USFWS") on September 5, 2006.

The basic concept of the proposed revision is to provide the Maximum Sustainable Release that can be supported by JWLD, up to 10,000 cfs. The Maximum Sustainable Release is calculated each week as a function of the total available storage using forecasting techniques established by USGS. A release is deemed to be "sustainable" if the storage is available to support it without comprising the long-term performance of the system, including ability of the system to refill by June 1 each year. Calculations necessary to implement the proposed alternative are easily made using a spreadsheet and real-time data maintained by USGS.

As is shown in greater detail below, the proposed alternative is superior or equal to other alternatives for the implementation of RMP3 for almost every operational objective. This alternative substantially improves the performance of the IOP on the key biological performance measures evaluated by USFWS in the Biological Opinion. In some cases there are trade-offs, but the costs are generally marginal and the benefits are high. Overall the proposed alternative would have a substantial beneficial impact on protected species. At the same time, by keeping significantly more water in storage, the proposed alternative would provide substantial benefits to other project purposes. The proposed alternative would not have any adverse impact on flood plain connectivity, hydropower generation, flood control, or, to our knowledge, any other operating objective.

Although the proposed alternative substantially improves the IOP on every important operational objective, the IOP can be improved still further. Therefore the IOP should *still* be considered an "interim" plan, even after it is revised by adopting the Maximum Sustained Release Rule as per RPM3. Additional modifications to the revised IOP will need to be made, in particular, to accommodate long-term water supply demands. For now, however, the proposed revision should be adopted.

2. BACKGROUND

This proposal is submitted in response to a Biological Opinion issued by USFWS on September 5, 2006 to review the Interim Operations Plan for Jim Woodruff Lock and Dam ("JWLD"). The Biological Opinion (BiOp) studies the effect of the Interim Operations Plan ("IOP") for JWLD on certain threatened and endangered species present in the Apalachicola River — the threatened Gulf sturgeon and three species of threatened or endangered mussels.

As is explained further below, the Biological Opinion concludes that reservoir operations under the IOP are generally acceptable. The BiOp also recommends, however, that the IOP be revised to provide minimize instances when discharge at the Chattahoochee gage (below JWLD) is less than 10,000 cfs.

2.1 Legal Framework

The Endangered Species Act protects threatened and endangered species in two ways — by prohibiting "takings" and by prohibiting federal agencies from supporting or taking action that would "adversely impact" critical habitat.

The prohibition on "takings" is contained in Section 9. 7 U.S.C. § 1538. The act defines "take" to mean "to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect" it. 16 U.S.C. § 1532(19). Although "takings" "may include significant habitat modification or degradation," that is true only if the action "actually kills or injures wildlife by significantly impairing essential behavioral patterns, including breeding, feeding or sheltering." *See* 50 C.F.R. § 17.3. *See also Babbitt v. Sweet Home Chapter of Communities for a Great Oregon*, 515 U.S. 687 (1995). The prohibition against takings applies to all persons.

The second set of protections, applicable only to federal agencies, are contained in Section 7. *See*16 U.S.C. § 1536. Section 7 requires federal agencies to consult with the Fish and Wildlife Service ("USFWS") (or, for marine species, with the National Oceanic and Atmospheric Administration Fisheries Service (formerly known as the National Marine Fisheries Service), to ensure that their actions do not "jeopardize the continued existence" of any protected species or result in the "destruction or adverse modification" of "critical habitat." *Id.*

The result of formal consultation under Section 7 is a Biological Opinion indicating whether the proposed activity is likely to jeopardize the continued existence of listed species and/or result in the destruction or adverse modification of critical habitat. When USFWS issues a no-jeopardy opinion but concludes that "takings" of individual animals are nonetheless likely, USFWS is required to include an Incidental Take Statement (ITS) as part of the Biological Opinion. *See* 7 U.S.C. § 1536(b)(4). The ITS authorizes "takings" that would otherwise be prohibited by Section 9 of the ESA. *See* 7 U.S.C. § 1536(o)(2) ("any taking that is in compliance with the terms and conditions specified in [an ITS] shall not be considered to be a prohibited taking of the species concerned.").

2.2 Threatened and Endangered Species Potentially Affected by Reservoir Operations

The Corps initiated formal consultation with USFWS on March 7, 2006 to study the effects of reservoir operations on the Gulf sturgeon and the three mussel species. Detailed information concerning these species is provided in the Biological Opinion.

2.2.1 Gulf sturgeon

The Gulf sturgeon was listed as a "threatened" species in 1991. The Apalachicola River was designated critical habitat for the sturgeon in 2003. The Apalachicola River Critical Habitat Unit constitutes approximately 10% of the total river miles included within the designation.

According to USFWS reservoir operations have the potential to affect Gulf sturgeon habitat by reducing the flow of the river at times when flows are stored (i.e., when cumulative storage is increased) and by increasing flows in the river when reservoir storage is released (i.e., when stored water is released to augment the flow of the river). BiOp at 107. Such operations could potentially affect "flow regime" and "water quality" elements of the Gulf sturgeon critical habitat. The primary concern is for spawning habitat during the spring spawning season.

USFWS has identified 117 acres of potentially suitable spawning habitat, including about 30 acres at two sites where sturgeon eggs have been collected. BiOp at 69. Two sites are known to support sturgeon spawning within the action area. BiOp at 69. The most important spawning site is a rough limestone outcrop at RM 105. *Id.* The other known site is a smooth consolidated clay outcrop at RM 99. USFWS has also identified eight other sites that contain hard-bottom substrate potentially suitable for spawning. *Id.*

2.2.2 Mussels

The other species of concern are two species mussels — the endangered fat threeridge and the threatened purple bankclimber.[1] The main concern for the mussel species is to provide them with flowing water at all times.

USFWS has also indicated that "floodplain connectivity" may be important for the host fishes that support the larval stages of these animals. The Biological Opinion nonetheless concludes that reservoir operations are not likely to have a substantial effect on floodplain connectivity.

2.3 The IOP

The Interim Operations Plan for Jim Woodruff Lock and Dam ("IOP") was included as an attachment to the letter initiating formal consultation. The IOP was developed to ensure that operations at JWLD will not adversely affect Gulf sturgeon spawning grounds or critical habitat for listed mussels. The IOP sets flow levels for the spring spawning season based on a

[1] The Biological Opinion also addresses one other species — the Chipola slabshell — but notes that only one individual of this species has ever been documented within the action area. Therefore USFWS concluded that the probability of adverse impacts to this species resulting from reservoir operations was negligible. BiOp at 67.

percentage of "basin inflow." The plan also establishes certain minimum flow levels for the protected mussels.

The Corps adopted the Interim Operations Plan ("IOP") for Jim Woodruff Lock & Dam (JWLD) on March 7, 2006. A revised plan was adopted on June 12, 2006. The IOP was revised again on September 5, 2006 in accordance with the Biological Opinion issued on that date by USFWS.

2.3.1 Flow requirements in the IOP

Flow requirements under the IOP are computed in relation to Basin Inflow ("BI"). Basin inflow is the total inflow into the ACF Basin above Jim Woodruff Dam, less any water lost through evaporation or water withdrawals.

Specific flow requirements in the IOP, as amended through September 5, 2006, are as follows:

Time period	**Basin inflow (BI) (cfs)**	**Minimum Release (cfs)**
March – May	37,400 ≤ BI	Not less than 37,400
	20,400 ≤ BI < 37,400	≥ 70% of BI Not less than 20,400
	BI < 20,400	≥ BI, but not less than 5,000
June - February	23,000 ≤ BI	Not less than 16,000
	10,000 ≤ BI < 23,000	≥ 70% of BI, but not less than 10,000
	BI < 10,000	≥ BI, but not less than 5,000

2.3.2 Ramp-down requirements in the IOP

The IOP also imposes certain "ramp-down" requirements to ensure that river levels do not fall too rapidly all at once. The "ramp-down" is the speed with which river levels are allowed to fall after periods of high flow. Ramp-down requirements are prevent animals from getting stranded on the margins of a stream when the water recedes.

The ramp-down restrictions in the IOP are as follows:

Release range	**Maximum fall rate (ft / day) measured at Chattahoochee gage**
Flows greater than 30,000 cfs	No ramping restriction
Flows greater than 20,000 cfs but <= 30,000 cfs	1.0 to 2.0 ft / day
Exceeds powerhouse capacity (16,000 cfs) but <= 20,000 cfs	0.5 to 1.0 ft /day
Within powerhouse capacity and > 8,000 cfs	0.25 to 0.5 ft /day
Release within powerhouse capacity, but less than 8,000 cfs:	0.25day / less

2.3.3 Drought Operations

The IOP does not specify how the reservoirs will be operated in the event that there is insufficient storage to meet the 5,000 cfs minimum flow requirement.

2.4 The Biological Opinion

USFWS issued the Biological Opinion on September 5, 2006. The Biological Opinion is a “no jeopardy opinion” -- USFWS concluded that operations under the IOP will not threaten the survival of any listed species or adversely affected critical habitat. The Biological Opinion does, however, conclude that “takings” of individual mussels species “may occur” when flows fall below 10,000 cfs. BiOp at 140.

A more detailed overview of the “effects analysis” for each species is provided below.

2.4.1 Gulf sturgeon

For the Gulf sturgeon, the Biological Opinion concludes that the IOP will have a “small beneficial effect relative to the baseline on habitat availability at known spawning sites downstream of JWLD. BiOp at 137.

The Biological Opinion is primarily concerned with effects of the IOP on the flow regime for spawning habitat during the spring spawning season. The primary analysis employed to evaluate these effects was to quantify the amount of habitat at known and potential spawning sites inundated during the spawning season to depths appropriate for spawning. BiOp at 111. Based on egg collections during 2005 and 2006, USFWS considers habitat to be “available” if the habitat is inundated to depths between 8.5 feet and17.8 feet. BiOp at 70-72 (text) & 103-04 (figures). Channel configuration dictates that habitat availability is not necessarily proportional to flow, as intermediate flows can make some areas too deep while newly inundated areas are not deep enough for expected spawning.

Operations under the IOP provide slightly more water to the potential spawning grounds at the appropriate depths than historical or "run-of-river" operations. Therefore USFWS concluded that the IOP will result in a small benefit to the Gulf sturgeon.

2.4.2 Fat threeridge and purple bankclimber

For the fat threeridge and the purple bankclimber, the Biological Opinion concludes the IOP will have a "small, but not appreciable additional impact on the survival and recovery" of the species. Although the BiOp concludes that the IOP "will not appreciably diminish the ability of proposed critical habitat to function for the conservation of" either species, BiOp at 123, USFWS concluded that "takings" — in the form of "habitat modification" — "may occur" when flows are less than 10,000 cfs. BiOp at 123.

Of the five constituent elements of purple bankclimber and fat threeridge habitat, the BiOp concludes that the IOP is likely to adversely affect only the "flowing water" element. BiOp at 121. USFWS developed low-flow measures to assess this impact.

a) Low flow effects

The Biological Opinion is primarily concerned with the potential for mussels to be exposed during periods of low flow. Although mussels move in response to changing water levels, they sometimes are caught in areas too far from the receding shoreline or areas in which down-slope movement does not lead to adequately deep water. BiOp at 78. This risk of stranding is greatest when high flows are followed by low flows because mussels that move to higher ground during the high flow period may be stranded when the water level falls. Therefore, to evaluate the effect of reservoir operations, USFWS is primarily concerned with (1) rate of flow change and (2) the frequency and duration of low flows.

To study the potential impact of reservoir operations, USFWS considered the location of known mussel beds and determined whether and how often these areas would be exposed during low flows. Because the purple bankclimber prefers deeper portions of the channel, this animal is not as vulnerable to low-flow impacts as the fat threeridge. BiOp at 139. According to the Biological Opinion, fat threeridge mussels have been found in locations that are exposed at discharges as high as 10,000 cfs.

The BiOp acknowledges that flows less than 10,000 cfs occur "in almost all years" on the Apalachicola River — and hence that most mussel beds are located in areas that would not require flows of this magnitude to remain inundated. BiOp at 140. Nonetheless, USFWS speculates that, "during a series of wet years with few or no low-flow events, a fraction of the population may naturally occur at relatively high on the stream bed." BiOp at 140. USFWS also notes that "mussels may be deposited at higher elevations during flood events." *Id.* The BiOp concludes that "adverse effects will occur when low flows follow an extended period without low flows or follow a flood event that reshapes mussel habitat and/or redistributes mussels." BiOp at 141.

b) Host fish

USFWS also noted a concern for host fish necessary to support the larval stages of the protected mussels. Although host fish for the purple bankclimber are not known, the Biological Opinion indicates that the fat threeridge is a host fish "generalist" that may infect at least three different fish families, including certain species that utilize floodplain habitat. BiOp at 120. USFWS studied "floodplain spawning habitat availability" as the principal measure of effects to potential host species. BiOp at 121.

2.4.3 Reasonable and Prudent Measures

As a condition of the ITS, USFWS is required to impose mandatory "reasonable and prudent measures" ("RPMs") to minimize the take that will occur.

The third RPM is the subject of this proposal. RPM3 provides as follows:

> **RPM3. Drought provisions**. Develop modifications to the IOP that provide a higher minimum flow to the Apalachicola River when reservoir storage and hydrologic conditions permit.
>
> As proposed, the IOP uses reservoir storage to support a 5,000 cfs minimum flow. The available data indicates that higher flows can be supportable during normal and wet hydrologic periods, and during dry periods when the reservoirs are relatively full. Conversely, during extended drier than normal conditions, it may be prudent to store more water than allowed under the IOP during certain times of the year to insure (sic) minimum water availability later.

3. CONCEPTS PRESENTED BY THE CORPS TO IMPLEMENT RPM3

At a technical workshop on December 12, 2006, the Corps presented four "concepts" in response to RPM3. For each concept, the Corps has provided detailed modeling results; these output files were used to prepare the comparative graphs in the evaluation of alternatives in Section 4.

The Corps has described the four concepts under consideration as follows:

3.1.1 Concept #1

The first concept presented was to determine the maximum low-flow the system can support. As a modeling exercise, the Corps increased the 5,000 cfs minimum flow in the IOP to higher values — 6,000 cfs, 6,300 cfs, 6,600 cfs and 8,000 cfs. The Corps reported that the results were not acceptable for any of these increased minimum flows.

3.1.2 Concept #2

The second concept presented was to decrease spawning period high flows in connection with an increase in the low flow target. The 37,400 cfs high-flow target in the IOP was reduced to 25,000 cfs; the intermediate target of 20,400 cfs was reduced to 16,000 cfs; and the 5,000 cfs minimum flow was increased to 5,800 cfs (variation 1), 6,500 cfs (variation 2) and 7,000 cfs (variation 3). Again, the Corps reported that the results were not acceptable for any of these variations.

3.1.3 Concept #3

The third concept presented was to use "system composite storage" as a drought trigger for "desired flow" of 6,500 cfs and the "required flow" of 5,000. Under this concept, the drought trigger is activated when "system composite storage" is in Zone 3. The drought trigger would be deactivated when the system composite storage recovers to Zone 1. The Corps reported that het results for this concept appeared to be promising.

3.1.4 Concept #4

The fourth concept was to increase the percentage of flows that can be stored when Basin Inflow is greater than 10,000 cfs from 30% to 50%. This concept was modeled as an "add-on" to Concept #3. The Corps stated that this concept appeared to produce few benefits in addition to Concept #3.

4. PROPOSED ALTERNATIVE CONCEPT FOR THE IMPLEMENTATION OF RPM3

The proposed alternative for RPM3 is superior or equal to Concept #3 for almost every operational objective. This alternative, which will be called the Maximum Sustainable Release Rule ("MSRR"), substantially improves the performance of the IOP on the key biological performance measures evaluated by USFWS in the Biological Opinion. In some cases there are trade-offs, but the costs are generally marginal and the benefits are high. Overall the proposed alternative would have a substantial beneficial impact on protected species. At the same time, by keeping significantly more water in storage, the proposed alternative would provide substantial benefits to other project purposes. The proposed alternative would not have any adverse impact on flood plain connectivity, hydropower generation, flood control, or, to our knowledge, any other operating objective.

4.1 Overview

The basic concept of the MSRR is to provide the maximum sustainable release from Jim Woodruff Dam, up to 10,000 cfs, that can be maintained while also allowing the reservoirs upstream in the Chattahoochee Basin to refill by the following June 1. The maximum sustainable release is calculated based on the current storage in the reservoirs and a forecast of future inflows. The forecast is made using probabilistic streamflow forecasting techniques developed and published by the USGS.

Although the MSRR does not utilize reservoir storage to provide flows in excess of 10,000 cfs, such flows occur from Flint River flow and when the reservoirs are full. Because the MSRR allows the reservoirs to refill early and often, flows in excess of 10,000 cfs are provided in a pattern that is at least as beneficial (and often more beneficial) for the protection and enhancement of threatened and endangered species than the flows provided by the IOP, as demonstrated in the evaluation below.

The MSRR increases the minimum flow whenever sufficient water is available to meet the increased minimum, provide for the long-term support of all uses, and still refill the reservoirs by the following June 1. The calculation of the water available includes a conservative forecast of expected inflows (inflows expected to be exceeded 90% of the time) based on basin conditions. The forecast is done using a USGS developed technique that relies only on antecedent inflows, and not on weather forecasts. Documentation of this technique is available from the USGS, and is attached.

As stated above, the refilling of the reservoirs is crucial to the improved performance of the MSRR relative to the IOP for the protection of endangered and threatened species. Because the reservoirs fill early and often in the spring, crucial spawning flows are most often maintained at levels equal to the full basin inflow. Moreover, because the reservoirs do not often empty, there is usually sufficient water to maintain minimum flows well in excess of 5000 cfs, as envisioned in RPM3.

The MSRR stores the water necessary to meet the increased minimum whenever the inflow between Lake Eufala and Lake Seminole, including the Flint River inflow, rises above the maximum sustainable release. A new maximum sustainable release is computed each week so that as storage improves, the maximum sustainable release also rises. In addition, the MSRR restricts releases to 5000 cfs whenever there is not enough water in the system to sustain that flow over a repeat of the worst historical drought and still have a margin of safety. This ensures enough water will remain in the system to “insure minimum water availability later.”

As will be shown below, the rules contained in the MSRR implement RPM3 in a manner that substantially improves the IOP in its protection threatened and endangered species and many other performance measures.

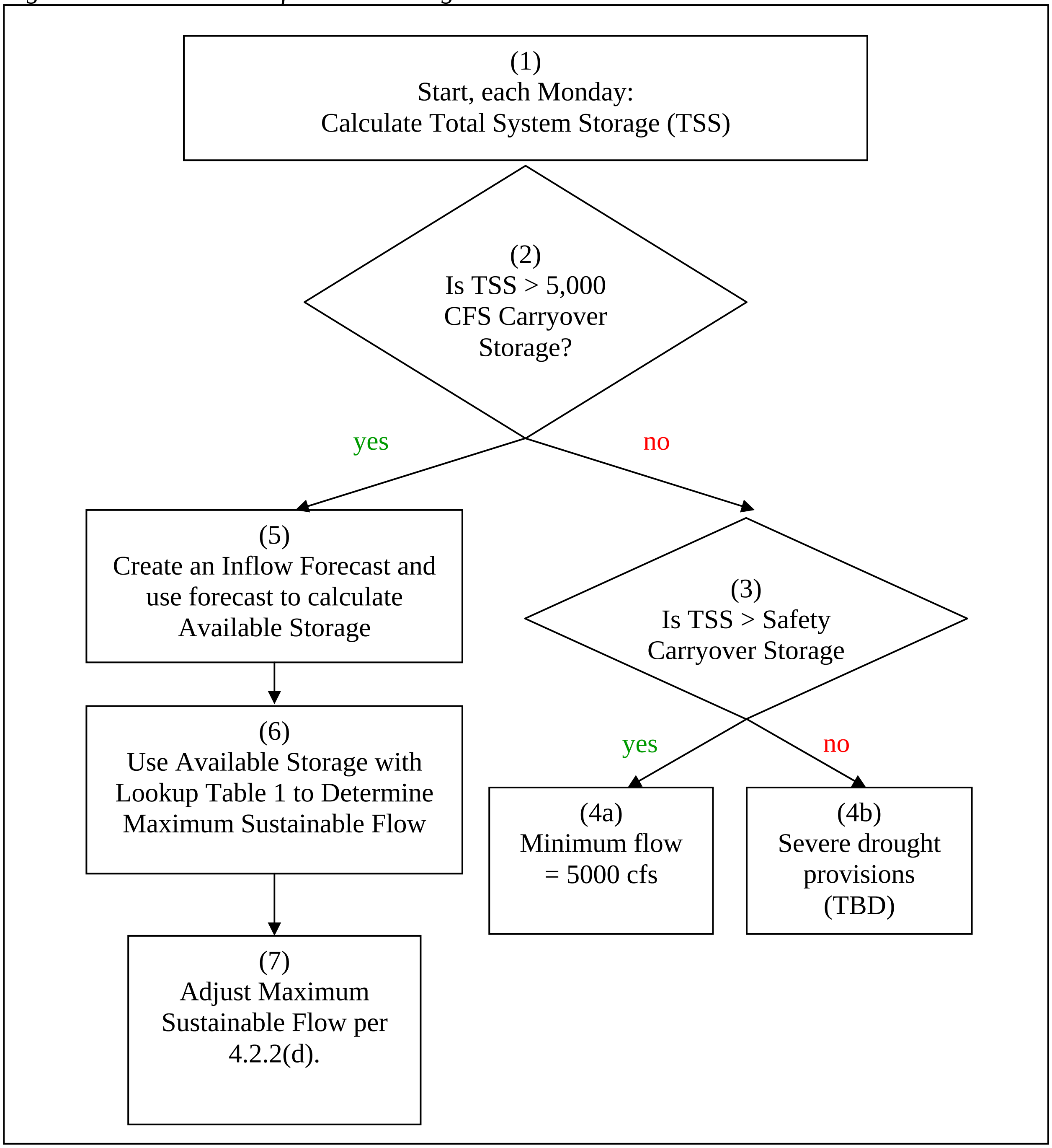
4.2 The Maximum Sustainable Release Rule (MSRR)

The basic concept of the proposed revision is to provide the Maximum Sustainable Release that can be supported by JWLD, up to 10,000 cfs. The Maximum Sustainable Release is calculated each week as a function of the total Available Storage using forecasting techniques established by USGS. A release is deemed to be “sustainable” if the storage is available to support it without comprising the long-term performance of the system, including ability of the system to refill by June 1 each year. Calculations necessary to implement the proposed alternative are easily made using a spreadsheet and real-time data maintained by USGS.

A decision tree is provided below (Figure 1) to show how to determine the Maximum Sustainable Flow on a weekly basis. The right side of the decision tree — dealing with “Carryover Storages” — is discussed in Section 4.2.1 below. The left side — calculation of the

Maximum Sustained Release when Total System Storage exceeds Carryover Storages — is discussed in Section 4.2.2.

Figure 1: Decision Tree for Determining Release



4.2.1 Carryover Storages

The primary goal of the MSRR is to provide the maximum sustainable flow at Woodruff as requested by RPM 3. Carryover Storages are storages that need to be preserved to meet critical needs over the long term. These storages are used to determine when flows must be curtailed to meet such needs. Two critical needs are given top priority: the protection of public health and safety and protection of endangered species. The amount of "Carryover Storage" necessary to support each of these needs throughout a critical drought has been calculated and is shown in Figure 3.

a) Public Health and Safety

Losing the ability to provide drinking water and fire protection to the citizens of Alabama, Georgia, and Florida would be devastating to the region. Therefore the volume of water needed to protect public health and safety through a multi-year drought, called the Public Health and Safety Carryover Storage (or Safety Storage), should be maintained in storage at all times. In the MSRR, this volume was determined by running a simulation with 2030 demands and minimum flow requirements at Atlanta and Columbus only. The maximum drawdown in the four major reservoirs over the historic record is designated as the Public Health and Safety Storage — this is the volume of water that would have been needed to get through the worst drought on record.

b) 5,000 CFS Carryover Storage

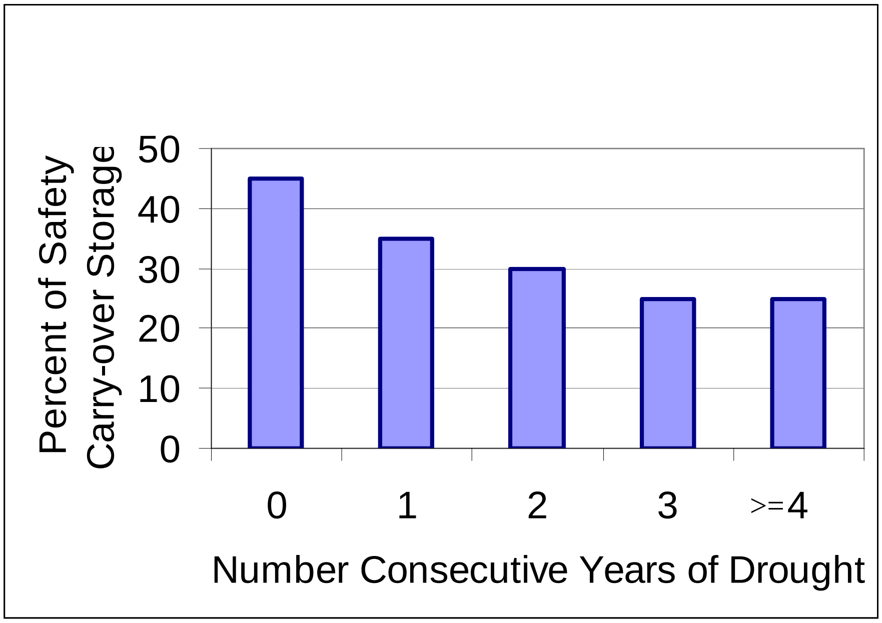
In addition to public health and safety, endangered species must be protected throughout a critical drought. Therefore the amount of storage needed to support threatened and endangered species must be preserved in system storage at all times. The storage set-aside to meet these needs is called the 5,000 CFS Carryover Storage.

In the MSRR, the 5,000 CFS Carryover Storage is set-aside to meet the 5,000 cfs minimum flow requirement and also to meet the ramping rates specified in the IOP. Larger minimum flows are supported when possible, but these are the minimum requirements. The amount of 5,000 CFS Carryover storage was determined using the same method as for the Public Health and Safety Carryover Storage: simulations were done with demands, minimum flow requirements at Atlanta and Columbus, and the releases at Woodruff listed above. The maximum drawdown in the four major reservoirs over the historic record is the volume of water that would have been needed to sustain the 5,000 cfs minimum flow and IOP ramping rates throughout the worst historical drought.

c) Margin of Safety

Because future droughts may be worse than the historical drought of record, a margin of safety is added to both Carryover Storages. The margin of safety decreases each year of an ongoing drought to balance the impacts of lower flows on the environment and water-use restrictions on public health and welfare against the risk that the drought will continue. The margins of safety used in the demonstration run are shown in Figure 2; these percentages are multiplied by the Public Health and Safety Carryover Storage to set-aside an additional volume of water. Although calculated as a percentage of the Public Health and Safety Carryover Storage, the Margin of Safety is divided evenly between the two Carryover Storages.

Figure 2: Margin of Safety

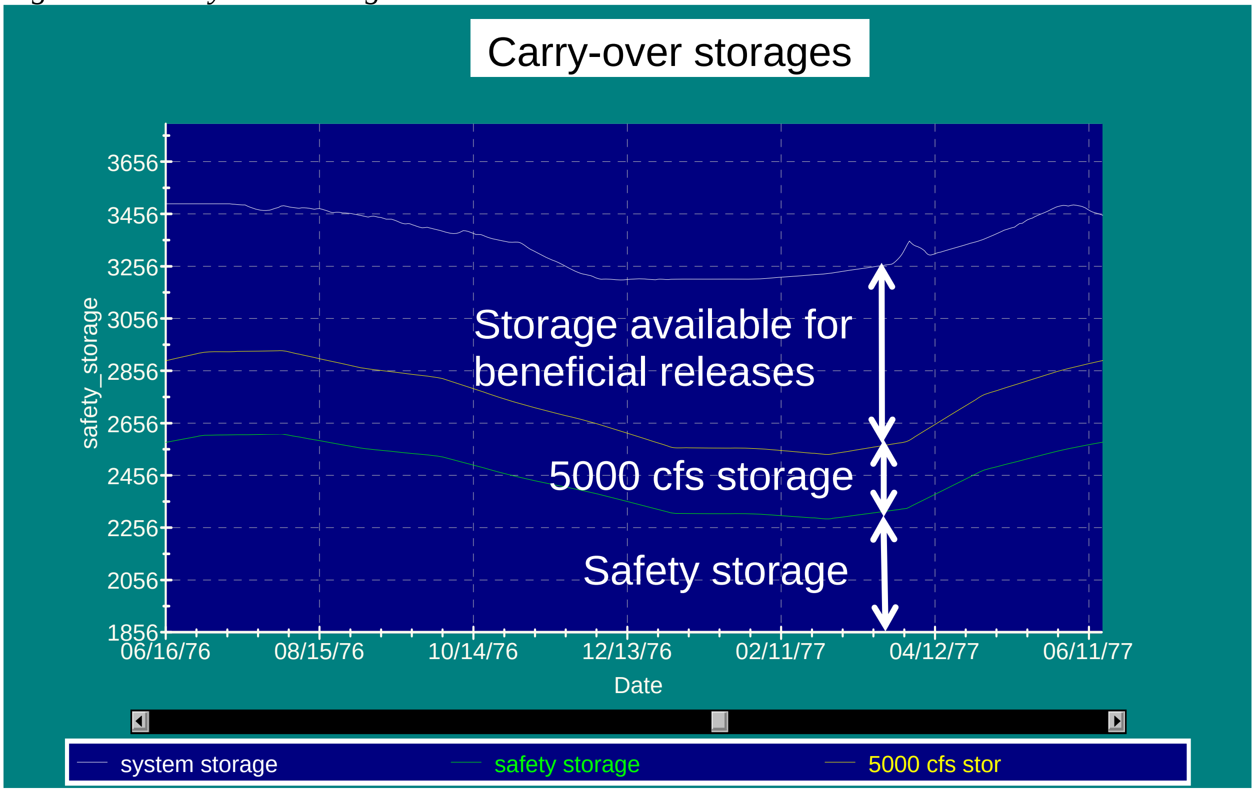


It is important to note that the MSRR manages storage in such a way that available storage will not reach or approach levels below those needed to maintain public health and safety during a repeat of any historical drought period. The provision of a margin of safety adds an additional measure of security, ensuring that the system can adapt to future droughts worse than those in the historical record. Further, it is important to understand that the performance of the MSRR will not be enhanced by reducing Carryover Storage or the Margin of Safety. The success of the MSRR is based on its strategy of allowing the reservoirs to refill early and often. Thus, providing a margin of safety would not conflict with achieving environmental objectives during a repeat of any historical drought. Also note that a similar margin of safety is provided for meeting critical instream flow needs below Woodruff Dam, as detailed below.

Figure 3 illustrates the Carryover Storages in relation to Total System Storage. The Carryover Storages vary seasonally following the drawdown pattern of the tops of conservation pools. A representative year, 1976, is shown in the figure; the seasonal pattern is the same in all other years. The margin of safety varies from year to year depending on the number of consecutive drought years. In 1976, there was no drought, so there is a 45% margin of safety added to the Carryover Storage. During prolonged droughts, this can drop to as low as 25%. The margin of safety was divided evenly between the Public Health and Safety Storage and the 5,000 CFS Carryover Storage. Therefore, the green line in Figure 3 shows the Public Health and Safety Carryover Storage — the maximum historical drawdown to meet public health and safety needs plus 22.5%. The distance between the yellow and green lines is the 5,000 CFS Carryover Storage—the maximum historical drawdown to support at least 5000 cfs at Woodruff and the ramping rates defined in the IOP plus 1/2 of the Margin of Safety.

The white line in Figure 3 shows the Total System Storage in 1976. System storage is defined as the sum of the storages in Lanier, West Point, and WF George. Whenever Total System Storage is less than the amount required for 5,000 CFS Carryover Storage, releases are curtailed unless necessary to meet the 5,000 cfs minimum and the IOP ramping rates. *This only* *happens once during the entire period of record in the MSRR, for about three months in 2000.* If Total System Storage were ever to fall below the amount required for Safety Storage, extreme drought provisions would be triggered and the 5,000 cfs minimum might need to be relaxed by necessity. This *never* happens in the historical simulation of the MSRR. The system storage remains above the Carryover Storages in large part because releases to benefit protected species are made so as to be sustainable. The process used to determined beneficial releases is described in the next section.

Figure 3: Carry-over storages



d) Operations During Extreme Drought: Release Decisions Based on Carryover Storage Levels

As stated above, the Carryover Storages are established to indicate when releases must be curtailed to preserve the ability of the system to meet critical needs over the long term. If Total System Storage is less than Instream Flow Carryover Storage, releases are restricted to the amount necessary to meet the 5,000 cfs minimum flow and IOP ramp-down provisions. If Total System Storage is less than the Safety Carryover Storage, the MSRR does not specify any definite minimum flow.

The IOP does not specify what emergency measures would be taken if a more severe than historical drought were to occur, either. Thus, the only way to compare the MSRR and the IOP with regard to extreme droughts is to look at the storage levels likely to occur when operators realize that the potential for such a drought exists and begin to take emergency measures. The more storage available at that time, the more flexibility the operators will have to deal with the situation.

By setting aside Carryover Storages based on the most severe drought on record plus a sufficient margin of safety, the MSRR is designed to minimize or eliminate the likelihood that such provisions will ever be triggered. Minimum system storage under the MSRR is considerably higher than the minimum storage that would have occurred using the IOP. This indicates that the MSRR provides a considerably higher level of reliability in the face of extreme drought than does the IOP.

4.2.2 Determining the Maximum Sustainable Flow When Total System Storage Exceeds Carryover Storages

The steps used to determine the Maximum Sustainable Flow when Total System Storage exceeds the Carryover Storages are discussed below. The logic of the rule is to increase the minimum flow whenever (1) Total System Storage exceeds the Carryover Storages, and (2) sufficient water is available in storage to allow the reservoirs to refill by the following June 1; and (3) such releases can be made without compromising the ability of the system to meet critical needs. The calculation of available storage includes a conservative forecast of expected inflows (inflows expected to be exceeded 90% of the time) based on basin conditions. This rule provides a rational, sustainable basis for determining how much water to release in excess of the minimum requirements. Enhancement releases are determined such that system storage will refill each year with a high level of certainty.

a) Create an Inflow Forecast

The first step is to create an Inflow Forecast to provide expected amounts of inflows corresponding to different levels of probability. This information is used to determine the maximum flow that can be maintained at Woodruff while still allowing the system to refill each year with a high level of certainty.

While future rainfall cannot be accurately predicted, there are two sources of information to guide operational decision-making: historical statistics and forecasts of inflow. Forecasting methods make use of the correlation between current and future conditions: if inflows have been low, they tend to stay low, and vice versa. This is essentially because when conditions are dry, there is more evaporation and infiltration and hence less runoff, and vice versa.

Within about four month's time, the inflows forecast by conditional forecast methods converge to the inflows that would be forecast using historical statistics. In other words, although streamflow conditions are strongly autocorrelated from one month to another, the correlation weakens as the forecast period is lengthened, and the correlation is essentially zero by the time the forecast period is extended to four months. At this point, historical statistics provide the best available forecast.

There are a number of forecasting techniques, all of which give a shift in mean and variance based on antecedent inflows. A technique has been developed by Robert Hirsch of the USGS, and that program has been adapted for ease of use and integration with HECDSS by HydroLogics Inc. Documentation of this technique from the USGS is attached. The USGS technique is easy to implement. The adaptations made by Hydrologics do not affect the underlying methodology, and the forecast program can be made available to the USACE free of charge. Alternatively, the USACE could obtain the original program from the USGS. In practice, running the forecast program requires that antecedent inflow data be kept current and formatted to suit the program. The data is already kept current and formatting can be easily automated. Running the forecast program takes less than one second.

Hydrologics has used the program to re-create the forecasts that would have been made each week in the hydrologic record. These "historical" forecasts were used to show how the MSRR would have performed in the past, using the forecasts. The results prove that the combination of the forecasting technique and the MSRR is effective given the existing accuracy and precision of the USGS forecasting technique. Producing and using forecasts in the manner incorporated in the MSRR is eminently practical. Such forecasts are currently being used operationally by a number of agencies, including the North Carolina Department of Natural Resources.

b) Calculate Available Storage — Storage in Excess of the Amount Necessary to Allow the System to Refill by June 1

The next step is to calculate "Available Storage" based on the Inflow Forecast at the 90% probability level (such that inflow has a 90% probability of exceeding the forecasted value). Available Storage is the amount of storage on hand in excess of the amount necessary to allow the system to refill by June 1.

Available Storage is calculated as the forecasted 90% inflow less (1) water supply (expected demand for all users above and including Whitesburg); (2) minimum flow requirements at Atlanta (number of days till June 1 times 750 cfs); (3) evaporation (average between now and June 1); and (4) void (volume in Lake Lanier between current storage and top of conservation pool on June 1[2]). The resulting volume — Available Storage — is roughly the amount of water that can be released from Lake Lanier while maintaining a 90% chance of refill by the following June 1.

c) Calculate the Maximum Sustainable Release

The Maximum Sustainable Release is determined as a function of Available Storage. This determination is made each Monday in the simulation. The Maximum Sustainable Release is given as a function of Available Storage in the lookup table provided in Table 1.

[2] For this calculation, Lake Lanier is used as a surrogate for system storage — it is assumed that the entire system will be full if Lake Lanier is full. Lake Lanier is a reasonable surrogate for the entire system because Lake Lanier takes much longer to refill than any of the other reservoirs.

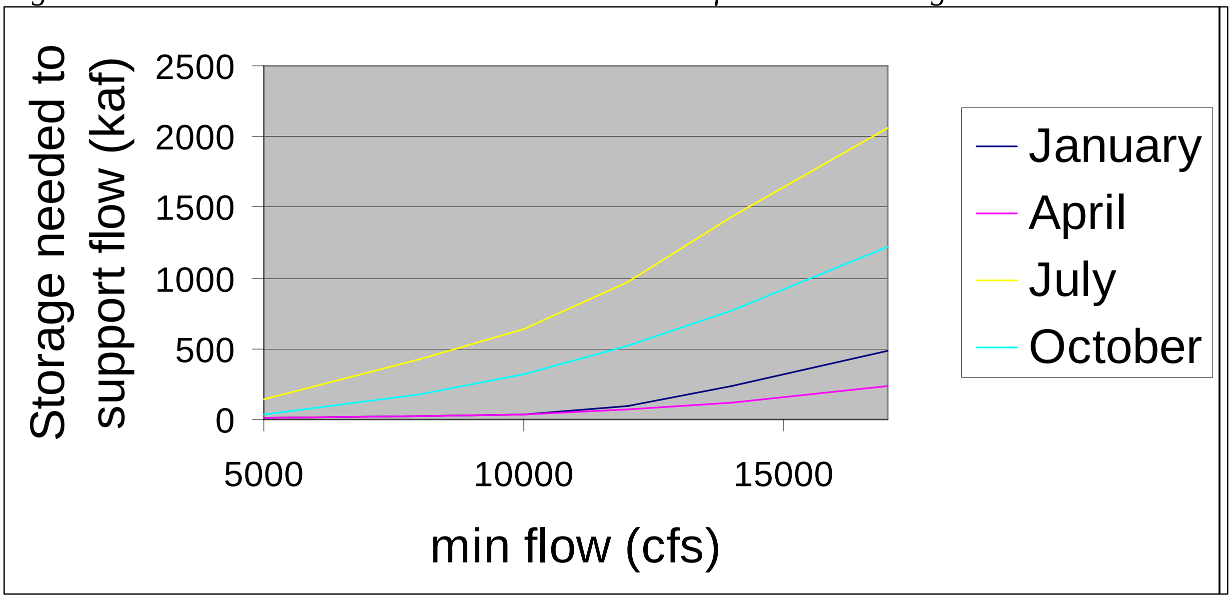
Table 1: Maximum Sustainable Release from Woodruff (cfs)

Available Storage (af)	**1/1**	**2/1**	**3/1**	**4/1**	**5/1**	**6/1**	**7/1**	**8/1**	**9/1**	**10/1**	**11/1**	**12/1**
0	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000
7000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000
14000	5000	6432	6544	6544	6546	5000	5000	5000	5000	5000	5000	5546
21000	5571	9700	9700	9704	9707	5000	5000	5000	5000	5000	5522	6155
28000	6243	10000	10000	10000	10000	5000	5000	5000	5000	5000	5720	6672
42000	9106	10000	10000	10000	10000	5000	5000	5000	5000	5088	6184	9238
49000	9753	10000	10000	10000	10000	5000	5000	5000	5000	5213	6391	10000
56000	10000	10000	10000	10000	10000	5000	5000	5000	5000	5313	8683	10000
63000	10000	10000	10000	10000	10000	5000	5000	5000	5000	5432	8922	10000
77000	10000	10000	10000	10000	10000	5000	5000	5000	5046	5853	9345	10000
84000	10000	10000	10000	10000	10000	5000	5000	5000	5302	5942	9369	10000
98000	10000	10000	10000	10000	10000	5000	5000	5000	5470	6171	10000	10000
105000	10000	10000	10000	10000	10000	5000	5000	5000	5554	6282	10000	10000
112000	10000	10000	10000	10000	10000	5000	5000	5000	5607	6597	10000	10000
126000	10000	10000	10000	10000	10000	5000	5000	5043	5985	6817	10000	10000
133000	10000	10000	10000	10000	10000	5000	5000	5128	6068	6924	10000	10000
140000	10000	10000	10000	10000	10000	5094	5000	5307	6118	6990	10000	10000
154000	10000	10000	10000	10000	10000	5359	5084	5476	6280	8988	10000	10000
161000	10000	10000	10000	10000	10000	5501	5148	5557	6360	9111	10000	10000
168000	10000	10000	10000	10000	10000	5315	5282	5616	6635	9175	10000	10000
182000	10000	10000	10000	10000	10000	5577	5409	5932	6795	9407	10000	10000
189000	10000	10000	10000	10000	10000	5717	5471	6009	6874	9519	10000	10000
196000	10000	10000	10000	10000	10000	5932	5517	6058	6920	9867	10000	10000
210000	10000	10000	10000	10000	10000	5777	5747	6203	8780	10000	10000	10000
217000	10000	10000	10000	10000	10000	5916	5807	6272	8874	10000	10000	10000
231000	10000	10000	10000	10000	10000	6286	5904	6592	9017	10000	10000	10000
238000	10000	10000	10000	10000	10000	6450	5960	6660	9109	10000	10000	10000
245000	10000	10000	10000	10000	10000	6097	6097	6725	9506	10000	10000	10000
259000	10000	10000	10000	10000	10000	6463	6245	8494	9633	10000	10000	10000
266000	10000	10000	10000	10000	10000	6623	6299	8569	9701	10000	10000	10000
273000	10000	10000	10000	10000	10000	6791	6352	8642	9769	10000	10000	10000
287000	10000	10000	10000	10000	10000	6625	6600	8733	10000	10000	10000	10000
294000	10000	10000	10000	10000	10000	6782	6651	8801	10000	10000	10000	10000
308000	10000	10000	10000	10000	10000	8655	6725	9251	10000	10000	10000	10000
315000	10000	10000	10000	10000	10000	8878	6773	9315	10000	10000	10000	10000
322000	10000	10000	10000	10000	10000	6927	6927	9377	10000	10000	10000	10000
336000	10000	10000	10000	10000	10000	8818	8498	9826	10000	10000	10000	10000
343000	10000	10000	10000	10000	10000	9034	8553	9875	10000	10000	10000	10000
357000	10000	10000	10000	10000	10000	9499	8660	9970	10000	10000	10000	10000
364000	10000	10000	10000	10000	10000	8966	8943	9960	10000	10000	10000	10000
378000	10000	10000	10000	10000	10000	9397	9045	10000	10000	10000	10000	10000
385000	10000	10000	10000	10000	10000	9624	9095	10000	10000	10000	10000	10000
399000	10000	10000	10000	10000	10000	9308	9308	10000	10000	10000	10000	10000
406000	10000	10000	10000	10000	10000	9521	9501	10000	10000	10000	10000	10000
420000	10000	10000	10000	10000	10000	10000	9547	10000	10000	10000	10000	10000

427000	10000	10000	10000	10000	10000	10000	9591	10000	10000	10000	10000	10000
430000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000

The flows in Table 1 were derived from a series of graphs similar to Figure 4. To determine the Maximum Sustainable Flow on July 1 from Figure 4, first determine the Available Storage. If Available Storage is 500 kaf, the Maximum Sustainable Flow is about 8500 cfs. This is the flow can be supported at Woodruff without compromising the ability of the reservoirs to refill by June 1. Note that the same amount of Available Storage in April could be used to support a much higher minimum flow.

Figure 4: Maximum Sustainable Flow as a Function of Available Storage



Curves similar to those shown in Figure 4 have been developed for each month of the year, as reflected in Table 1. These graphs were generated by calculating the difference between the desired flow and historical inflows each day to give the water needed from storage that day, if any. These daily values were then summed between present and June 1. To provide a high level of reliability, the 90th percentile of historic inflows were used, meaning that if all years in the historic record were ranked from wettest to driest, 10% of the years would be drier and 90% wetter than the inflows used in the analysis. 90th percentile inflows to the basin remain above 7000 cfs for much of the year, so the average of the driest three years was used in place of the 90th percentile below 7000 cfs and values were interpolated between these values and the 90th percentile at 9000 cfs.

In addition, when the value of Maximum Sustainable Flow obtained from the curves is greater than 7,000 cfs, it is adjusted upward by 20%. Trial and error has shown that the upwardly adjusted flows can be maintained without impact on other objectives. The boosted values are reflected in Table 1.

d) Adjust the Maximum Sustainable Flows

Finally, once the Maximum Sustainable Release is determined from Table 1, it is subject to three possible alterations developed by trial and error to enhance the performance of the operating rules: (1) a ramping rate restriction and (2) a limitation on maximum sustainable releases over 10,000 cfs. Again, all three of these alterations improved the performance of the MSRR on the performance measures shown in the previous section.

i *Ramping rate restriction.*

To avoid extreme jumps in the minimum flow requirement from week to week, a ramping rate restriction of 1,400 cfs / week is imposed. The daily change in releases from Woodruff, and thus impacts due to ramping on by endangered species in the Apalachicola, are controlled by the ramping rates used in the IOP.

ii *Limitation on Maximum Sustainable Releases Over 10,000 cfs.*

In the MSRR, flows above 10,000 cfs are not supported from storage. Imposing this limit resulted in significantly better flows for the mussels and caused little change in sturgeon spawning habitat or floodplain connectivity. Flows above 10,000 cfs are still common due to inflows from the Flint River and spill from the reservoirs — this is the reason the MSRR performs well on the sturgeon spawning performance measure.

4.2.3 Other Operational Criteria

a) Hydropower Releases

In the MSRR, releases equivalent to three hours of generation at capacity are made under the following conditions: (1) stages are above initial recreation impact level, (2) the day-ahead projected prices are above average, and (3) forecasted inflows for the year are above the 35^{th} percentile. Otherwise, there is no provision for making hydropower releases, or even for reducing releases on weekends to increase the value of power generated during the week. In spite of this limited attention to hydropower, the MSRR produces slightly more power, and slightly more valuable power than does the IOP. In evaluating the value of hydropower, it is assumed that releases are made during peak hours whenever possible.

For this generation rule, the current stage at Lanier and forecasted inflows to Lanier were used to flag days when power releases should be made. For day-ahead projected prices the average daily day-ahead ERCOT prices from 2002-2005 were used; the first Mondays in January for each of these years were aligned to determine the average, and leap-day was accounted for.

b) Reservoir Balancing

The MSRR moves water from upstream reservoirs to downstream reservoirs to balance storage in zones, as does the IOP. The MSRR zones have been adjusted to provide a balance of recreation impact days between the three reservoirs. All three reservoirs are drawn down together insofar as possible to the level where initial recreational impacts begin to occur. Below that level, the reservoirs are emptied by zones, from downstream to upstream. Details of the reservoir balancing scheme and its performance relative to the IOP are discussed below.

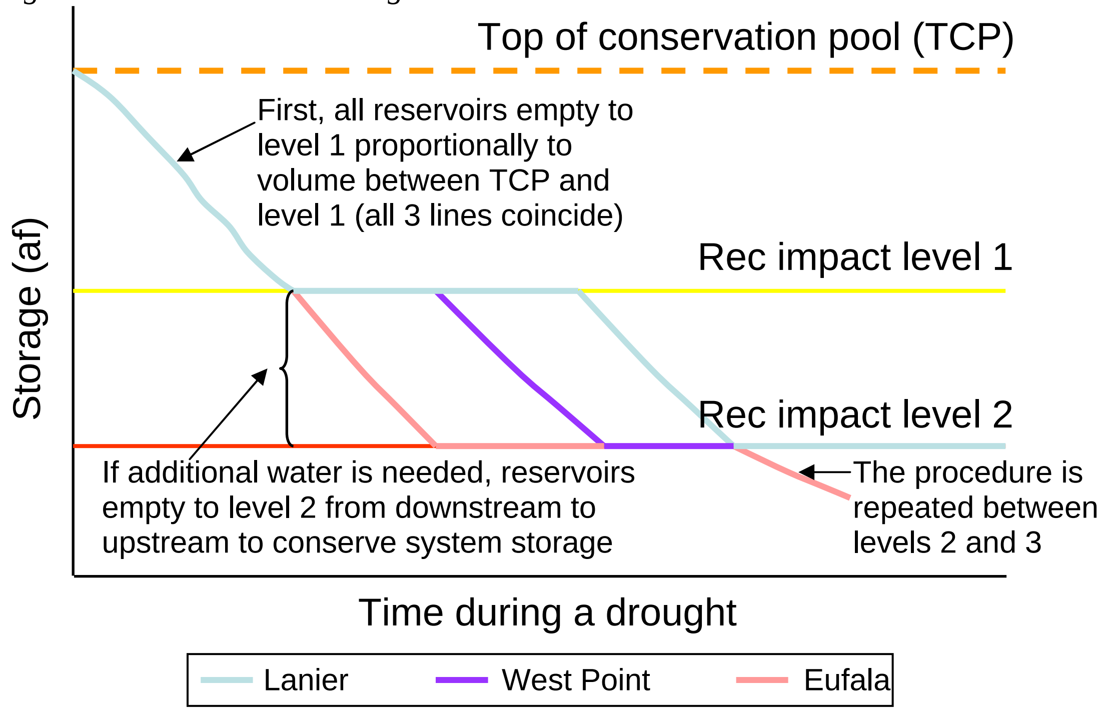
Recreation impact levels were taken from the USACE 1989 Draft Water Control Plan; the values are shown in Table 2. In the following discussion, initial recreation impact is referred to as level 1, recreation impact as level 2, and water restriction as level 3, as shown in columns A and B. Note that applying these impact levels at Eufala for reservoir balancing resulted in stages below historical, so the numbers were increased as shown in the table: Eufala was balanced according to the amended values (column F), while recreation impact was assed with the EIS values (column E).

Table 2: Corps Recreation Impact Levels

A	B	C	D	E	F
Recreation impact level	Terminology from EIS	Lanier (ft)	West Point (ft)	Eufala EIS (ft)	Eufala MSRR (ft)
Level 1	Initial impact	1066	632	187	187
Level 2	Impact	1063	628	185	186.5
Level 3	Water restriction	1060	627	184	185.5

When water is needed from storage, the Lanier, West Point, and Eufala stages are reduced together between their top of conservation pools and recreation Impact Level 1. Specifically, the percentage of the volume between Impact Level 1 and the top of conservation pool is kept the same for the three reservoirs. This is shown in Figure 5, which illustrates the reservoir balancing rules implemented in the MSRR. Note that the shape of these lines depends on the rate of storage emptied from the system. The recreation impact levels and top of conservation pool are in equivalent storages.

Figure 5: Reservoir Balancing Rules



Once the stages of the three reservoirs are at Impact Level 1, there is the real possibility that the system will not refill in the spring, so water is conserved upstream. Specifically, Lanier and West Point are kept at level 1, while Eufala's stage is reduced to Impact Level 2; then Lanier and Eufala are kept at levels 1 and 2 respectively as West Point is reduced to Impact Level 2; and finally Lanier is reduced to level 2, while West Point and Eufala stay at Impact Level 2 (see Figure 5). If more water is needed from storage, the procedure is repeated between recreation Impact Levels 2 and 3. In theory, the same procedure would be used between level 3 and dead storage, but the only time the reservoirs fall below level 3 in the MSRR period of record run is in the 2000 drought, and in this case, all three reservoirs empty below level 3 as they meet local flow requirements and consumptive demands.

One of the reasons reservoir levels do not drop further in the 2000 drought is that by preserving water upstream when the reservoirs fall below impact level 1, there is more system storage entering the drought (May 2000) in the MSRR that the IOP or historically. By preserving water upstream when necessary, all the reservoirs benefit in the following year, as evidenced by the dramatically better performance of the MSRR on the recreation performance measures.

In practice, the reservoir stages do not follow Figure 5 exactly. While this is the guiding principle, the reality is complicated by two issues: water cannot be moved from downstream to upstream and there are physical limitations on the rate at which water can be moved downstream. For example, water from Lanier must be used to meet all of the demands and instream flow requirements north of West Point. As a result, Lanier may be pulled down more rapidly to meet these needs, but the reservoirs are rebalanced when possible.

Recreation impact levels were not included in the EIS for Lake Seminole. In the MSRR, Seminole is kept at top of conservation pool until the stages of other three reservoirs reach level 1. Seminole is then brought down to bottom of conservation pool (76 feet) before Eufala is taken below level 1. Eufala drops below bottom of conservation pool in the 2000 drought only; in this case, the stage is kept above 75.5 feet at all times. Operations at Seminole can be further refined with appropriate recreation impact information.

The stages for top and bottom of conservation pool was taken from the IOP: the MSRR does not alter flood control rules.

4.3 Summary

The required releases from Woodruff are summarized in Table 3.

Table 3: Summary of Required Releases

Level of System Storage	**Minimum Release from Woodruff**
Total System Storage > full	100% of Basin Inflow
Total System Storage > Instream Flow Carryover Storage	Maximum Sustainable Release
System Storage > Public Health and Safety Carryover Storage	5000 cfs + IOP Ramping
System Storage < Public Health and Safety Carryover Storage	Severe Drought Provisions (TBD)

5. IMPLEMENTATION

5.1 Similarities and Differences Between MSRR and IOP / Concept #3

The MSRR is a refinement of Concept #3 in that both use a measure of available storage to determine whether flows higher than the 5,000 cfs minimum can be provided. The main difference between this plan and Concept #3 is (1) the use of a conditional forecasting technique to determine when flows *higher* than the “desired flow” of 6,500 cfs can be provided; and (2) the use of “available storage” to determine the *maximium* flow that can be sustained, instead of using “system composite storage” as an on-off “drought trigger” to toggle between “minimum flow” of 5,000 cfs and the “desired flow” of 6,500 cfs. This alternative also incorporates elements of concept #4, which was to increase the amount of basin inflow that can be stored when basin inflow exceeds 10,000 cfs. Under the MSRR, flows in excess of 10,000 cfs are stored to permit the reservoirs to refill.

Other provisions of the IOP (and/or “existing operations”) are directly incorporated in the MSRR. These include:

1) Top of conservation pool rule curves and flood control operations,

2) Bottom of conservation pool assumptions,

3) Instream flow requirements upstream of Jim Woodruff dam,

4) Water supply requirements

5) Ramping rates

6) Minimum flow requirement of 5000 cfs at Jim Woodruff Dam

In addition, the MSRR is based on many concepts that are implemented in the IOP, although in a different form. These include the following:

1) In the IOP, release requirements at Jim Woodruff Dam are based on Basin Inflow and time of year. Concept #3 also includes consideration of system storage in determining releases. In the MSRR, releases below Woodruff are based on those factors, and on storage in the system as a whole and on forecasts. These changes are necessary to implement the requirement of RPM3 to base minimum releases on basin conditions.

2) Releases in both the IOP and the MSRR seek to maintain natural patterns of flows below Woodruff Dam. The IOP does this by specifying that the releases be a percentage of Basin Inflow. The MSRR achieves this objective more effectively by ensuring that the reservoirs fill early in most years. Once the reservoirs are full, they must pass 100% of Basin Inflow in order to maintain flood control storage. The result of this change in implementation strategy is better performance for all the biological performance measures used in the BiOP. The change in strategy is an implementation of the RPM3 directive to "store more water than allowed under the IOP during certain times of the year to insure minimum water availability later." The water stored by filling the reservoirs early is used to establish appropriate sustainable minimum flow (which ca be any value between 5000 and 1000 cfs). In most years that flow is substantially in excess of 5,000 cfs, per the directives in RPM3.

3) Both the IOP and the MSRR contain provisions for maintaining hydropower generation. The IOP requirements provide for setting a number of hours of weekday generation at individual reservoirs based on the storage in each reservoir. The MSRR bases this requirement for all reservoirs on a variety of conditions, including storage in Lake Lanier, forecast inflows, and historical day-ahead energy prices. All of this information should be readily available to operators in real time. The reason this is done is, again, to "store more water than allowed under the IOP during certain times of the year to insure minimum water availability later." The result of implementing this strategy is improved biological performance, slightly higher overall power generation, and slightly higher value of power generated. The changes in power benefits are not significant in our opinion.

4) Both the IOP and the MSRR contain provisions for balancing storage among reservoirs. In the MSRR this is designed to balance two objectives: (a) maintain the highest level of system storage over the long run, and (b) equalize the number of days of recreation impacts among the reservoir pools.

The balancing strategy employed by the MSRR effectively equalizes recreational impacts among the lakes without significantly affecting water supply reliability or environmental or any other purposes. Coupled with the strategy of storing water to ensure higher minimum flows, the balancing strategy results in a wholesale reduction in recreational impacts compared to the IOP and Concept #3.

5.2 Ease of Implementing the MSRR

The MSRR is an extremely practical operating rule. All the data needed to evaluate releases each day are available, the forecast technique is available, uses only up to date flow data, which is also available, and takes very, very little time and almost no training to run. Historical day-ahead energy prices are also available. The calculations necessary are easily implemented in a spreadsheet. We see no practical impediments to expeditiously implementing the MSRR.

That said, we recognize that USACE will need to validate the results presented below before implementing MSRR as RPM3. ARC and Hydrologics will make available to USACE any information, data or other resources necessary to validate the rule. Copies of the input and output files are attached.

Moreover, although the MSRR is superior in performance to the IOP and Concept #3, we are certain that operating rules superior to the MSRR can be developed. We stand ready to work with the USACE towards the development of better operating policies. However, we will firmly oppose the implementation of operating policies that are clearly inferior to the MSRR.

6. EVALUATION OF PROPOSED ALTERNATIVES FOR RPM3 BASED ON SPECIFIC OPERATIONAL OBJECTIVES

As is shown in greater detail below, the MSRR significantly out-performs the IOP on many objectives and does not perform significantly less well on any of the others. This alternative provides superior protection to threatened species while, at the same time, keeping significantly more water in storage and thus benefiting other project purposes. The proposed alternative would not have any adverse impact on flood plain connectivity, hydropower generation, flood control, or, to our knowledge, any other operating objective.

The parameters of an operating rule (e.g. the exact values in lookup tables relating available storage to releases, or the exact levels (rule curves) used for balancing storage among reservoirs) are derived by trial and error using simulation models (i.e. the parameters of the rule are "tuned" to achieve superior performance). This was done, at least to some degree, in developing the IOP. Lack of time has prevented us from extensive tuning of the parameters of the MSRR. Therefore, we are certain that the rule presented below can be tuned for even better performance. In addition, it is likely possible to invent alternative forms for operating rules. Such rules could be superior to the MSRR. We urge the USACE to work with stakeholders to develop better forms of operating rules, and we stand ready to assist.

The following sections compare the performance of the proposed implementation of the MSRR with historical operations and operations under the IOP.

6.1 Protection and Enhancement of Threatened and Endangered Species

The conclusions in the Biological Opinion are based on the "biologically relevant" characteristics of the flow regime for each species. USFWS developed graphs developed to plot these characteristics for the "baseline" (historical) and "run-of-river" scenarios against the IOP. USFWS then used following chart to determine whether the IOP would have an "adverse" or "beneficial" effect on the species.

Figure 6 (BiOp Figure 4.2.A): Evaluation of Effects

Biologically Relevant Flow Regime Characteristic

	Adverse ←	Condition Gradient	→ Beneficial	Interpretation of IOP Alteration
1	Baseline	IOP	RoR	Beneficial, but not attributable to the IOP
2	Baseline	RoR	IOP	Beneficial
3	IOP	Baseline	RoR	Adverse
4	IOP	RoR	Baseline	Adverse
5	RoR	Baseline	IOP	Beneficial
6	RoR	IOP	Baseline	Adverse, but not attributable to the IOP

The same graphs, and the same chart, should be utilized to evaluate any proposed revision to implement RPM3. The actual graphs utilized by USFWS in the Biological Opinion are reproduced in Section 4, except that one line has been added to each graph to represent the Corps' "Concept #3" and another has been added to represent the revision proposed by ARC (the "Maximum Sustainable Release Rule").

Based on these performance measures, the proposed alternative out-performs the IOP and Concept #3 in the protection and enhancement of habitat for threatened and endangered species. The proposed alternative also performs better than or at least equal to the "baseline" and "run-of-river" alternatives for every performance measure evaluated by USFWS in the Biological Opinion.

6.2 Mussel Species

Figure 7 (BiOp Figure 4.2.2.A): Flow Frequency at the Chattahoochee Gage

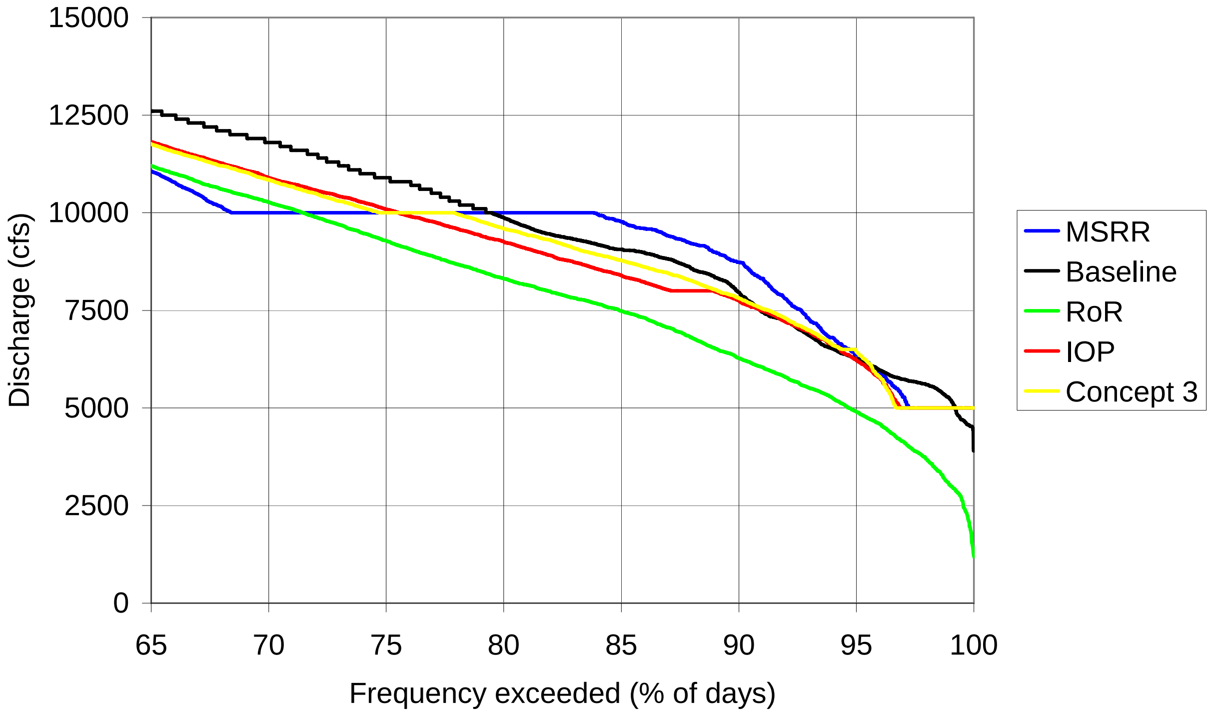


Figure 7 (BiOp Figure 4.2.2.A) shows the flow frequency at the Chatahoochee gage. Higher values are better According to the BiOp, fat threeridge mussels may occasionally be affected by flows below 10,000 cfs. The graph shows the distribution of such flows for each of the cases. The MSRR has significantly lower frequencies of flows from 10,000 cfs to approximately 6000 cfs, and approximately the same frequency of flows lower than 6000 cfs compared to the IOP and Concept 3. Therefore the MSRR is more desirable in terms of this performance measure.

Figure 8 (BiOp Figure 4.2.5.A): Inter-Annual Frequency of Discharge Events

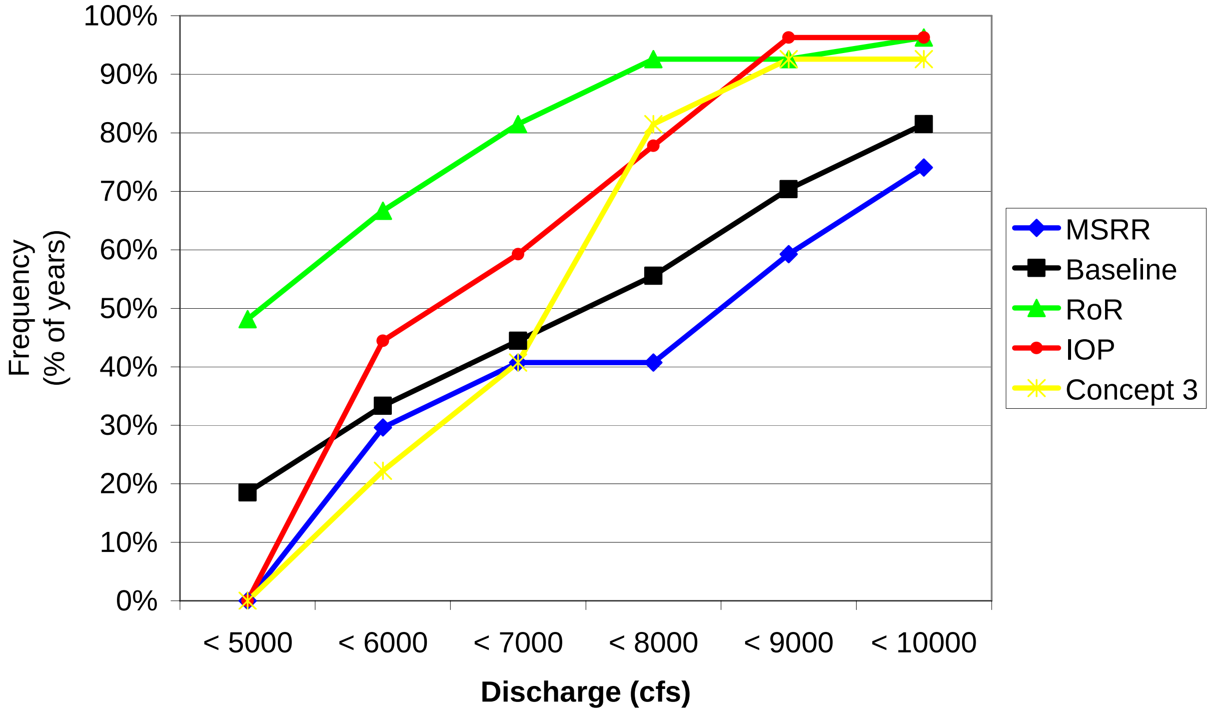


Figure 8 (BiOp Figure 4.2.5.A) shows the percent of years with flows below thresholds from 5,000 to 10,000 cfs in 1,000 cfs increments. Lower numbers are better. With the minor exception of Concept 3 at flows of 6,000 cfs, the MSRR performance is superior.

Figure 9   (BiOp Figure 4.2.5.B): Number of Low-Flow Days in the Worst Year

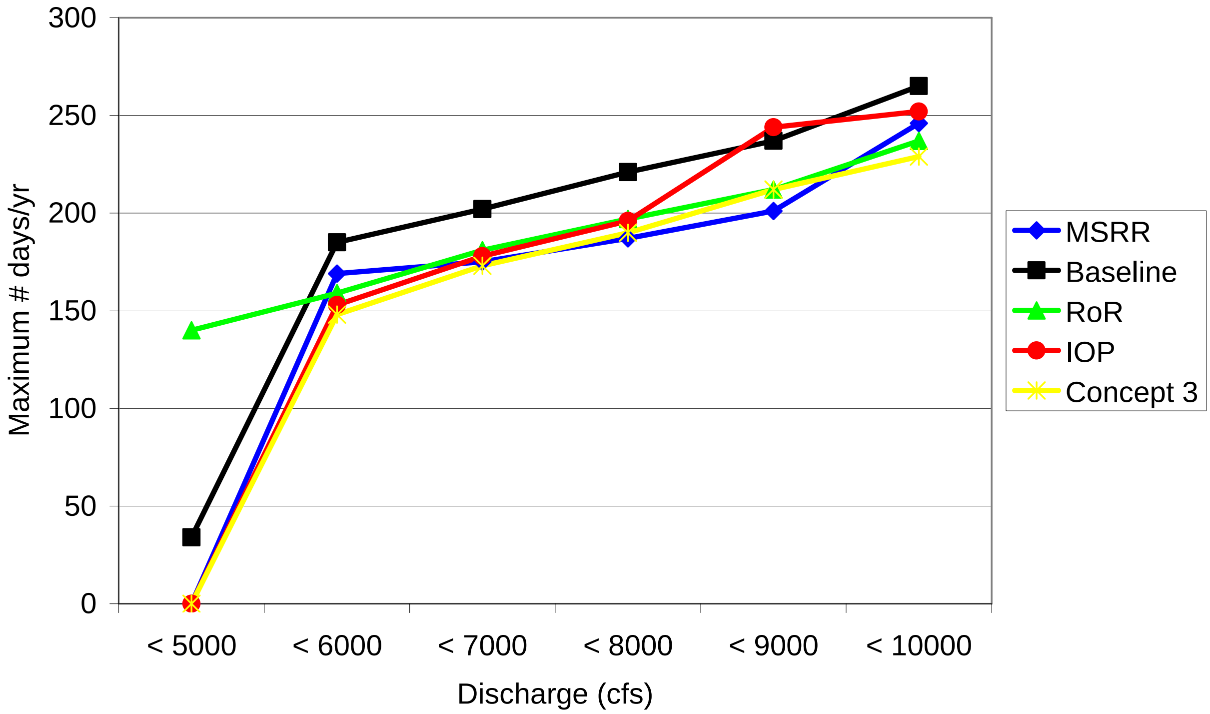


Figure 9 (BiOp Figure 4.2.5.B) shows the number of low flow days in the worst year to the record for the same thresholds as the previous figure. Fewer days are better. The performance of the MSRR is not significantly different in this performance measure than either of the other operating rules.

Figure 10 (BiOp Figure 4.2.5.C): Number of Consecutive Low-flow Days in Worst Year

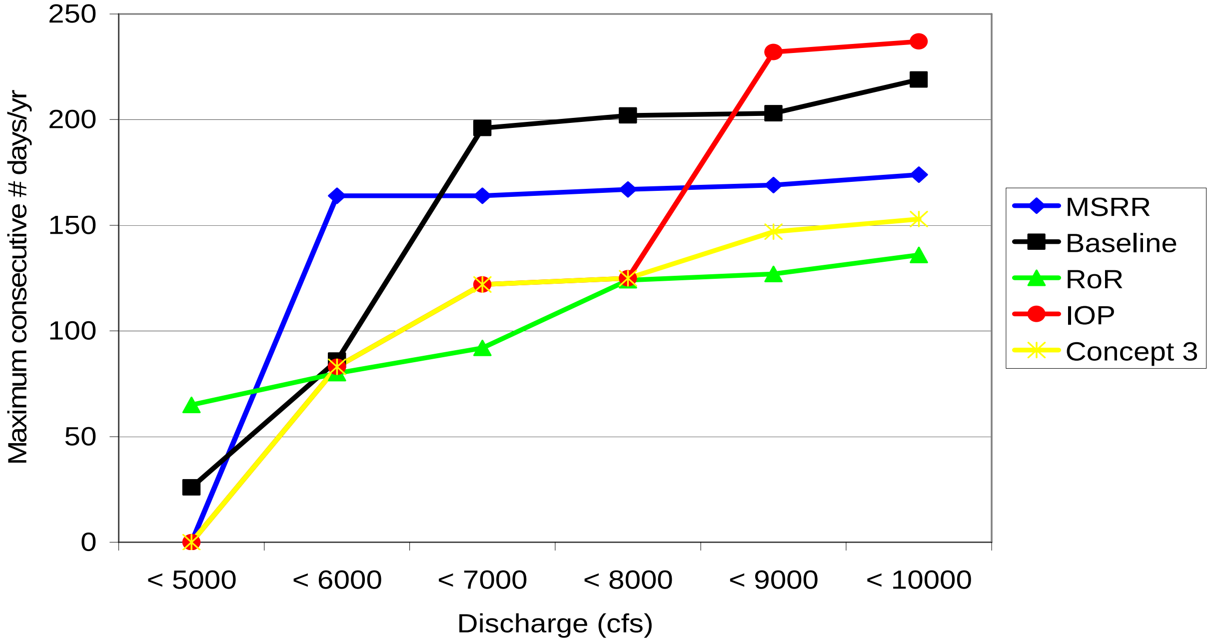


Figure 10 (BiOp Figure 4.2.5.C) shows the number of consecutive days of low flow in the worst year. Lower numbers are better. While the MSRR does not perform as well as the IOP or Concept 3 on this measure, the difference is not significant. This is especially true because the total number of days in the year is approximately the same, and mussels are impacted primarily when the flows fall. Arguably, for the same number of days of low flow, it is better for the mussels if the flows fall only once as opposed to several times. More days of consecutive low flow imply fewer rises. This is beneficial because those rises could induce mussels that have survived by moving to lower elevation habitats to move back to higher elevation habitats where they would again be vulnerable if flows fell again. In other words, at extreme low flows, it more important to provide stable flows than it is to provide higher flows that can be sustained for only a short period of time.

Figure 11 (BiOp Figure 4.2.5.D): Number of Low-flow Days in Median Year.

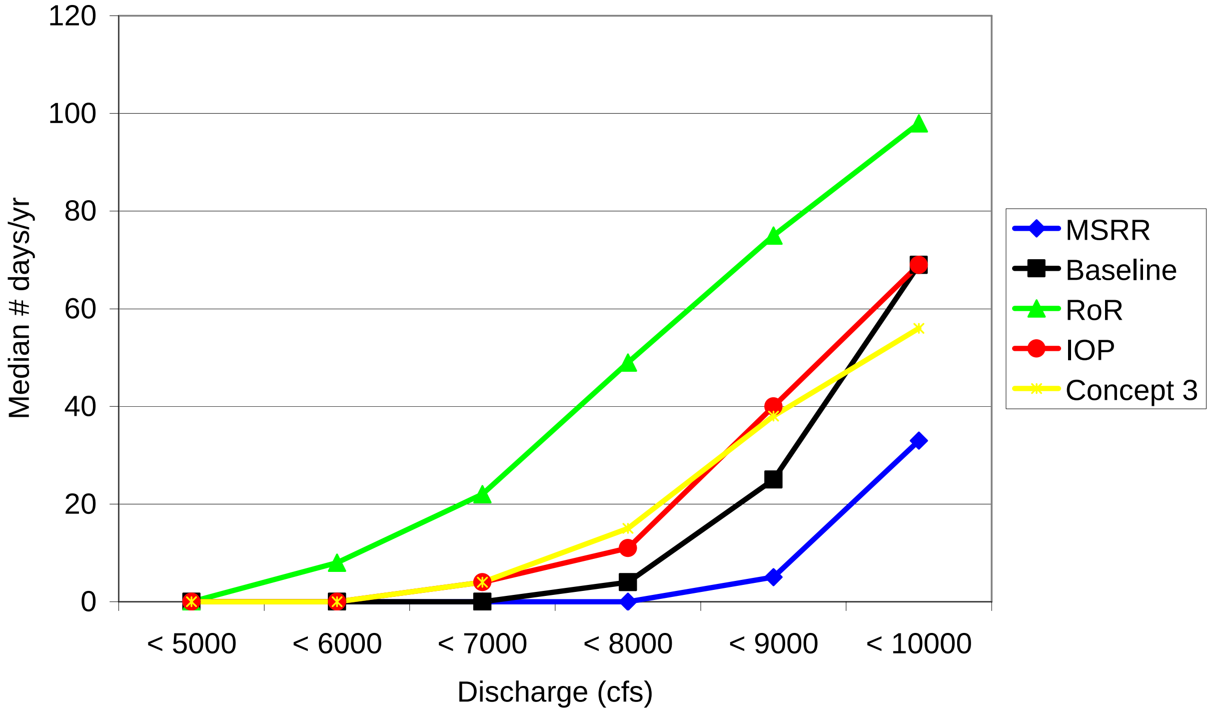


Figure 11 (BiOp Figure 4.2.5.D) shows the median number of days of flow below thresholds in a given year. Lower is better. The MSRR performance with regard to this criteria is clearly and substantially superior for mussels. The figure reflects the fact that more than half of the years have no days with less than 8000 cfs under the MSRR. The corresponding flow for the IOP and Concept 3 is 6000 cfs. Note that the MSRR is the only operating rule that outperforms historical flows for this performance measure.

Figure 12: Frequency of Sustained Low Flows 1975-2001

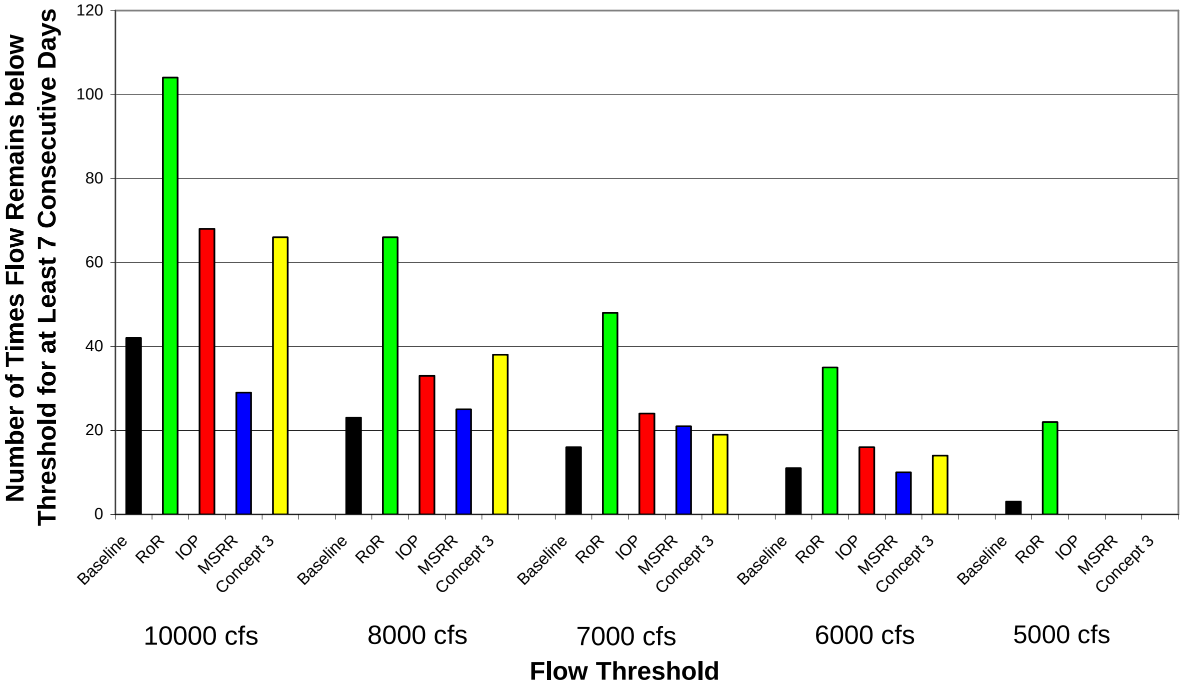


Figure 12 is not contained in the BiOp, but clearly shows the superior of performance of the MSRR with regard to benefits to endangered mussels. It shows the number of times in the simulated record that flows fall below thresholds for at least seven days. This is important because mussels can survive short periods of dewatering. The MSRR clearly outperforms the IOP and Concept 3 at the 10,000 8.000 and 6,000 cfs thresholds, and is equivalent to both rules at the 7,000 cfs threshold.

Figure 13: (BiOp Figure 4.2.4.A): Max Number of Consecutive Days per Year of Flow Less than 16,000 cfs

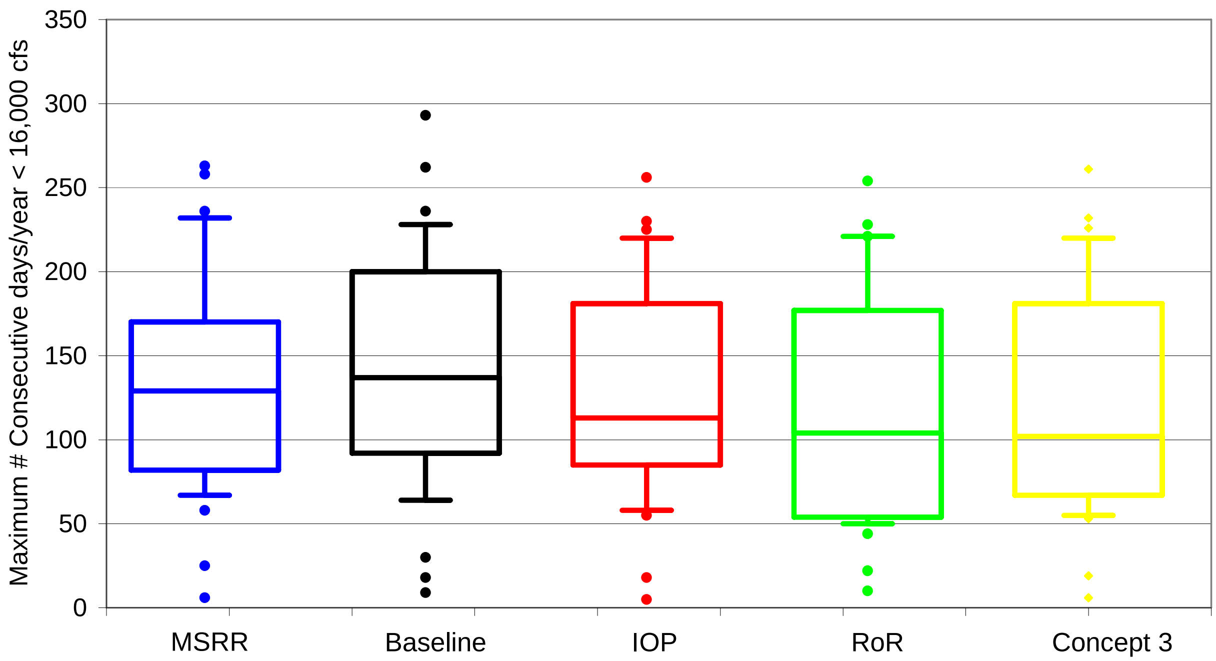


Figure 13 (BiOp Figure 4.2.4.A) shows the distribution of the number of days per year below 16,000 cfs for all cases. It is difficult to distinguish the performance of the alternatives based on this performance measure.

The mussels are also affected by the daily change in stages, which is why ramping rates on the reduction of flows at Woodruff is part of the IOP. The next two performance measures are designed to evaluate the rate of change of stage experienced by the mussels. The first of these, Figure 14 (BiOp Figure 4.2.5.F), shows the rate of stage change for flows under 10,000 cfs only. Based on the IOP ramping rates, all days should fall under the first two categories: rising or stable or <= 0.25 ft/day. The MSRR respects the ramping rate restrictions at these low flows much better than the IOP or Concept 3; however, this may be because OASIS is able to enforce the ramping rates more closely than HEC 5 rather than an actual difference in the operating policies.

This difference in the modeling tools also affects the next performance measure, Figure 15 (BiOp Figure 4.2.5.E). Given these differences it is difficult to evaluate these performance measures. They are included for completeness, nonetheless.

Figure 14 (BiOp Figure 4.2.5.F): Frequency of Daily Stage Changes When Releases from Woodruff are Less than 10,000 cfs

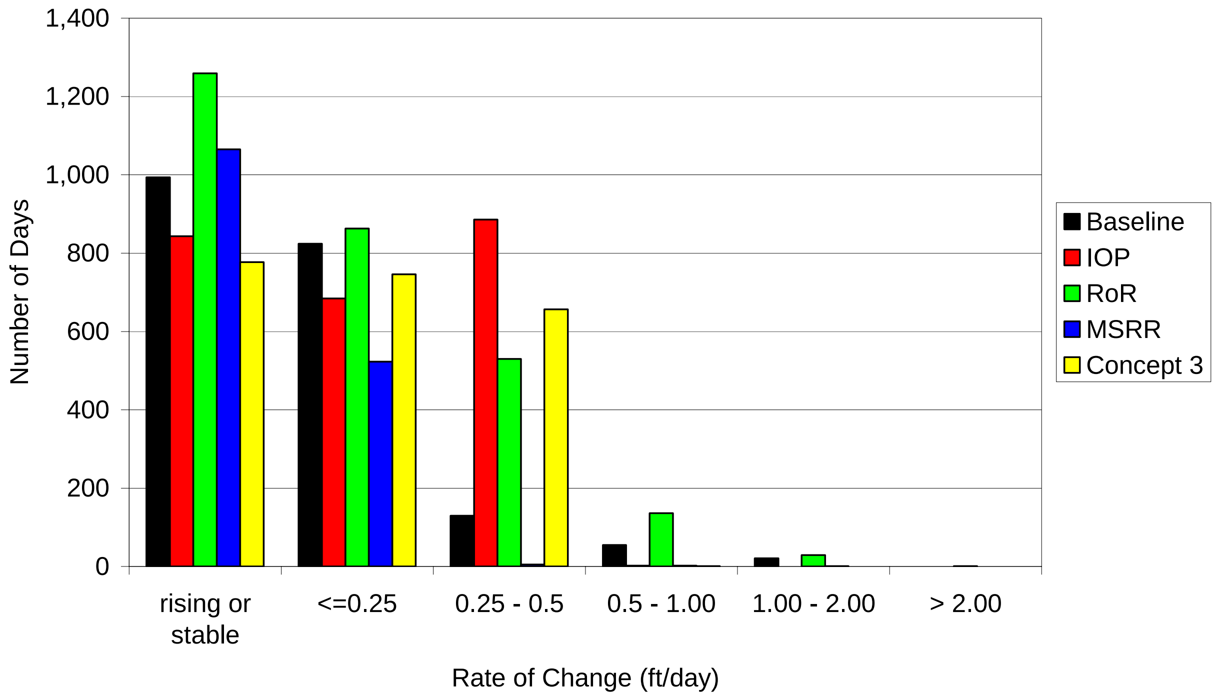
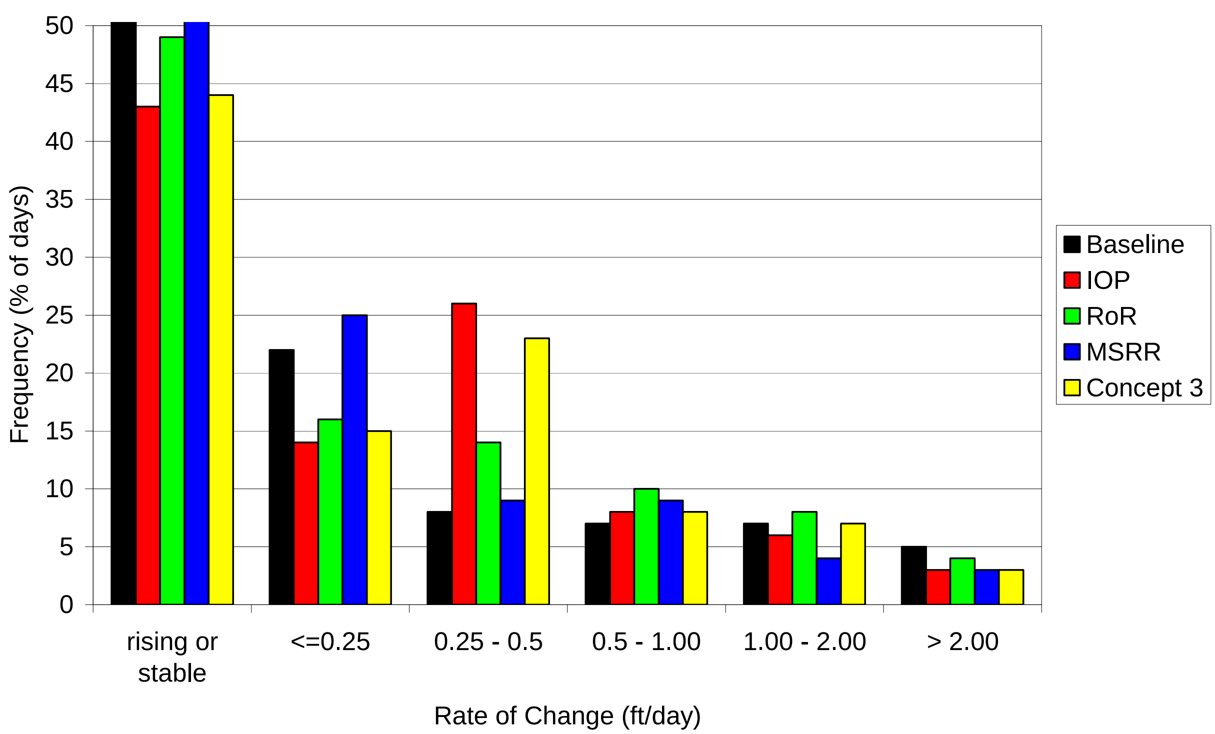


Figure 15 (BiOp Figure 4.2.5.E): Frequency of Daily Stage Changes



Floodplain connectivity is important for the lifecycle of the host fish that support the mussel species. The next two performance measures, Figures 10 and 11, quantify the number of floodplain acres connected to the main channel during growing season. Note that the relationship between acres of connected floodplain and flow was estimated from BiOp Figure 3.3.2.B, so the lines do not match those in the BiOp figures exactly.

Figure 16 (BiOp Figure 4.2.6.A) shows the percent of days in which amounts of habitat area are connected. Most of the runs follow the same trend, with the IOP higher for some habitat areas, lower for others.

Figure 16 (BiOp Figure 4.2.6.A): Frequency of Floodplain Connectivity to the Main Channel During Growing Season

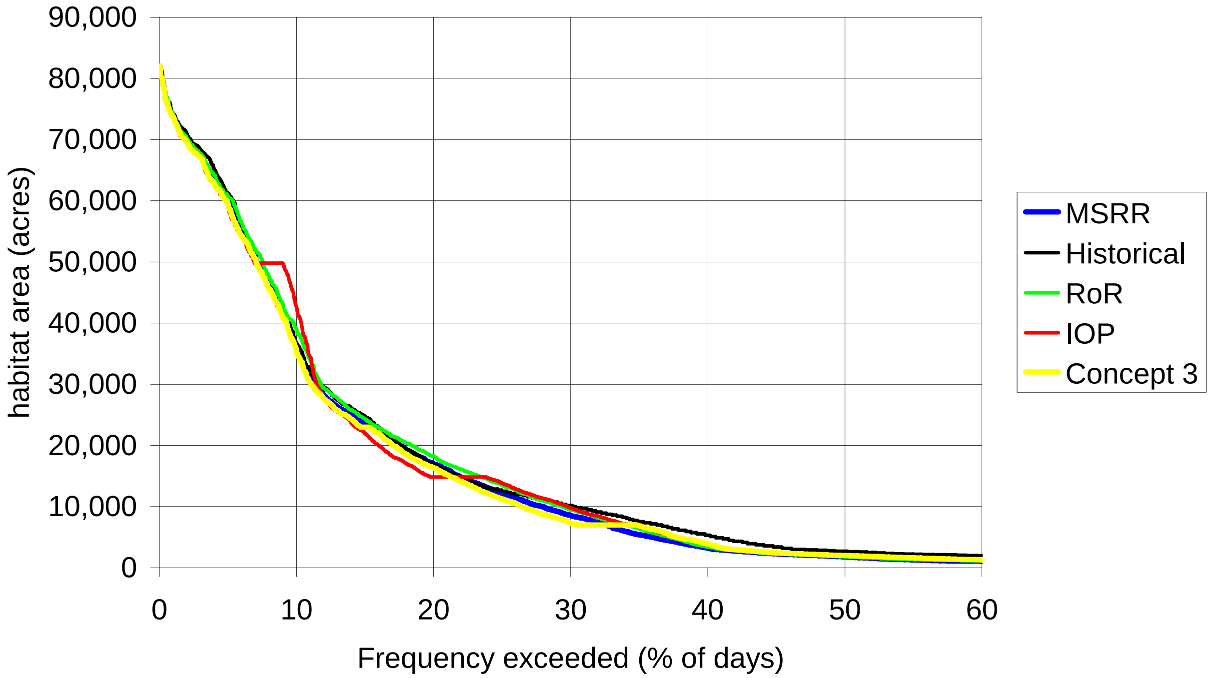
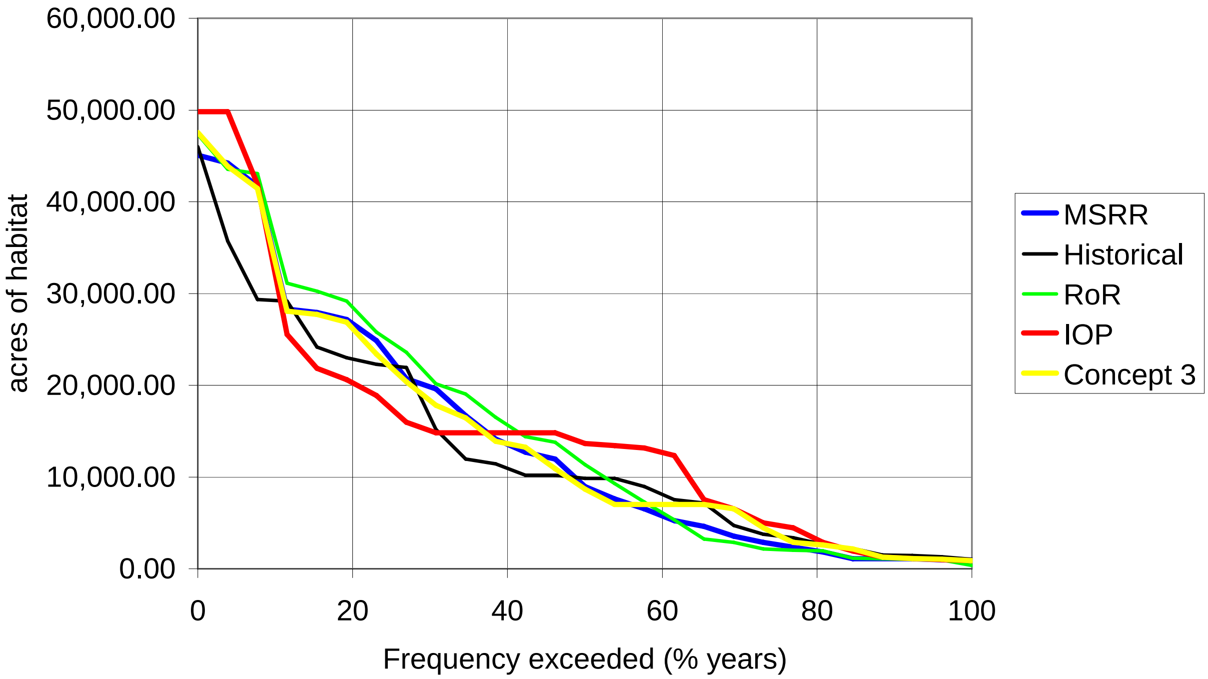


Figure 17 (BiOp Figure 4.2.6.B), the next performance measure, looks at the amount of habitat area connected for at least 30 days each year. The IOP is higher for some ranges, the MSRR for others. In general, the runs are comparable and do not appear to be inferior to historical. Note that storing more water in the spring under Concept 3 shifted the IOP trace closer to that of the MSRR. The MSRR more closely mimics run-of-river (ROR) than does the IOP. This may be desirable.

Figure 17 (BiOp Figure 4.2.6.B): Max Floodplain Habitat Connected to the Main Channel for at least 30 Days During Growing Season

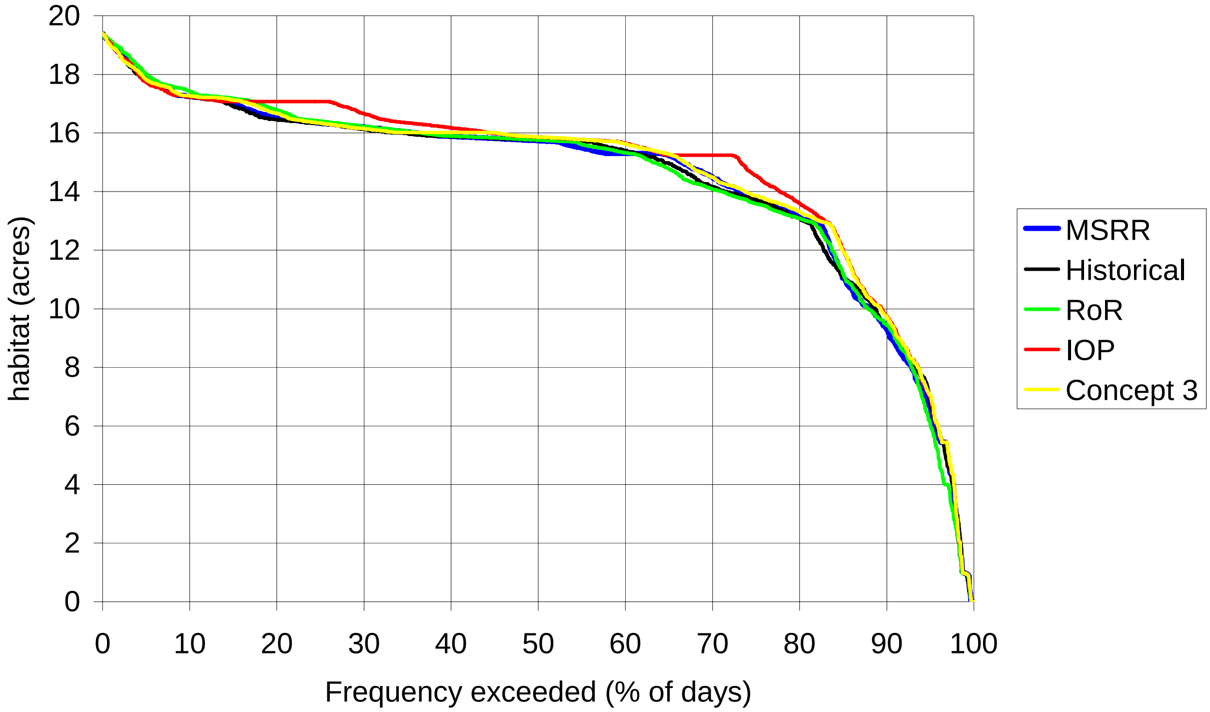


6.2.1 Gulf Sturgeon

As demonstrated in the previous section, the MSRR is clearly superior for the mussels overall. Based on the gulf sturgeon habitat measures from the BiOp, the MSRR is no worse for the sturgeon. We do recommend that these performance measures be refined for the reasons discussed below.

The first performance measure, Figure 18 (BiOp Figure 4.2.3.A), shows the frequency of days that different amounts of habitat are available during spawning season. The traces are not significantly different with the exception of the IOP, which provides spawning habitat around 15 acres and 17 acres more frequently than the other scenarios. Note that the increase in stored water in the spring under Concept 3 removes these features of the IOP trace, and Concept 3 follows the other traces more closely. The differences are small and do not appear to be significant.

Figure 18 (BiOp Figure 4.2.3.A): Frequency of Spawning Habitat Availability



The next performance measure, Figure 19 (BiOp Figure 4.2.3.B), shows the maximum amount of habitat sustained for at least 30 days during spawning season each year. The IOP performs somewhat better than the other traces on this measure. The increase in sustained habitat, however, is at most about 1.5 acres, which is not likely to significantly affect such a small population of spawning fish. Furthermore, the changes planned to the IOP by the USACE illustrated by Concept 3 reduce the advantage of the IOP on this measure. The MSRR provides more sustained habitat than the Baseline or RoR, signifying no impact to the sturgeon based on the BiOp criteria. Finally, the performance on this particular measure is greatly influenced by the bathymetry at RM 99.5, the location at which very few eggs have been collected compared to RM 105.

The relationship between flow and sturgeon habitat is shown in Figure 20 (BiOp Figure 3.6.1.4.C). Note that at flows greater than 50,000 cfs, the available habitat decreases down to zero at 150,000 cfs. In addition, habitat at RM 99.5 decreases dramatically at 23,000 cfs. Therefore, high flows do not necessarily correspond to higher availability of spawning habitat. Further, the decrease in habitat at RM 99.5 at flows above 23,000 cfs causes a dip in total habitat below 14 acres between 29,000 and 34,000 cfs. Avoiding flows in this particular range can have a significant impact on the sustained habitat performance measure. In 1979, for example, flows at the Chattahoochee gage fall in the range for the MSRR on May 3, causing the habitat to fall from about 15 to 13 acres. Flows in the IOP fall between May 6 and 10 as well, but they skip the habitat dip, dropping from 37,000 to 24,000 cfs in a single day. The flows and corresponding habitat are shown in Figure 19 (BiOp Figure 4.2.3.B). Since these days in May fall within the 30-day maximum sustained habitat time frame, the value for the MSRR is about 13 acres for this year, while the value for the IOP is about 15 acres. This reduction in sustained habitat for the MSRR happens again in 1980.

Figure 19 (BiOp Figure 4.2.3.B): Max Habitat Sustained for At Least 30 Days During Spawning

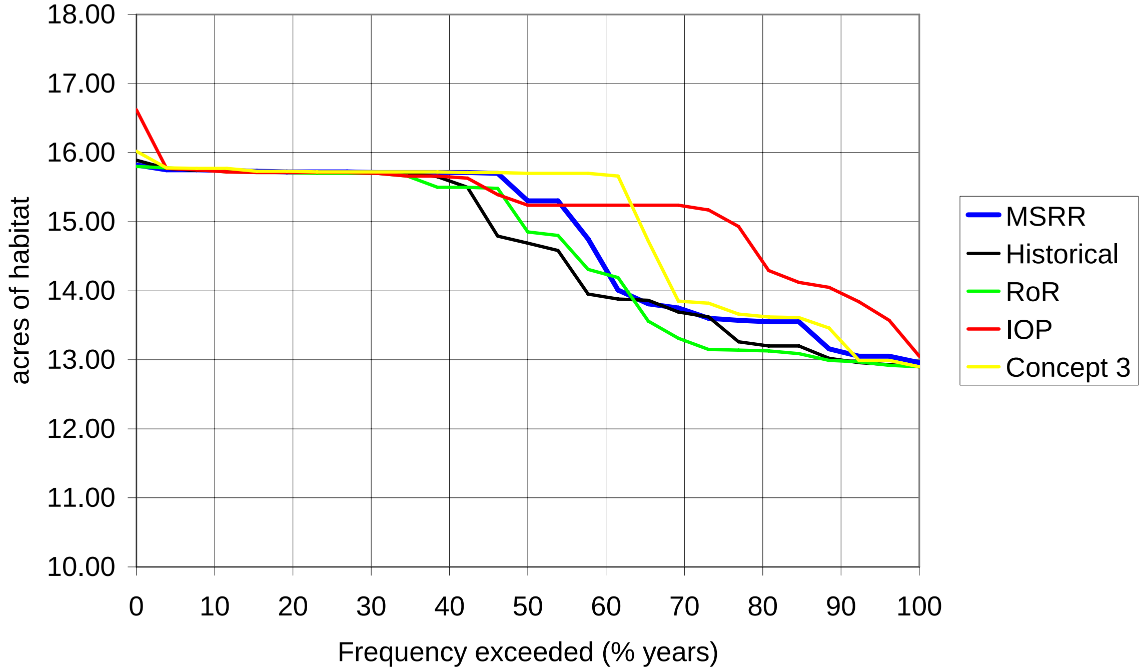


Figure 20 (BiOp Figure 3.6.1.4.C): Area of Gulf Sturgeon Spawning Habitat

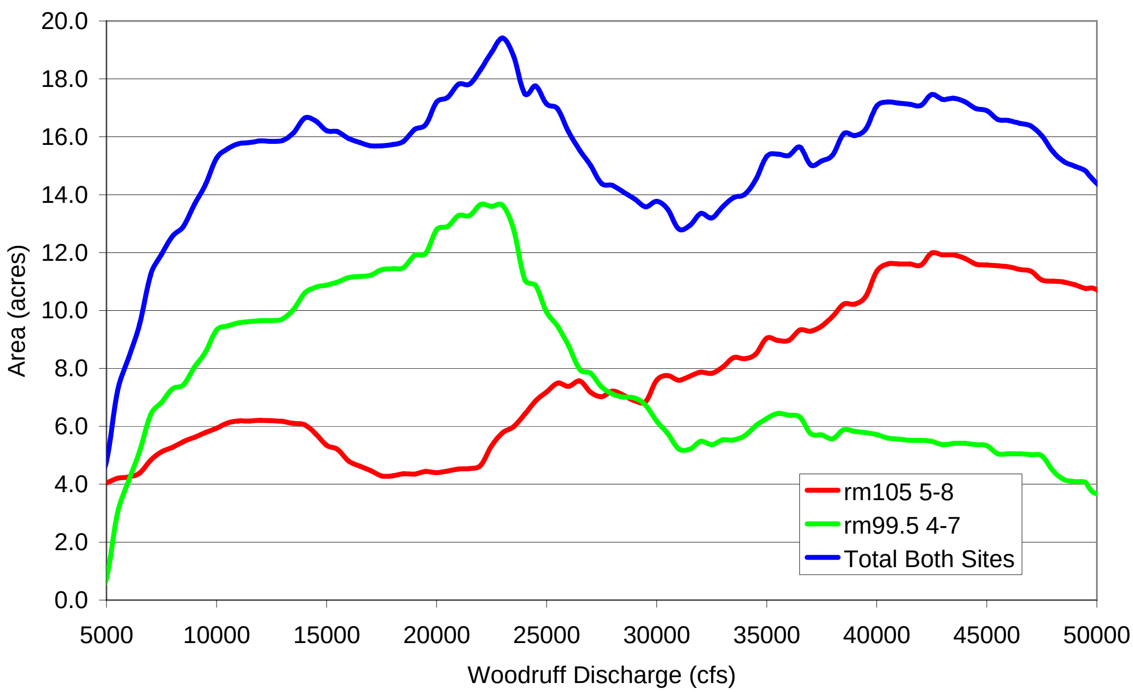
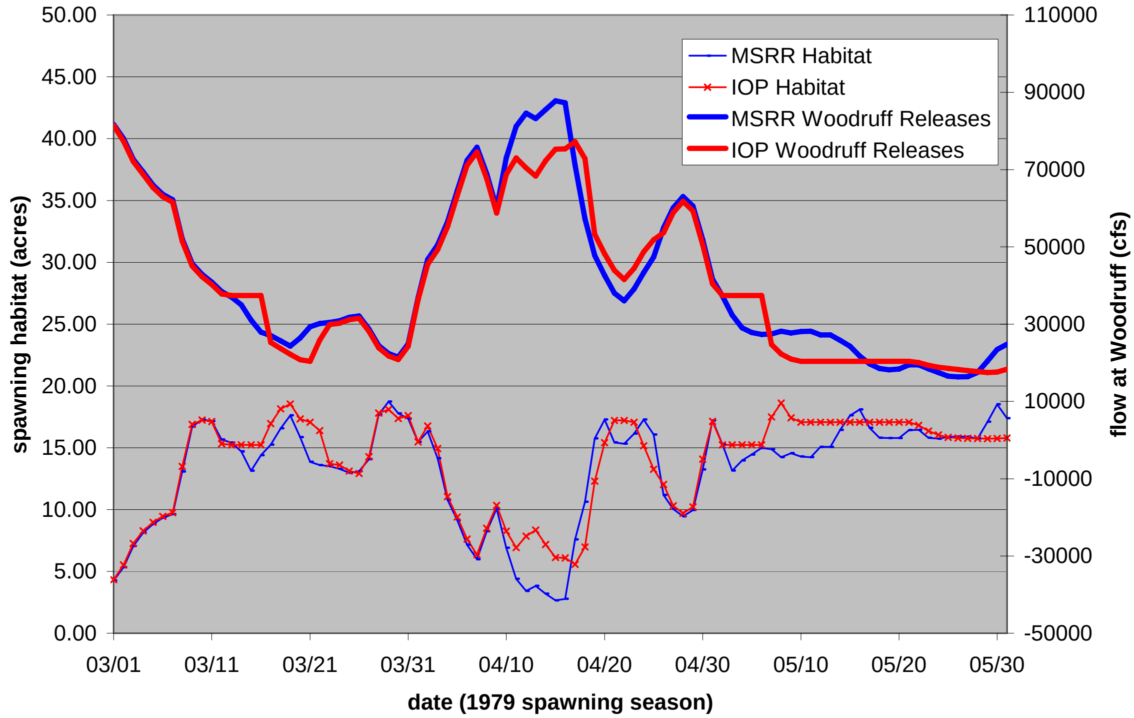


Figure 21 Spawning Habitat and Woodruff Releases in 1979



The MSRR could be tuned to avoid the problematic range of flows. We have not yet done so, however, for two reasons. First, the dip in habitat may or may not reflect an actual decline in usable habitat. Based on the "range of spawning depths observed" after the removal of the outliers, there will be some amount of habitat loss as flows increase simply as a matter of channel geometry. This is because at some point under increased flows, depths will increase to greater than 18.0 feet before other areas of the rock shoal are inundated with at least 8.5 feet of water. While the range of depths in the BiOp may be optimal based on this depth range rule, it is obvious from the 2005 and 2006 data that sturgeon will spawn at depths outside of this range. Habitat may not be lost as water depth increases in the main channel in response to flows that result in channel depths greater than 18 ft with shelf depths less than 8.5 ft. This casts doubt on differences in apparent available habitat among various management scenarios at intermediate flows.

In addition, the MSRR currently performs as well or better than the IOP at RM 105, the more important of the two spawning sites, at seen in Figures 18 and 19. Figure 18 shows that the MSRR has more days that fall below habitat in the 8 to 10 acre range, but less days that fall below habitat in the 4 to 6 acre range. Figure 19 shows that the MSRR supports more sustained habitat than does the IOP in the range of 5 to 7.5 acres, and equally as much as the IOP for all other values of habitat. We believe that the sustained habitat measure is the more critical of these two and so conclude that the performance of the MSRR with regard to sturgeon habitat is at least as good if not better than the performance of the IOP. The same holds true for the comparison of the MSRR and Concept #3. The performance of the MSRR is clearly no worse than the baseline or RoR, as well.

Figure 22 (BiOp Figure 4.2.3.A): Frequency of Spawning Habitat Availability at RM 105

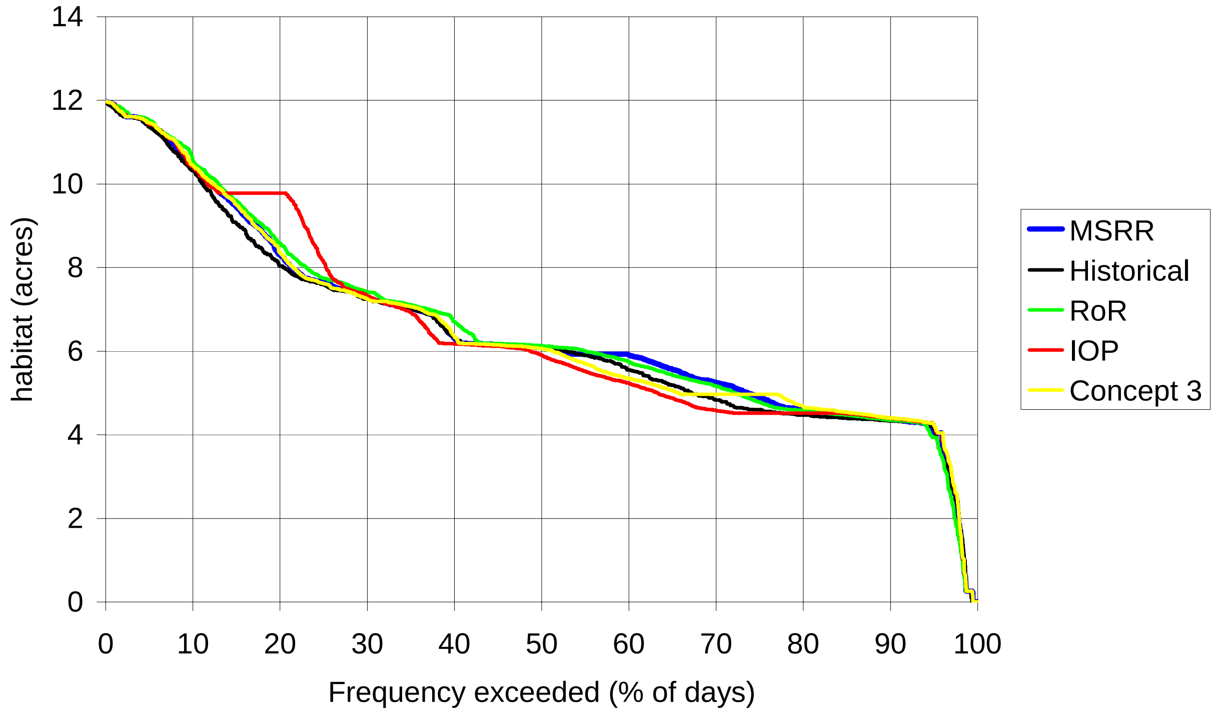
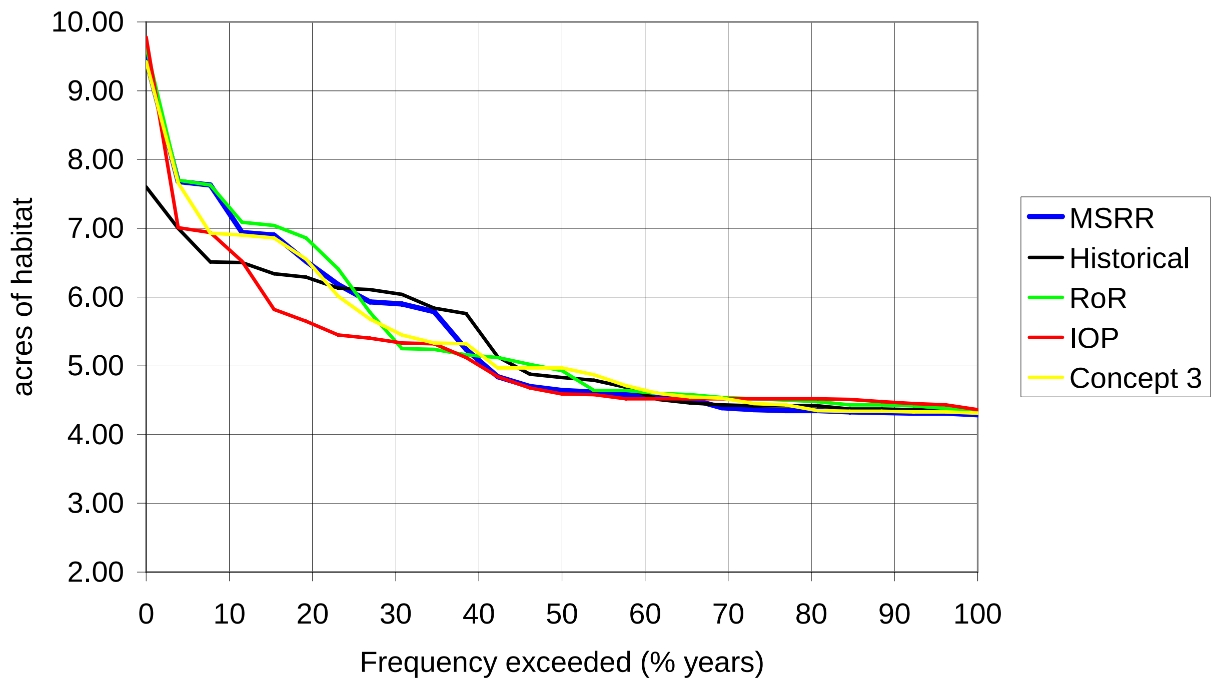


Figure 23 (BiOp 4.2.3.B): Max Habitat Sustained for At Least 30 Days During Spawning Season at RM 105



6.3 Other Operational Objectives

6.3.1 System Storage

Figure 24: System Storage 1940-2001

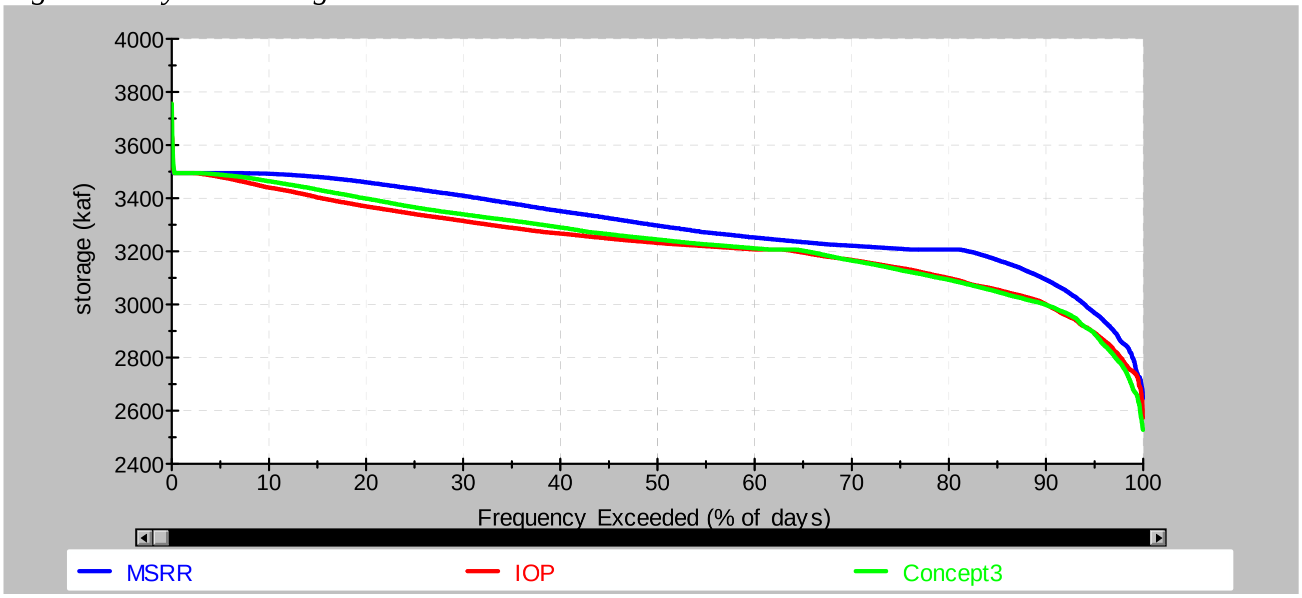


Figure 24 shows the cumulative distribution of system storage for all three operating rules. The graph indicates MSRR produces consistently higher values of storage under almost all operating conditions. This strongly suggests that the system will be better able to respond to drought events more extreme than historical droughts if operated using the MSRR.

6.3.2 Recreation Impacts

Figures 25, 26 and 27 show the benefits of implementing the MSRR relative to recreation impacts. Higher lines are better. The graph for Lanier (Figure 25) shows a wholesale reduction in impacts measured in recreation days at all impact levels.

The graph for West Point (Figure 26) is somewhat more complicated because operations for flood control lower the top of conservation pool, and thus reservoir storage, to the level 2 impact stage every year. The dotted orange line shows the recreational impact of maintaining the reservoir at the top of the seasonally-varying conservation pool at all times, with no other other lowering of the reservoir stage. The impact of operations for all other purposes is the difference between the orange line and the line corresponding to each operating rule. Again, the MSRR is substantially superior to either of the operating rules with regard to this performance measure for all levels of recreational impact.

The graph for Lake Eufala (W. F. George, Figure 27) shows that the MSRR produces more days of initial recreational impact at Eufala than the other two rules. The reservoir balancing scheme in the MSRR makes this happen because it tries to balance impacts among the three reservoirs while minimizing the total impact. The small additional drawdown in Lake Eufala allows that lake to capture water that would otherwise be spilled without significant benefit to other operating objectives. The drawdown contributes significantly to the achievement of all other operating objectives by preserving system storage upstream. The additional drawdown is quite equitable, as shown in Figure 29-31, and is substantially superior to historical conditions. The same is true for Lake Seminole (Woodruff), as shown in Figure 28. We have no estimates of recreational impact levels for Lake Seminole.

Figures 25, 26 and 27 summarize the recreational impacts for Lake Lanier, West Point Lake and Lake Eufala at each of the impact levels. The overall recreational impacts of the MSRR are clearly less than those of the other two rules, and more equitably apportioned between the lakes.

Figure 25: Frequency of Stages at Lake Lanier

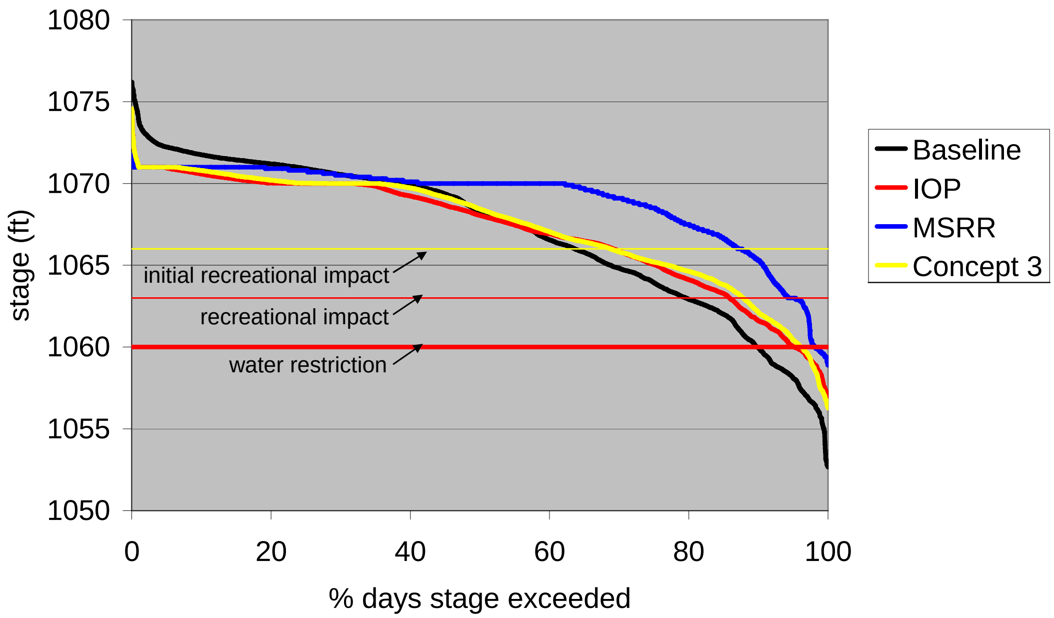
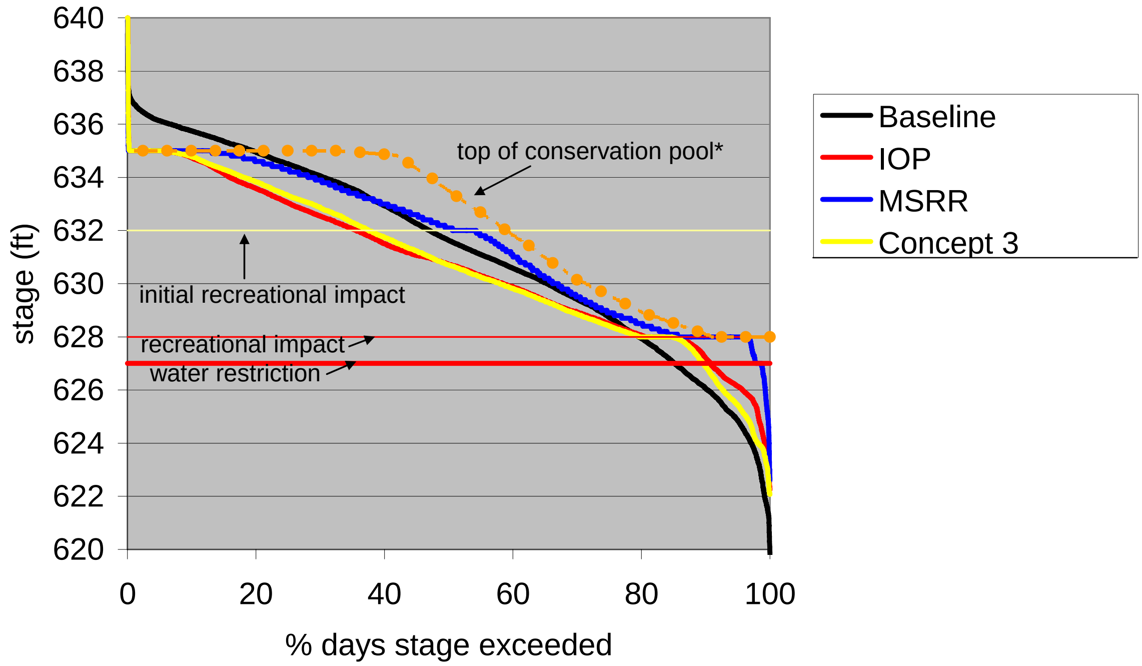


Figure 26: Frequency of Stages at West Point



**This line indicates reservoir levels when West Point is kept at the top of the seasonally-varying conservation pool every day.*

Figure 27: Frequency of Stages at Walter F. George

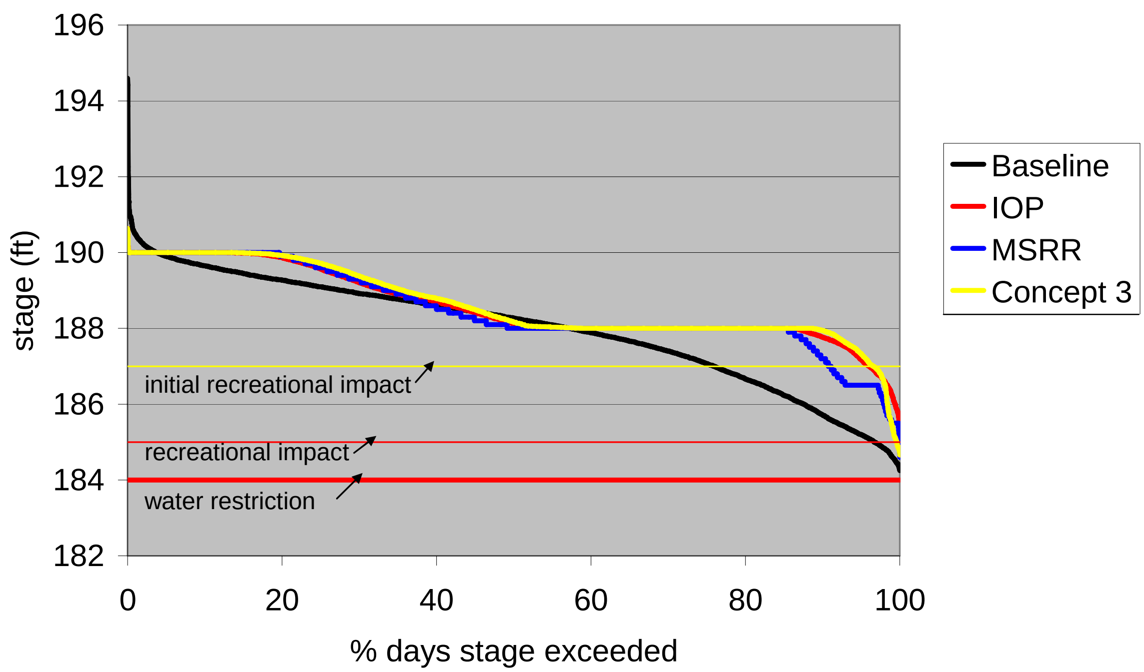


Figure 28: Frequency of Stages as Woodruff

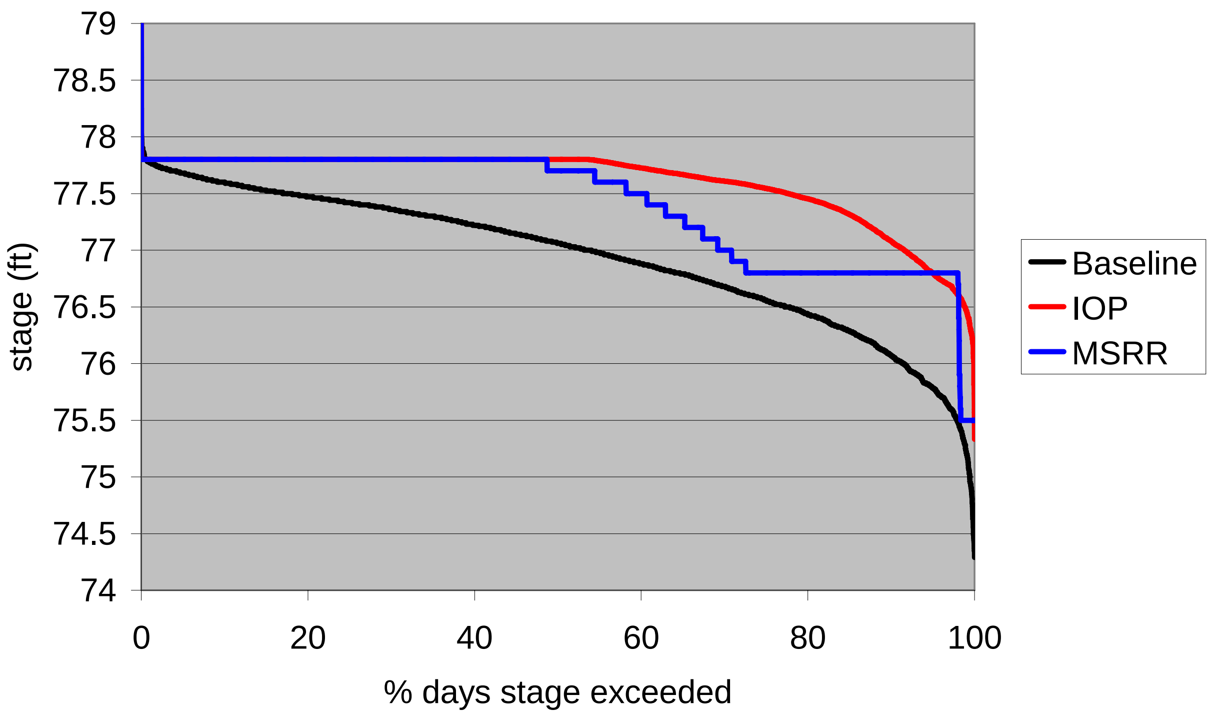


Figure 29: Recreation Impact (1975-2001) - Impact Level 1 (Initial Impact)

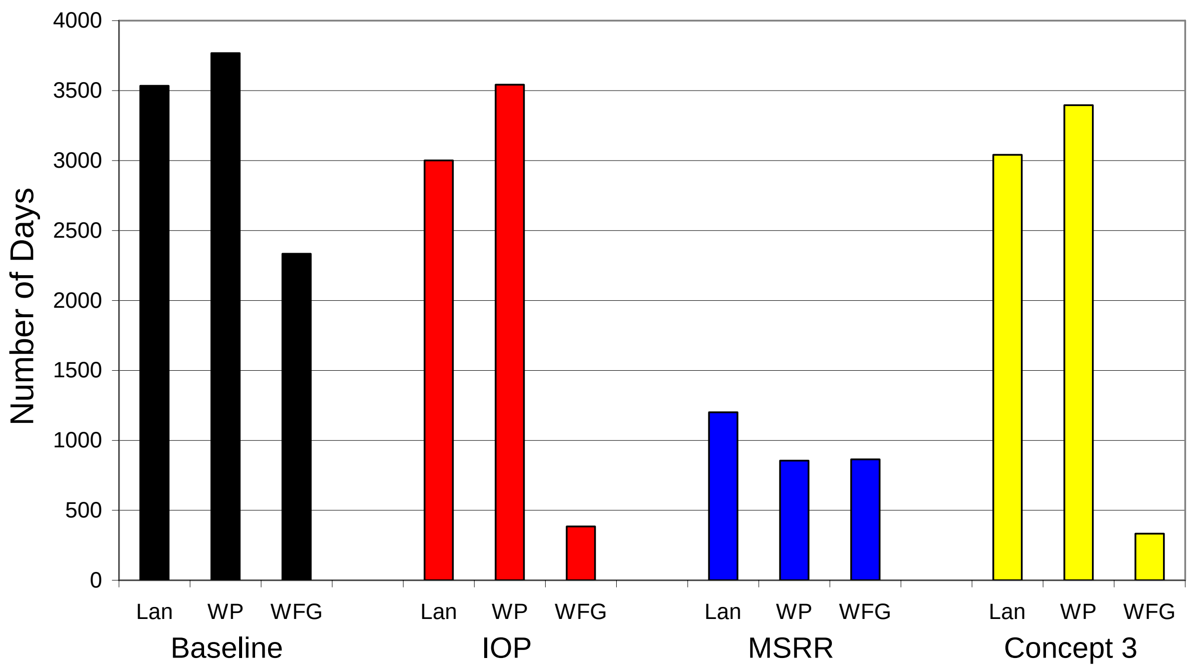


Figure 30: Recreation Impact (1975-2001 - Impact Level 2 (Recreation Impact)

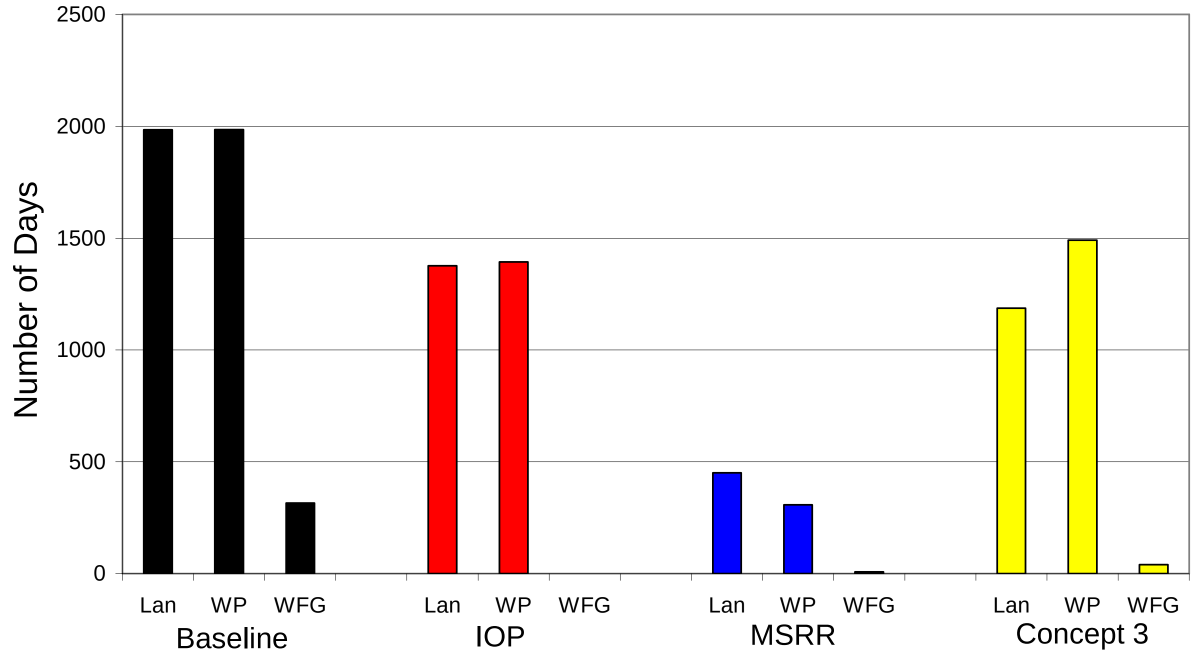
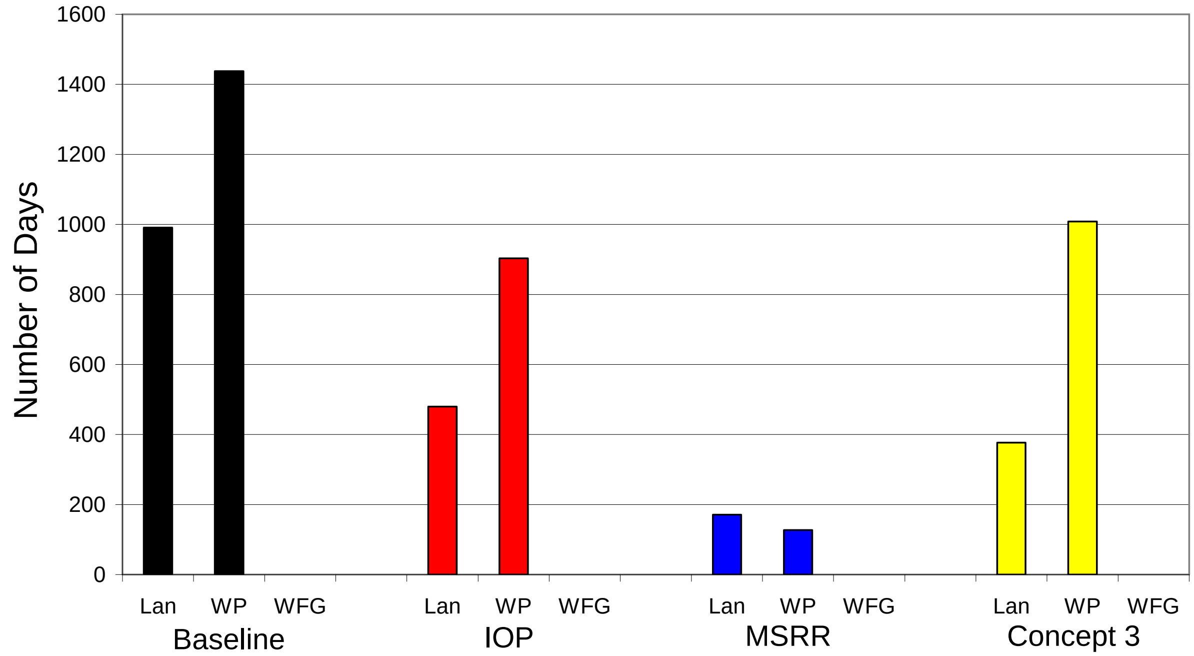


Figure 31: Recreation Impact (1975-2001) - Impact Level 3 (Water Restriction)



6.3.3 Hydropower

Figure 28 shows monthly hydropower generation for the IOP and for the MSRR, and the standard deviation for each month. The difference in total generation is insignificant, although the monthly distribution shows minor differences.

Figure 32: Average Monthly Energy Generated (1940-2001)

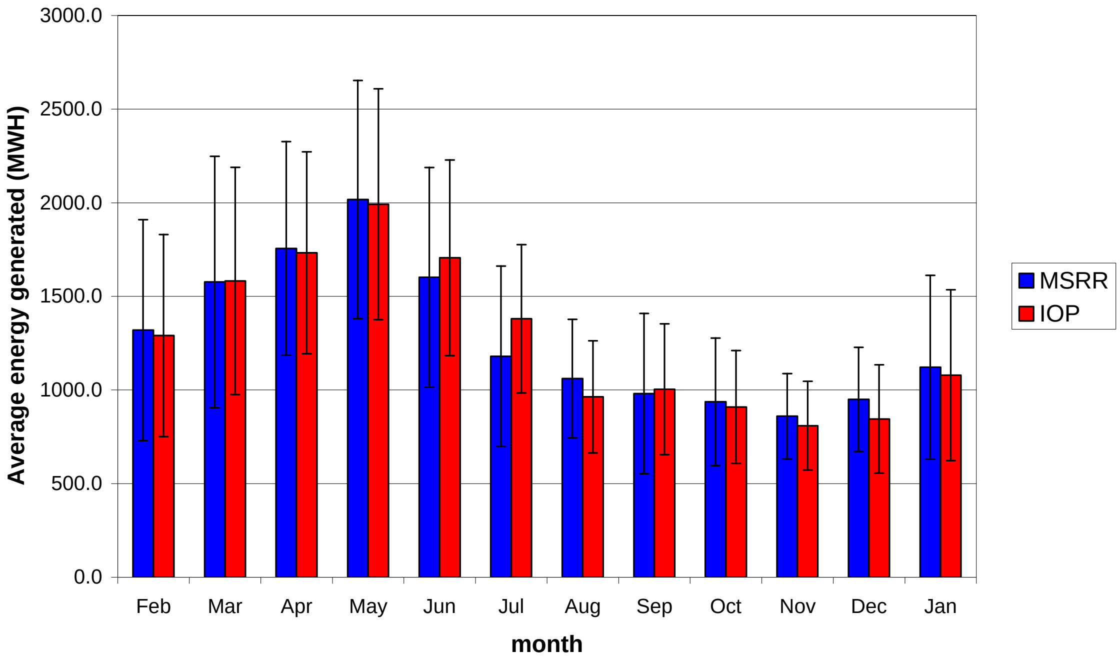
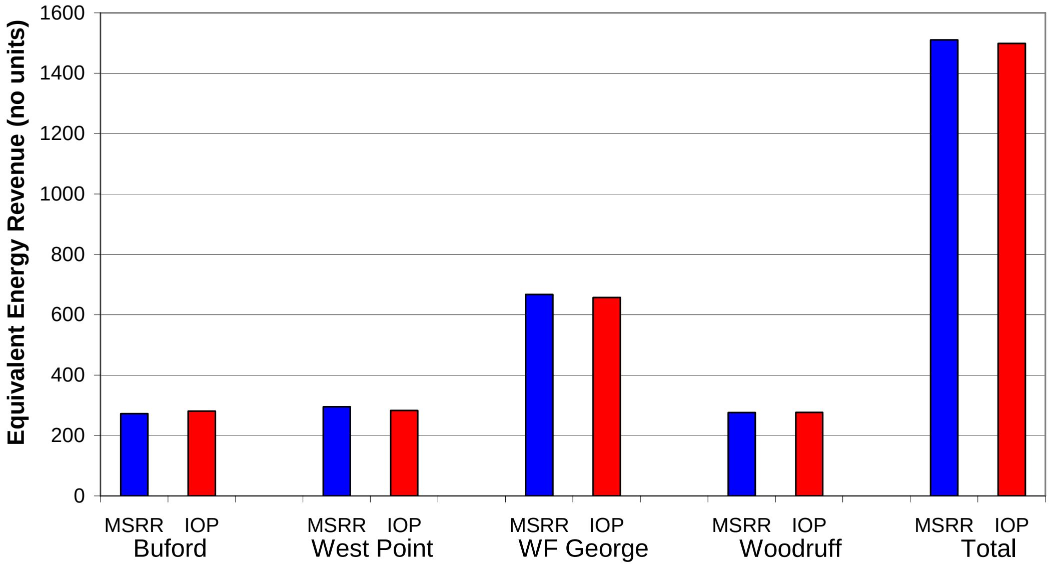


Figure 29 shows an estimate of the value of the power produced. This value is estimated using the average of 2001-2005 day-ahead peak power generation prices from the ERCOT hub. An individual price was generated for each day in the calendar year. The power generation for the day is divided by the generating capacity of the powerhouse for the day to give the number of hours of generation. At Buford, the capacity is a function of elevation, and at the other powerhouses it is constant. This is the same as the method used in HEC5. The first 3 hours of generation are priced at peak price levels, and the remaining hours at 1/3 of peak price levels to estimate the value of power generated for the day. We believe this is a reasonable first order estimate of value. The MSRR produces an insignificantly higher value for power produced even though it has minimal provisions for optimizing power generation.

It is important to note that the MSRR generates energy only when prices are high rather than everyday. As seen above, this not only increases the value of power generated, it also produces better biological performance.

Figure 33: Average Equivalent Energy Revenue



6.3.4 <u>Flood Control</u>

The proposed alternative does not include any requirements concerning flood control operations beyond those associated with the seasonal curve for specifying the top of conservation pool in each reservoir. Top of conservation rule assumptions are unchanged from current levels. Therefore, implementing the proposed alternative will not impact flood control performance.

7. CONCLUSION

The Maximum Sustainable Release Rule ("MSRR") is proposed as a revision to the IOP for the implementation of RPM3:

- The MSRR responds to RMP3 by increasing minimum flows below Woodruff to the maximum sustainable flow whenever basin conditions permit.

- The MSRR ensures that such releases will not compromise the ability of the system to meet critical needs over the long-term.

- The MSRR performs better in terms of many operating objectives, including but not limited to those relating to the protection of threatened and endangered species. MSRR does not perform significantly worse in terms of any operating objective.

- The MSRR provides improved ability to cope with droughts worse than the drought of record with regard to maintaining environmental flows and maintaining public health and safety.

- The MSRR is a practical rule that is easily implemented.

- We appreciate the Corps' consideration of this approach and will make available to any information, data or other resources necessary to validate the rule. We also stand ready to assist the Corps in any way possible.