Appendix C
Assessment of Flows Passing Morelos Dam with Future Drop 2 Reservoir Operations

TECHNICAL MEMORANDUM

Date: August 30, 2006

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Project: Reservoir Capacity Restoration Project

Subject: Assessment of Historical Flows Arriving at and Passing Morelos Dam and Assessment of Potential Reductions That May Result from Future Drop 2 Reservoir Operations

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INTRODUCTION

This technical memorandum presents the results of an assessment of the historic Colorado River flows arriving at and passing Morelos Dam. The assessment also considers how future flows at this location may change with the construction and future operation of the proposed Drop 2 Reservoir. This assessment considers the flows delivered by the U.S. Bureau of Reclamation (Reclamation) to the Northern International Boundary (NIB) between the United States and Mexico, the Mexico diversions by Mexico at their Alamo Canal Diversion which is located above Morelos Dam, and the surface water that passes over Morelos Dam and enters the Limitrophe Reach of the Colorado River. The Limitrophe Reach is the section of the river that extends between the NIB and the Southerly International Boundary (SIB) between the United States and Mexico.

The construction and future operation of the Drop 2 Reservoir will increase the ability of the river operators to re-regulate flows in the lower part of the Colorado River. This will improve Reclamation's ability to manage the water of the lower Colorado River. The proposed Drop 2 reservoir will facilitate conservation of flows that are currently considered to be non-storable due to inadequate re-regulating storage capacity in the lower part of the Colorado River. The future operation of theDrop 2 Reservoir may potentially affect the volumes of non-storable flows that arrive at NIB and that portion of the non-storable flows that are not diverted by Mexico and pass Morelos Dam. By definition, non-storable flows (NSFs) represent Colorado River or Gila River water that cannot be captured or put to beneficial uses in the United States at the time that it is in excess of the water demands of United States users.

BACKGROUND

Reclamation is evaluating the feasibility of constructing additional storage capacity that can be used to improve the management of the lower Colorado River water supply. The additional storage capacity will provide various benefits with the principal benefit being the enhancement of

Reclamation's ability to re-regulate the river flows in the river reach below Parker Dam. This enhancement will enable Reclamation and the various water users in the lower part of the river to conserve NSFs. The conserved water can then be made available for beneficial use in the United States.

The Drop 2 Reservoir will be an offstream reservoir. The site that is currently being considered for the proposed reservoir is located in Imperial County, California, is located adjacent and immediately north of the All-American Canal (AAC) and Interstate Highway 8 (I-8), and is located approximately 25 miles west of the Colorado River. Since the proposed reservoir site is located in the vicinity of Drop 2 of the AAC, Reclamation currently refers to this proposed reservoir project as the Drop 2 Reservoir. The proposed reservoir site comprises some 615 acres and can readily accommodate the construction of the proposed 8,000 AF Drop 2 Reservoir. Figure 1 shows the general location of this proposed Drop 2 Reservoir site.

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Figure 1
General Location of Proposed Drop 2 Reservoir Site

CURRENT RIVER OPERATIONS

Reclamation operates the Lower Colorado River system to control floods, regulate the flow of the Colorado River, deliver stored water for beneficial uses in the United States and Mexico, and generate electrical energy, among other purposes.

Reclamation and the agencies that utilize Colorado River water operate various facilities under a coordinated program to maximize the beneficial use of water in the United States and Mexico. However, the operational efficiency of a water system is largely dependent upon the ability of the operators to manage water on a real time basis. The more options available to hold, transfer, deliver, and release water, the more responsive and efficient river operations can be.

Currently, there are inherent inefficiencies associated with the lower Colorado River regulation and delivery of water for beneficial use within the United States and Mexico. These inefficiencies are due in part to the approximate five-day travel time required for water released from Hoover Dam to arrive at Imperial Dam, and the lack of sufficient system storage capacity to enable better management of the demands and flows arriving at Imperial Dam. Releases from Hoover Dam are regulated in Lake Mohave and releases from Davis Dam are regulated in Lake Havasu.

Water released from Parker Dam (and Lake Havasu) takes approximately three days to travel the 143 river miles to Imperial Dam where diversions from the river are the greatest and the ability to regulate flows is the least. Factors such as evaporation and phreatophyte losses, channel and bank storage gains or losses, weather conditions, unscheduled pumping from the river, and variations in return flows from water users can significantly affect water deliveries and river regulation. The limited regulating capacity that is available downstream of Parker Dam is located principally in Senator Wash Reservoir, behind Imperial Dam, and behind Laguna Dam. Since 1992, operating restrictions have been imposed on Senator Wash Reservoir. The operational restriction of Senator Wash Reservoir is associated with Safety of Dams concerns and have reduced the useable storage capacity from 12,259 acre-feet (AF) to 7,567 AF. These operational limitations imposed on Senator Wash Reservoir have made it much more difficult for river operators to manage the mismatches between water orders and water arriving at Imperial Dam.

Once released from Parker Dam, there is limited capacity to regulate river flows to accommodate changes in demand for water by downstream users. Water released from Parker Dam pursuant to a user's order may be rejected by that user for the following reasons:

1. Unexpected changes in weather including rain, wind, or cooler than expected temperatures.
2. Unexpected damage or failure of canal facilities.
3. Unexpected changes in water requests from farmers due to on-farm irrigation system problems or unexpected on-farm management problems.

Any water ordered exceeding actual demand at the time of arrival at Imperial Dam (i.e., the amount of a user's order rejected after it has been released from Parker Dam) by any one of the downstream users is managed in one of the following ways:

1. Put in storage at Senator Wash Reservoir or behind Imperial Dam.
2. Delivered to another water user needing to divert more water than it ordered.
3. Delivered to Mexico as part of its scheduled delivery or as non-storable water.
4. Released from Imperial Dam and passed through the Laguna Desiliting Basin and Laguna Dam to temporarily store the water or slow down the transit time.

Any water above actual demands that arrives at Imperial Dam that cannot be managed by any or a combination of the above options is inadvertently delivered to Mexico and is considered to be non-storable water. If the monthly sum of the NSFs causes the deliveries to Mexico to be in excess of their monthly order, then this excess water is in excess of Mexico's scheduled delivery for the month. The U.S. receives no credit for water that is over-delivered to Mexico under non-floodflow conditions.

Non-storable water may also result from infrequent and unregulated inflow from numerous desert washes that discharge into the Colorado River between Parker Dam and Imperial Dam. Flood control releases from Hoover Dam are normally in excess of downstream demands that also results in NSFs.

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The available regulatory storage capacity in Senator Wash Reservoir and behind Imperial and Laguna Dams is insufficient to adequately manage the mismatches in water demands and the non-storable water. The limited capacity is further exacerbated by the maximum water surface elevation restrictions that have been imposed on Senator Wash Reservoir on an indefinite basis.

MEXICO DELIVERIES

Mexico is entitled to receive an aggregate of 1.5 million acre-feet per year (mafy) of Colorado River water delivered at the NIB and SIB consistent with the 1944 Treaty between the U.S. and Mexico (1944 Treaty). Of this amount, approximately 1.36 maf are required to be delivered in the bed of the Colorado River at the NIB and approximately 140,000 AF in aggregate of Colorado River water (normally consisting of drainage returns and wasteway flows) are delivered at the section of the Limitrophe Reach located downstream of Morelos Dam and the SIB.

In the event a surplus year is declared by the Secretary, Mexico may increase its annual water order by 200,000 AF for a total of 1.7 maf. In the event of a declared shortage, water deliveries to Mexico may be reduced in proportion to the reduced consumptive use in the United States.

In December of each year, Mexico provides the United States with an advance monthly water order for the following year. This water order can only be changed by providing the United States 30 days advance notice, and each monthly water order can be increased or decreased by no more than 20 percent of the original monthly water order.

Mexico's daily water orders are submitted to the schedulers at Imperial Dam on Wednesday for the following week which starts on Monday for scheduling purposes. Mexico's daily water order cannot be changed once it is received by Reclamation. This order contains both Mexico's total daily water order and their desired delivery at the SIB. The difference between Mexico's total water order and their requested flow at SIB is calculated and becomes the target water delivery for Mexico at NIB.

LIMITROPHE REACH OF THE COLORADO RIVER

The Limitrophe Reach of the Colorado River is the segment of the river that extends from the NIB to the SIB. This reach of the Colorado River serves as the international boundary between Mexico and the United States. The Limitrophe Reach has a meandering channel with extremely irregular channel geometry and significant variation in channel sinuosity and slope. In general, the invert slope decreases and the channel width increases downstream from NIB. The Limitrophe Reach is approximately 24 miles long and begins upstream at the NIB, southwest of Yuma, Arizona, and ends downstream at the SIB.

Located 1.1 miles downstream of the NIB is Morelos Dam. This dam functions as a diversion control structure for the Alamo Canal, which conveys water to Mexico. The Alamo Diversion (the intake to the Alamo Canal) is located immediately upstream from Morelos Dam on the Mexico side of the river. The Alamo Diversion and Alamo Canal are owned by Mexico.

All or most of the water that arrives above the Alamo Diversion, under normal conditions, is diverted by Mexico at the Alamo Diversion and conveyed to water users on the Mexico side of the river via the Alamo Canal. The water arriving above the Alamo Diversion can comprise of:

1. U.S. delivery of Colorado River water to Mexico pursuant to water ordered by Mexico consistent with the Mexico Treaty of 1944, and
2. Non-storable flows.

The non-storable flows result from mismatches between water orders and water arriving above Imperial Dam or from floodflows. The mismatches principally correspond to the water orders from users that take delivery of water at or above Imperial Dam.

The U.S. has no control of the water once it arrives at NIB. Mexico has the ability to and often does divert water in excess of their order amount if such is available. Any water that arrives at NIB and that is not diverted by Mexico, passes over Morelos Dam and enters the portion of the Limitrophe Reach that extends below Morelos Dam.

Other active flow structures from the irrigation canal systems on the U.S. side of the river located within the Limitrophe Reach include the 11-Mile and 21-Mile wasteways. The water entering the river from these wasteways generally consists of tail water and return and drainage flows from the Gila and Yuma valleys. A third wasteway referred to as Mode No. 3, is located immediately downstream of Morelos Dam but has not been used in many years.

There is another wasteway located between NIB and Morelos Dam that is commonly referred to as the Cooper Wasteway. The water discharge from this wasteway to the river generally consists of return and drainage flows from the agricultural irrigation systems in the Yuma Valley. The combined flows of the water arriving at NIB plus the flows provided by the Cooper Wasteway comprise the flows that we hereinafter refer to as the flows arriving above the Alamo Diversion.

ASSESSMENT OF HISTORIC FLOWS

In order to determine whether the water that will be conserved by the proposed Drop 2 Reservoir will reduce the volume of water that enters the portion of the Limitrophe Reach that extends below Morelos Dam, it is first necessary to evaluate and better understand the historic flows that have been observed in the part of the river located above and below Morelos Dam. This part of the analysis was simplified by focusing on the flows that occur at the following three general locations:

1. Historic NSFs arriving at NIB and/or above the Alamo Diversion,
2. Portion of historic NSFs diverted by Mexico, and
3. Portion of historic NSFs that passed Morelos Dam.

In addition, the analysis also attempted to quantify the other surface flows that enter the Limitrophe Reach, i.e. discharges from the Mode No. 3, 11-Mile and 21-Mile wasteways.

Figure 2 provides a schematic that shows the general layout of the main features of the Colorado River and the various conveyance facilities that divert from, or discharge to, the Colorado River in the Yuma area.

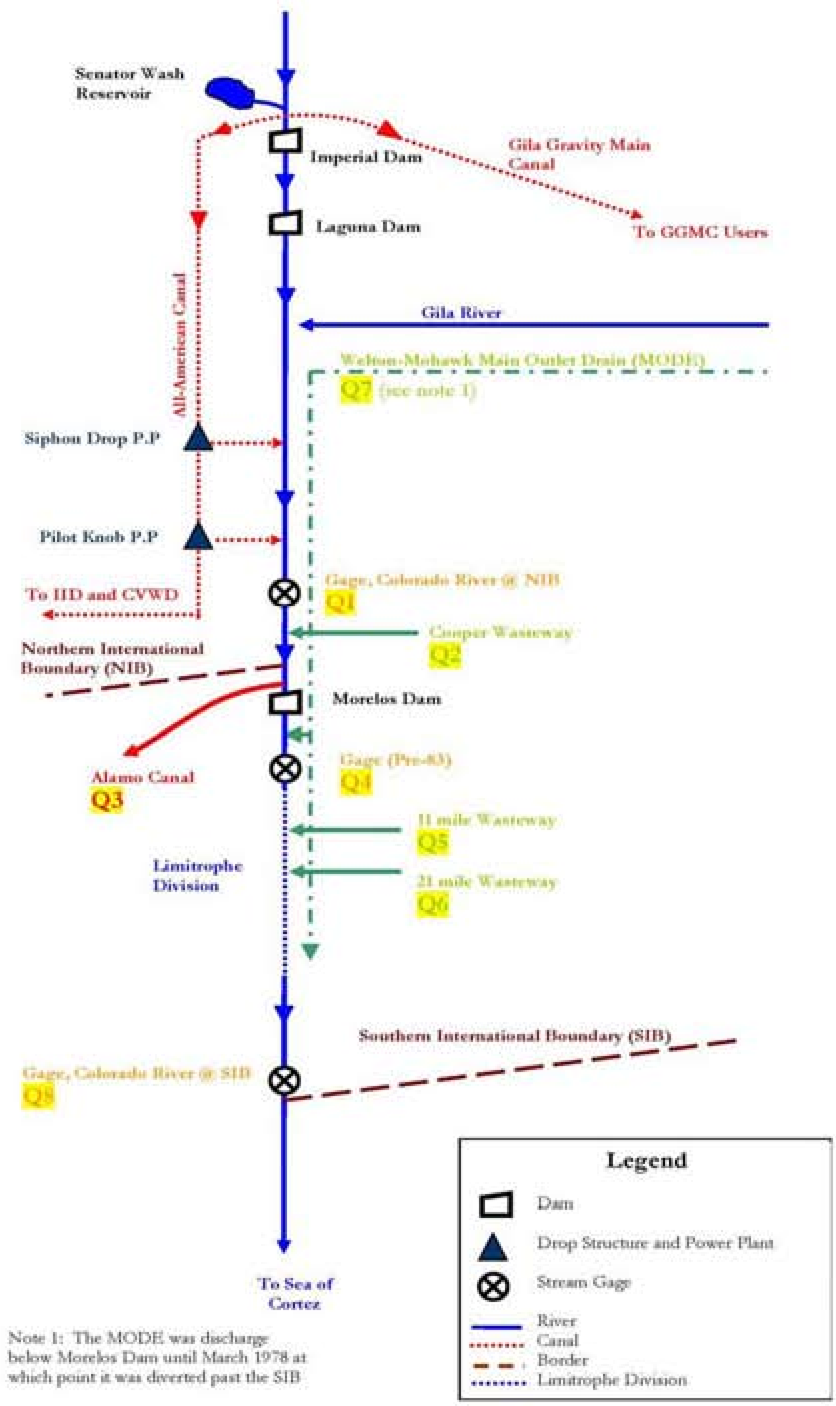
PERIOD OF ANALYSIS AND FLOW VALUES

The analysis included an evaluation of available flow records that could be used for this analysis. The goal was to provide a large enough period of analysis to assess how the NSFs have varied under different hydrologic and river operation conditions. The 31-year period from 1974 to 2004 was selected based on the availability of data.

The flow data analysis used mean daily flow values (in cubic feet per second [cfs]). The flow records obtained from Reclamation provided the data already in mean daily flow values using cfs as the units of measurement and reporting. The data received from Reclamation was in the form of both paper and electronic format. The flow records obtained from the U.S. Section of the International Boundary and Water Commission (USIBWC) was also in mean daily flow values.

However, the units of measure for all of this data was in cubic meters per second (cms). All of the data provided by USIBWC required conversion from cms to cfs values.

Figure 2
General Layout of Colorado River Facilities in the Yuma Area



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Data Collection and Flow Calculations

Historic data was collected and/or calculated for flows on the Colorado River between Imperial Dam and the Southern International Border (see Figure 2) as follows:

Water Arriving Above the Alamo Diversion:

The water arriving above the Alamo Diversion was calculated by adding the mean daily flow values reported at the NIB gage to the mean daily flow values reported for the Copper Wasteway gage. The NIB gage is located within the mainstem of the Colorado River. The Copper Wasteway discharges to the Colorado River at a location between NIB and Morelos Dam.

Mexico Orders and Diversions

Two flow factors were considered for Mexico, their daily water orders (Mexico Orders) and the daily flows that were diverted by Mexico at their Alamo Diversion (Mexico Diversion). Mexico's daily orders are as reported by Reclamation in the daily delivery schedules. The Mexico Diversions are the flow values reported at the Alamo Diversion gage.

Non-Storable Flows (NSFs)

The NSFs were calculated by comparing the flows arriving above the Alamo Diversion to the Mexico Orders. If the flows arriving above the Alamo Diversion exceeded the Mexico Orders, the difference was assumed to be the mean daily value of the NSF.

Baseflows Arriving Above the Alamo Diversion

The baseflows arriving above the Alamo Diversion were calculated by subtracting the calculated NSF values from the water arriving above the Alamo Diversion. This baseflow value is used in subsequent steps of the analysis.

Portion of Historic NSFs Diverted by Mexico

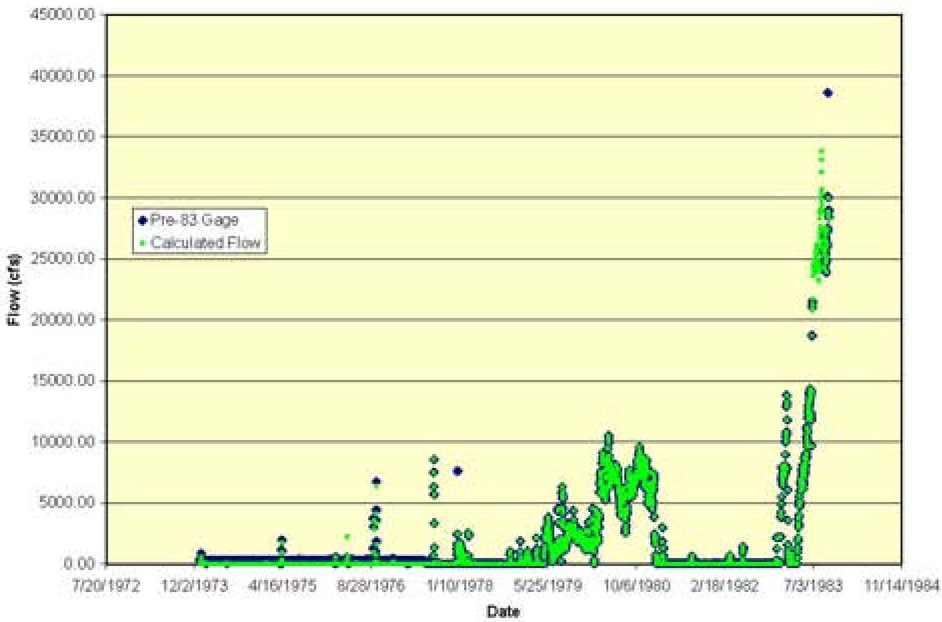
The portion of historic NSFs diverted by Mexico were calculated by comparing the Mexico Diversions to the Mexico Orders. If the mean daily flow values of the Mexico Diversions were greater than the mean daily flow values of the Mexico Orders, then the difference was assumed to represent the portion of the NSF diverted by Mexico. However, the calculated portion of historic NSFs diverted by Mexico were also compared to the total NSF amount and adjusted so as to not exceed the calculated NSF values.

Portion of Historic NSFs that Passed Morelos Dam

Prior to 1983, a gage recorded flows below Morelos Dam. However, in 1983, the gage was washed out during a flood and it has never been replaced. As such, two methods were used to determine the portion of the historic NSFs that pass Morelos Dam. First, for years 1974 to 1982, mean daily flow values reported for the gage located downstream of Morelos Dam were assumed to represent the portion of the NSF that passed Morelos Dam. However, prior to 1979, the Mode No. 3 Wasteway discharged flows into the mainstem at a location between Morelos Dam and the Pre-83 Morelos Dam gage. As such, these mean daily flows were subtracted from the mean daily flow values reported for the gage located downstream of Morelos Dam to gain a more accurate representation of the portion of the historic NSFs that pass Morelos Dam.

As noted above, the gage that was used to record flows below Morelos Dam was washed out in 1983. Since then, the portion of the NSF that pass Morelos Dam have been calculated by USIBWC by subtracting the Mexico Diversions from the water arriving above the Alamo Diversion. A similar process was used in this analysis. For this analysis, the portion of the historic NSFs that pass Morelos Dam were calculated by subtracting the portion of historic NSFs diverted by Mexico from the total calculated NSF value. A correlation analysis was made to ascertain how the flow values calculated using this second method compared to the actual flow measurements reported for the Pre-1983 gage. The graph below shows how the two flows matched-up and also shows that there is a good correlation between the two sets of values.

Figure 3
Comparison of Gage Flow Readings to Calculated Flow Below Morelos Dam



For consistency purposes and in order not to mix data sources in this analysis, the portion of the historic NSFs that pass Morelos Dam were calculated by subtracting the portion of historic NSFs diverted by Mexico from the total calculated NSF value. This method was used for the entire period of analysis (1974 to 2004).

Other Surface Flows That Enter the Limitrophe Reach

There are three locations within the section of the Limitrophe Reach that extend from Morelos Dam to SIB where other surface flows are introduced into the mainstem from the U.S. side of the river. These correspond to discharges from the Mode No. 3, 11-Mile and 21-Mile wasteways. The Mode No. 3 Wasteway is reported to have been active only through 1979. Since then, no discharges from this wasteway to the mainstem have been reported. Both the 11-Mile and 21-Mile Wasteways are still active and discharge to the river. The mean daily flow values for these facilities are the values reported for the gages at each respective facility.

Historic Flows at SIB

A gage at the SIB records flows in the Colorado River at a point just upstream of the SIB. The SIB mean daily flow values used in this analysis were as reported at the SIB gage.

FINDINGS FROM HISTORIC FLOW ANALYSIS

Mean daily flow values were produced for each day within the 31-year period of analysis. This enabled an assessment of the frequency, magnitude, and source of flows at the above noted locations.

Figure 4 presents a comparison of the Mexico Orders to the water arriving above the Alamo Diversion and also shows the daily values of the NSFs.

Figure 4
Comparison for Mexico Orders, Flows Arriving Above Alamo Diversion and Total Non-storable Flows Arriving Above Alamo Diversion

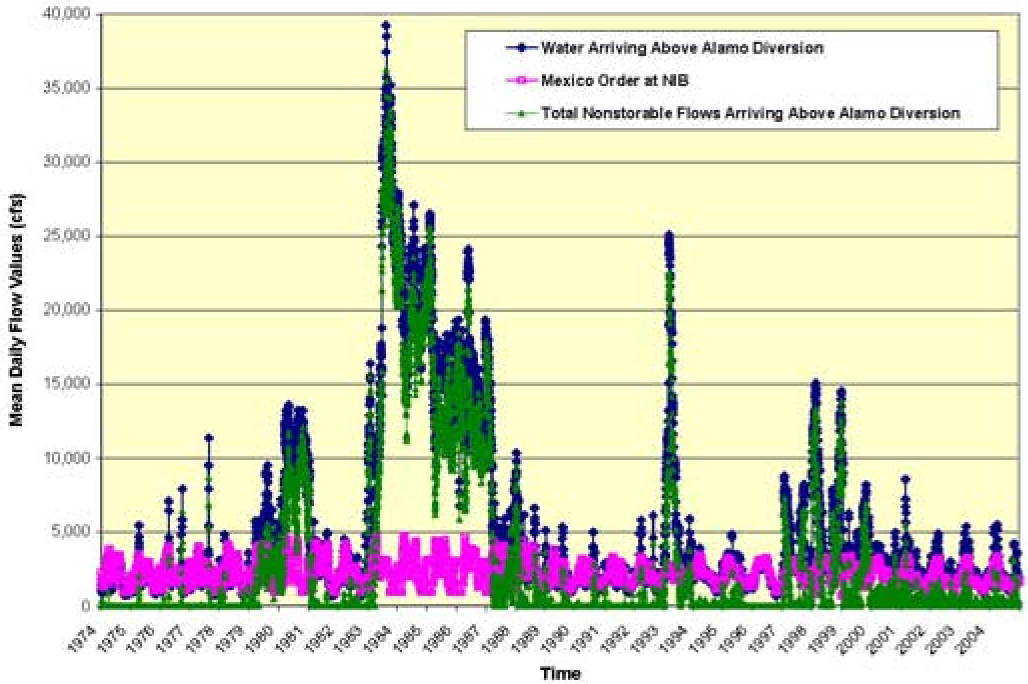


Figure 4 shows that under normal flow conditions, both the water arriving above the Alamo Diversion and the Mexico Orders are at about 5,000 cfs or less. However, the flows can be substantially higher than this under flood flow conditions.

Figure 5 presents a comparison of the Mexico Orders to Mexico Diversions and also shows the portion of the NSFs that were diverted by Mexico. Figure 5 shows that Mexico's daily diversions quite often exceed their orders. This is made possible by the fact that Mexico is able to divert a significant portion of the NSFs that arrive above the Alamo Diversion.

Figure 6 presents a comparison of the NSFs to the portion of the NSFs that passed Morelos Dam and also shows the portion of the NSFs that were diverted by Mexico.

Figure 5
Comparison of Mexico Orders to Mexico Diversion and Portion of NSFs Diverted by Mexico

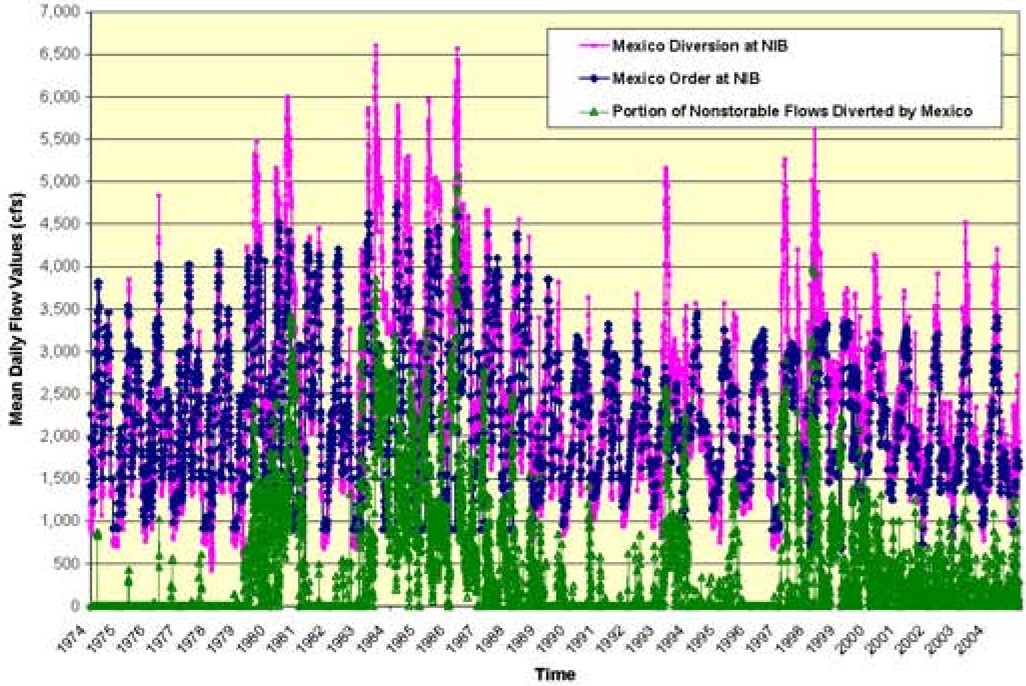


Figure 6
Comparison of Non-storable Flows Arriving Above Alamo Diversion, Portion of NSFs Diverted by Mexico, and Portion of NSFs That Pass Morelos Dam

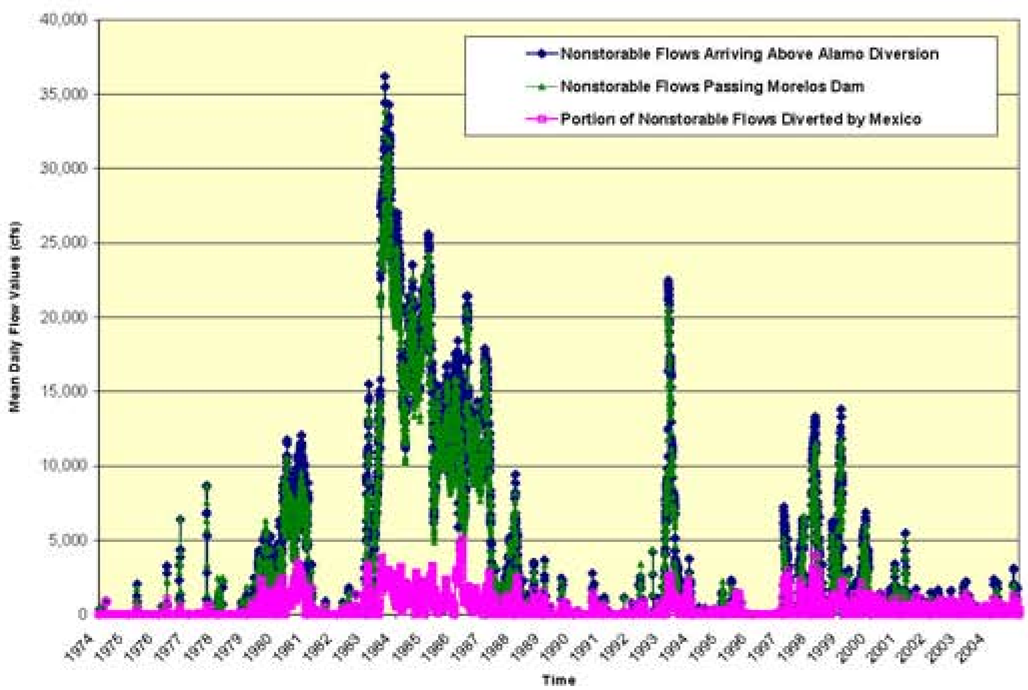


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Figure 6 confirms the observation that Mexico does divert a good portion of the NSFs that arrive above the Alamo Diversion and also that under flood flow conditions, all or most of the NSFs pass Morelos Dam.

Table 1 provides a summary of the annual average historic flows at the different river locations that are of interest to this analysis. As noted before, the average annual Mexico Order at NIB is about 1.36 maf. As shown in Table 1, the average annual flows arriving above the Alamo Diversion is approximately 3.61 maf, which is 2.65 times the average annual order. This high level of NSFs is principally due to the frequent and high value of the flood flows that were observed in past years, particularly in the mid-1980s and again in the 1990s (see Figure 4).

Table 1
Summary of Historic Annual Flow Values

Flow Factor	Observed Values	
Days in Period	11,323	Days
Years in Period	31	Years
Water Arriving Above Alamo Diversion	3,614,029	Average AF/year
Mexico Diversion @ Alamo Diversion	1,766,443	Average AF/year
Mexico Order @ Alamo Diversion	1,548,687	Average AF/year
NSF Arriving Above Alamo Diversion	2,121,954	Average AF/year
Portion of NSF Diverted by Mexico	289,730	Average AF/year
Portion of NSF Passing Morelos Dam	1,847,586	Average AF/year

CONSERVATION OF WATER IN DROP 2 RESERVOIR

A spreadsheet model was developed to evaluate what portion of the NSFs observed in the 31-year period of analysis could be conserved if the Drop 2 Reservoir had been in service during that period. As previously noted, mean daily flow values for the NSFs were calculated using the historic flow data. These NSFs served as input to the reservoir model. The spreadsheet model is set up as a series of equations that looks at the daily NSF values to determine how much can be diverted into the Drop 2 Reservoir.

The spreadsheet model was configured to account for Drop 2 Reservoir physical and operation constraints. The physical constraints include the proposed inflow capacity of 1,800 cfs, an outflow capacity of 1,700 cfs, and a total reservoir storage capacity of 8,000 AF.

The reservoir model was configured to reflect several anticipated Drop 2 Reservoir operational constraints as follows:

1. The conservation of water in Drop 2 Reservoir cannot occur independent of the operation of Lake Havasu and Parker Dam. Water placed in storage in Drop 2 Reservoir cannot be released until a demand for such water is created. This demand is created by reducing or trimming the scheduled Parker Dam releases by an amount equal to the amount of water that was placed in storage. The transit time for flows traveling from Parker Dam to Imperial Dam is approximately 3 days. As such, this 3-day lag has to be considered in scheduling the release of stored water from the Drop 2 Reservoir. To simulate this three day lag, the reservoir model includes an algorithm that releases water from the Drop 2 Reservoir three days after it is placed in storage.

This simple operating strategy attempts to create under-deliveries at Imperial Dam whenever there is water held in the Drop 2 Reservoir. The created deficit between the flows arriving at Imperial Dam and the water orders is made up by releases of the water temporarily stored in the new reservoir. Because there is an approximate three day travel time from Parker Dam to Imperial Dam, the spreadsheet model keeps track of the previous deficits to ensure these cutbacks do not arrive at Imperial Dam after the storage reservoir has been emptied. This reservoir operating strategy helps empty the reservoir quickly while ensuring the flow deficits created are not larger than the water in storage. The goal is to empty the reservoir as quickly as possible to make the storage capacity available to capture more NSFs, should they occur.

2. A 10 percent volume factor is assumed for operational storage. Essentially, the model attempted to keep this operational storage volume (800 AF) in reserve. This simulates the anticipated difficulties associated with trying to fully vacate the reservoir, future lost storage capacity that may be attributed to sediment deposition, and other general operational inefficiencies.
3. Once the reservoir is filled, additional water cannot be placed in storage until capacity is made available. The three day lag time described in Item 1 above and the outlet capacity are determinant factors for the reservoir draining rate.
4. The amount of water released from Drop 2 Reservoir cannot exceed the volume of water held in storage.

The model keeps track of the daily volumes of water that are placed in storage in the Drop 2 Reservoir (Conserved NSFs). However, due to the physical and operation constraints and the high frequency and magnitude of observed NSFs in some years, not all NSFs could be conserved. Therefore, the reservoir model also kept track of the portion of the NSFs that could not be captured The portion of the NSF that could not be conserved are herinafter referred to as the Residual NSFs.

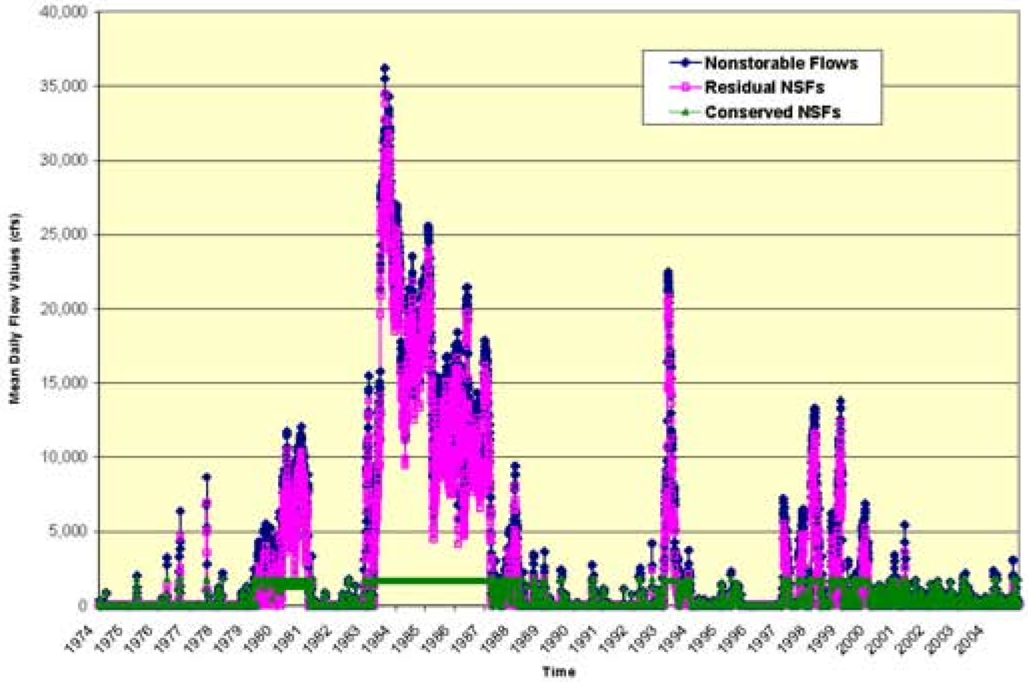
Figure 7 provides a graphical comparison of the NSFs, the portion of the NSFs that were captured by the Drop 2 Reservoir (Conserved NSFs), and the Residual NSFs.

Table 2 provides a comparison of the observed NSFs, Conserved NSFs, and Residual NSFs.

Table 2
Comparison of Non-storable Flows, Conserved NSFs, and Residual NSFs

Flow Factor	Average Annual Values
Non-storable Flows	2,121,954 AF/year
Conserved Non-storable Flows	385,886 AF/year
Residual Non-storable Flows	1,736,068 AF/year

Figure 7
Comparison of Non-storable Flows, Conserved Portion of Non-storable Flows, and Residual Non-storable Flows



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The initial results of this analysis showed that the Drop 2 Reservoir conserved an average annual amount of 385,886 AF/year over the 31-year period of analysis. However, a quick assessment of these values show that the methodology used in this analysis overestimates the amount of water that may be conserved. Recall the operational constraint that states that the conservation of water in Drop 2 Reservoir may not occur independent of the operation of Lake Mohave and Parker Dam. To effect the release of conserved water from the Drop 2 Reservoir, the scheduled Parker Dam releases need to be trimmed to affect a supply deficit at Imperial Dam three days later. The supply deficit is offset and water orders are completed by releasing water from the Drop 2 Reservoir. Under floodflow conditions on the mainstem, this process becomes ineffective because Parker Dam and perhaps the other upstream reservoir are spilling. This means that the flows from Parker Dam cannot be regulated. Usually, these floodflow conditions can last for several weeks and sometimes months. In the case of the mid-1980s, the Colorado River floodflow conditions lasted almost five years.

Table 5 shows the months when floodflow conditions existed either on the Colorado River, Gila River, or both.

Table 3
Months Determined to be in Floodflow Conditions on the Colorado River and Gila River

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1979	14,764	86,243	130,990	127,599	139,876	125,397	132,418	144,220	135,671	132,934	134,124	138,785	1,443,021
1980	209,231	151,920	**440,028**	**450,979**	**549,811**	**487,070**	**433,586**	**414,926**	**560,717**	**663,164**	**574,317**	**404,819**	5,340,568
1981	**302,140**	15,697	16,938	1,898	117	287	141	4,340	67	223	269	355	342,472
1982	114	375	4,191	448	7,253	7,954	1,907	5,313	1,170	720	310	19,563	49,318
1983	**585,524**	**213,139**	8,555	**278,360**	**545,951**	**868,798**	**1,702,572**	**1,838,400**	**1,737,835**	**1,902,334**	**1,474,278**	**1,333,910**	12,489,656
1984	**1,520,767**	**1,339,967**	**1,021,171**	**855,832**	**984,943**	**1,106,061**	**1,244,973**	**1,107,028**	**1,075,103**	**1,119,031**	**1,154,999**	**1,263,142**	13,793,017
1985	**1,328,134**	**1,270,564**	**1,027,110**	**522,478**	**706,605**	**754,373**	**722,607**	**703,473**	**890,868**	**710,381**	**672,530**	**802,175**	10,111,298
1986	**997,389**	**729,432**	**831,556**	**536,277**	**965,669**	**920,476**	**737,239**	**659,486**	**697,134**	**702,825**	**603,669**	**732,577**	9,113,729
1987	**1,017,992**	**692,380**	**339,318**	**58,402**	**81,110**	**48,916**	**30,265**	**55,578**	**133,746**	**183,956**	**98,203**	**206,617**	2,946,483
1988	**354,915**	**125,830**	8,719	11,206	3,603	1,828	224	55,674	21,863	23,626	10,156	13,067	630,711
1989	37,077	3,291	2,296	368	87	280	11,305	13,956	10,465	9,356	439	688	89,608
1990	2,760	25	276	431	334	259	278	21,940	12,500	2,761	158	266	41,988
1991	13,912	237	647	247	209	108	59	451	2,717	336	276	1,674	20,873
1992	378	143	13,796	13,407	12,141	386	83	17,924	753	12,545	1,466	7,710	80,732
1993	129,015	451,669	1,180,811	795,122	452,938	199,878	64,253	52,663	67,664	143,246	125,747	29,766	3,692,772
1994	152	78	674	119	3,318	63	129	1,964	775	671	3,700	13,877	25,520
1995	7,485	1,083	65	19,150	23,216	75,538	78,315	5,581	245	691	833	121	212,323
1996	113	281	238	421	94	441	50	176	35	2,446	126	911	5,332
1997	**109,693**	**255,296**	**172,865**	**32,405**	124	919	1,154	**216,660**	**305,820**	**25,615**	**18,699**	**33,207**	1,172,457
1998	**588,274**	**650,870**	**357,184**	**125,488**	41,051	9,546	1,786	9,444	**208,526**	**141,999**	**267,573**	**616,700**	3,018,441
1999	**342,583**	14,941	4,414	15,708	10,554	15,878	33,244	4,841	**187,368**	**294,144**	**205,460**	**64,970**	1,194,105
2000	14,958	7,410	24,011	12,969	29,643	13,648	18,291	29,111	38,195	74,784	41,749	32,369	337,138
2001	29,676	31,836	37,609	12,987	7,790	2,406	17,037	17,179	13,787	17,687	4,785	7,798	200,577
2002	10,844	2,616	20,068	16,107	13,909	9,417	8,058	4,480	19,994	9,698	4,230	3,742	123,163
2003	4,196	26,551	7,240	11,389	3,788	118	664	992	2,478	1,169	1,784	1,486	61,855

Normal Text = Normal

Blue Bold = Flood on Colorado River

Highlighted = Flood on Gila River

Highlighted & Red Bold = Floods on both Gila and Colorado Rivers

To develop a more reasonable and accurate estimate of the NSFs that can be conserved with the Drop 2 Reservoir, the input data was adjusted to take into account the likely ineffectiveness of the Drop 2 Reservoir during floodflow conditions. Specifically, the mean daily flow values for the months that were identified as floodflow conditions on either the Colorado River, Gila River, or both were not deleted from the reservoir model. These floodflow periods are those shown on Table 3.

Table 4 summarizes the number of days that were deleted from the original period analysis to account for the exclusion of the floodflow periods.

Table 4
Number of Days Deleted From Period of Analysis to Account for Exclusion of Floodflow Periods

	Original Modeled Period	Floodflow Periods	Adjusted Modeled Period That Excludes Floodflow Periods
Days in Period	11,323	3,772	7,551
Months In Period	372	124	248
Years in Period	31	10.3	20.7

Figure 8 provides a graphical comparison of the NSFs, the portion of the NSFs that were captured by the Drop 2 Reservoir (Conserved NSFs), and the Residual NSFs with the floodflow periods excluded.

Figure 8
Comparison of Non-storable Flows, Conserved Portion of Non-storable Flows, and Residual Non-storable Flows With Floodflow Periods Excluded

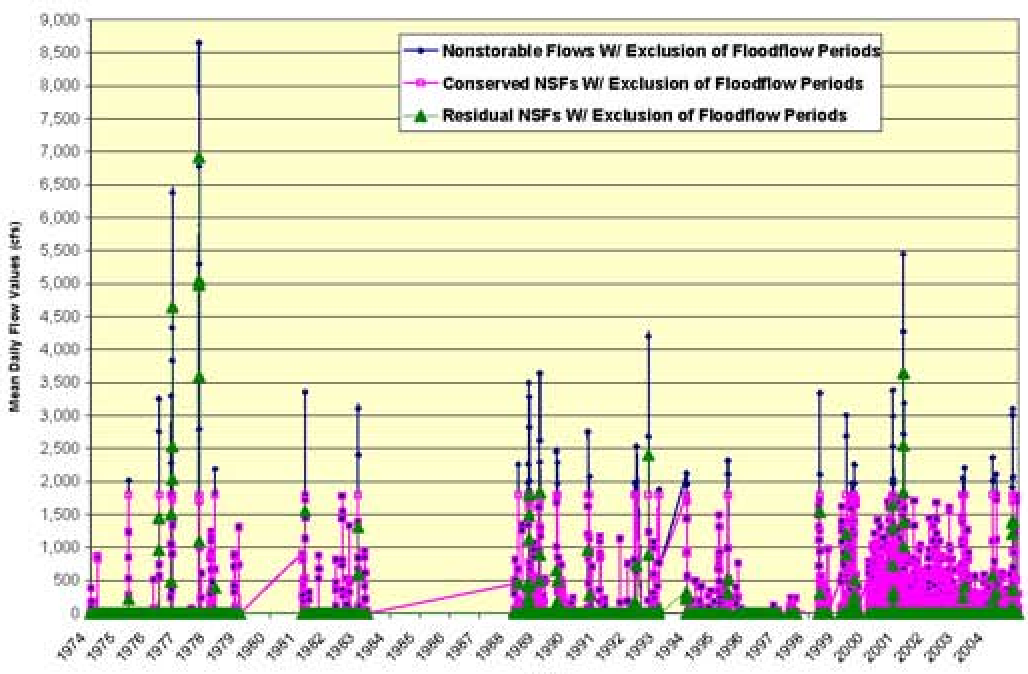

Table 5 provides a comparison of the observed NSFs, Conserved NSFs, and Residual NSFs with the floodflow periods excluded.

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Table 5
Comparison of Non-storable Flows, Conserved NSFs, and Residual NSFs Under the Conditions that Consider the Exclusion of the Floodflow Periods

Flow Factor	Average Annual Values
Non-storable Flows	79,703 AF/year
Conserved Non-storable Flows	71,643 AF/year
Residual Non-storable Flows	8,060 AF/year

As shown on Table 5, the estimate of the annual average Conserved NSFs without the floodflow periods is about 71,643 AF/year. This is significantly different than the values that were presented in Table 2, which shows the overestimate of Conserved NSFs when the floodflow periods are included in the analysis.

EFFECT OF CONSERVED WATER ON FLOWS PASSING MORELOS DAM

The last part of this assessment was to ascertain how the flows that pass Morelos Dam and enter the Limitrophe Reach may be affected by construction of the Drop 2 Reservoir. Recall that only a portion of the NSFs actually pass Morelos Dam because Mexico diverts a portion of the NSFs. Therefore, a reduction of the NSFs through the conservation of the water in the Drop 2 Reservoir does not result in a reduction of the flows passing Morelos Dam by an equivalent amount.

The effect of the Drop 2 Reservoir was analyzed by rerouting the Residual NSFs down to NIB and comparing this flow value to the portion of the NSF that was previously diverted by Mexico. If the portion of the NSF that was previously diverted by Mexico was equal to or less than the Residual NSF, then it was assumed that Mexico would still be able to divert a similar amount. In this case the portion of the NSF that was previously diverted by Mexico was subtracted from the Residual NSF. The difference is the portion of the Residual NSF that passes Morelos Dam. However, if the portion of the NSF that was previously diverted by Mexico was greater than the Residual NSF, then it was assumed that Mexico would divert an amount equal to the Residual NSF. In this case, no water passes Morelos Dam. This process was used to account for the fact that Mexico has in the past, and will in the future, continue to divert portions of the NSFs that arrive at Morelos Dam.

Figures 9, 10 and 11 compare the different components of the NSFs with and without the modeled Drop 2 Reservoir and with the floodflow periods excluded from the input data. Figure 9 compares the NSFs to the Residual NSFs. Again, the Residual NSFs are that portion of the NSFs that were not able to be captured or conserved by the Drop 2 Reservoir. Figure 10 compares the portion of the NSFs that were diverted by Mexico with and without the modeled Drop 2 Reservoir. Figure 11 compares the portion of the NSFs that pass Morelos Dam with and without the modeled Drop 2 reservoir.

Figure 9
Comparison of Non-storable Flows to Residual NSFs With Exclusion of Floodflow Periods
(Residual NSF is portion of NSF that could not be captured by Drop 2 Reservoir)

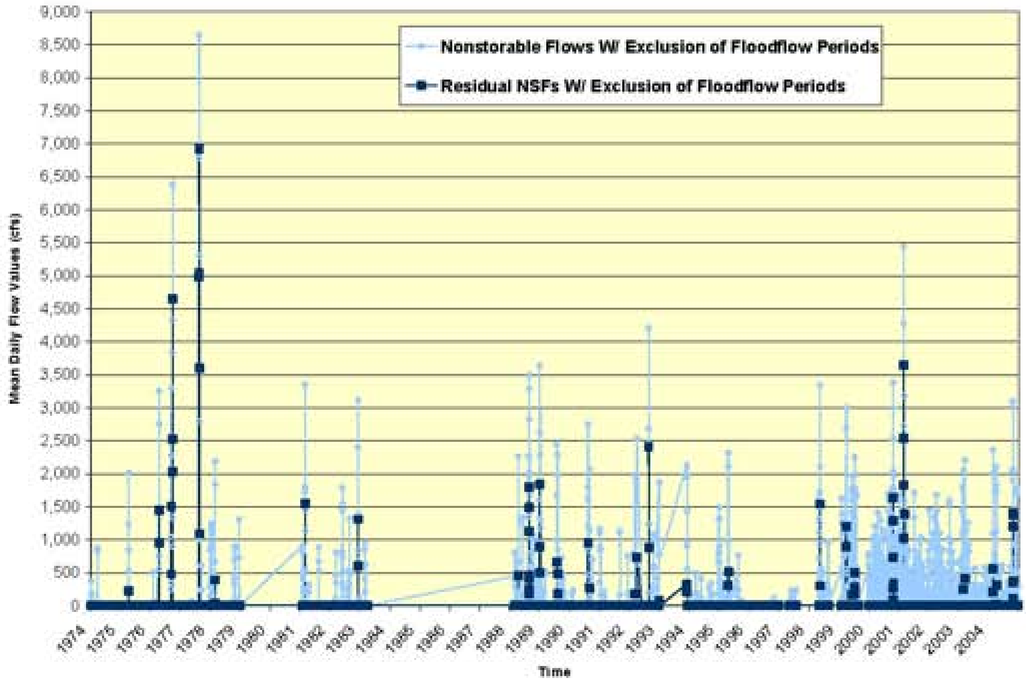

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Figure 10
Comparison of Portion of Non-storable Flows Diverted by Mexico to Portion of Residual NSF Diverted By Mexico s With Exclusion of Floodflow Periods

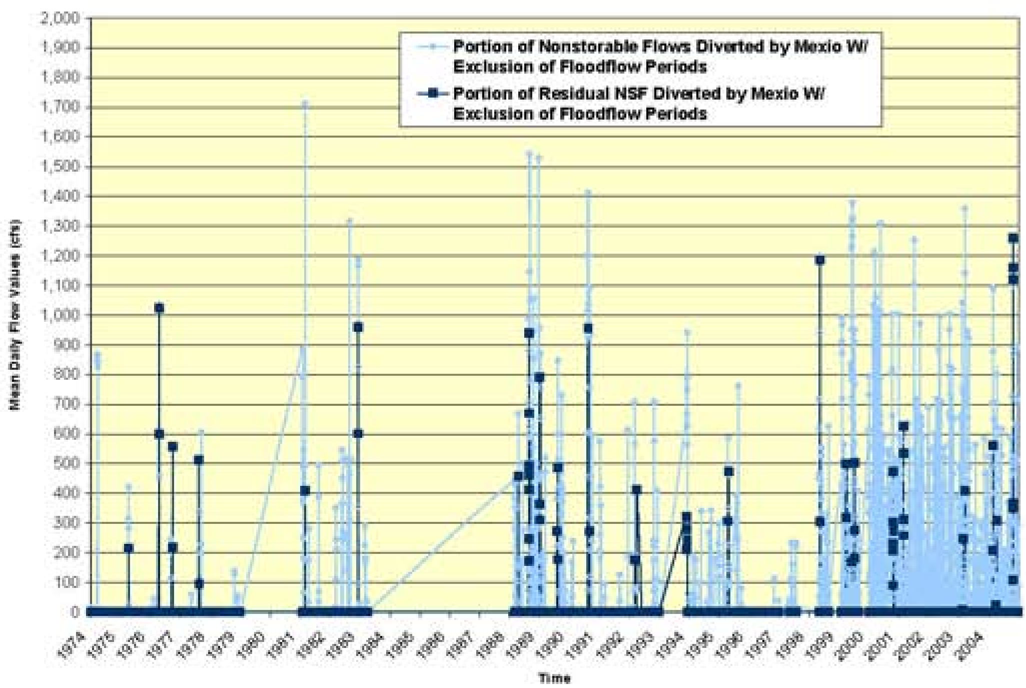
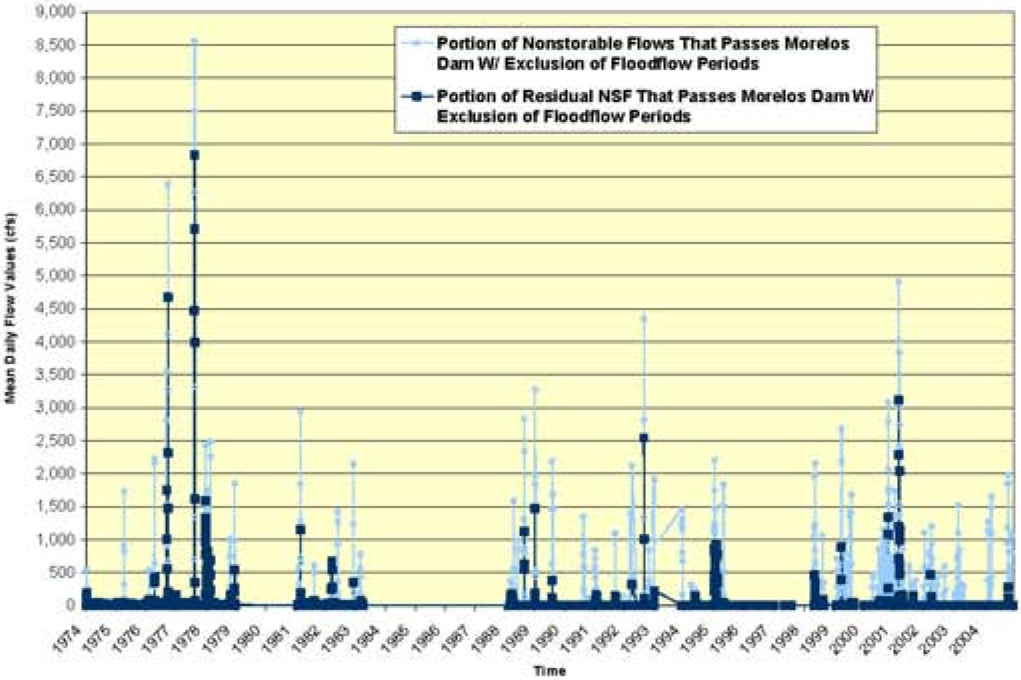


Figure 11
Comparison of Portion of Non-storable Flows Passing Morelos Dam to Portion of Residual NSF Passing Morelos Dam With Exclusion of Floodflow Periods



As noted previously, the modeled Drop 2 Reservoir conserves an average of about 71,643 AF/year of NSFs. However, as shown in Figure 10, Mexico diverts a good portion of the NSFs that arrive at Morelos Dam. In the future, it is anticipated that Mexico will continue to divert portions of the NSFs that arrive at Morelos Dam. This likely future condition was modeled and is reflected in Figure 10. The net effect on the flows that pass Morelos Dam is not as great as the Conserved NSFs because some of the NSFs that are conserved in the Drop 2 Reservoir were previously diverted by Mexico and previously did not pass Morelos Dam. This is better explained in Table 6. The average annual NSFs passing Morelos dam without the reservoir was only about 45,541 AF/year. With the modeled Drop 2 Reservoir, the average annual NSFs passing Morelos Dam was about 13,490 AF/year. The difference of about 32,051 AF/year is the net effect that the Drop 2 Reservoir had on the flows that pass Morelos Dam based on the modeled condition. However, recall that the average annual NSF that passes Morelos Dam when the floodflow periods were included was estimated to be approximately 1,847,586 AF/year. As such, the change in the NSFs that pass Morelos Dam due to water conserved by the Drop 2 Reservoir (32,051 AF/year) is only about 1.7 percent of this amount.

Table 6
Comparison of Non-storable Flows Passing Morelos dam With and Without Drop 2 Reservoir
(Excludes Floodflow Periods)

Flow Factor	Average Annual Values
Non-storable Flows Passing Morelos Dam With No Reservoir	45,541 AF/year
Non-storable Flows Passing Morelos Dam With Drop 2 Reservoir	13,490 AF/year
Change in NSFs Passing Morelos Dam Due to Water Conserved by Drop 2 Reservoir	32,051 AF/year

FINDINGS

The following observations were made during the course of the subject analysis.

1. The historic NSFs varied widely throughout the 31-year period of analysis and reflected the variability in hydrologic and operational conditions of the Colorado River.
2. The floodflow periods contributed greatly to the average annual NSFs that arrive at and that also pass Morelos Dam as shown in the Table 7.

Table 7
Comparison of Non-storable Flows With and Without Drop 2 Reservoir

Flow Factor	All Years Including Floodflow Periods (1974 to 2004)			No Floodflow Periods (1974 to 2004)		
	No Reservoir	With Drop 2 Reservoir	Change	No Reservoir	With Drop 2 Reservoir	Change
Days in Period	11,323			7,551		
Years in Period	31			20.7		
Water Arriving Above Alamo Diversion (AF)	3,614,029	3,228,143	(385,886)	1,528,561	1,456,917	(71,643)
Mexico Diversion @ Alamo Diversion (AF)	1,766,443	1,713,383	(53,060)	1,483,020	1,443,428	(39,592)
Mexico Order @ Alamo Diversion (AF)	1,548,687	1,548,687	0	1,531,427	1,531,427	0
NSF Arriving Above Alamo Diversion (AF)	2,121,954	1,736,068	(385,886)	79,703	8,060	(71,643)
Portion of NSF Diverted by Mexico (AF)	289,730	236,670	(53,060)	42,309	2,716	(39,592)
Portion of NSF Passing Morelos Dam (AF)	1,847,586	1,514,760	(332,826)	45,541	13,490	(32,051)

3. Mexico has historically diverted a significant portion of the NSFs, a condition that will likely continue into the future.
4. The net effect of the modeled Drop 2 reservoir on the flows that pass Morelos Dam is an annual average reduction of approximately 32,051 AF/year. When this is compared to the total observed NSFs that passed Morelos Dam throughout this 31-year period (inclusive of the flood flow conditions) this amount translates to about a 1.7 percent reduction of the average annual NSFs flows observed in the 31-year period of analysis.
5. Several long periods of time were observed where no NSFs passed Morelos Dam. Figure 12 shows the frequency and magnitude of NSFs passing Morelos Dam for the 5-year period between 2000 and 2004. Table 8 presents the frequency of occurrence of different period lengths where no NSFs were observed. Both Figure 12 and Table 8 show that during this 5-year period, there were at least two periods greater than six months where no NSFs passed Morelos Dam. In addition, in the 31-year period of analysis, there were at least two periods that exceeded 12 months where no NSFs passed Morelos Dam.

Figure 12
Portion of Non-storable Flows Passing Morelos Dam
(5-year period between 2000 to 2004)

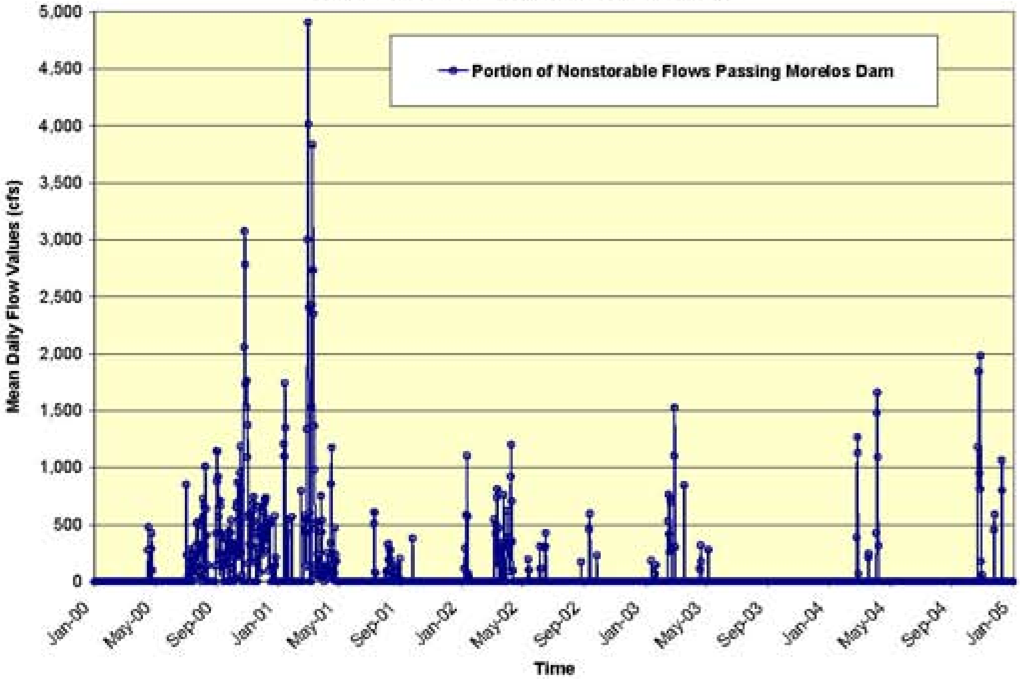


Table 8
Periods With No Non-storable Flows Passing Morelos Dam

Length of Period With No NSFs Passing Morelos Dam (number of days)	Number of Occurrences
30	9
90	5
180	2
270	1

Attachments

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The table below list the flow data used to compile the historic flow record and input for the reservoir model and list the source of the data.

Table A-1

Flow Data Sources

Flow Name	Data Source
Mexico Orders	USBR sent a CD of spreadsheets containing flows for the years 1998 to 2004 and scanned copies of handwritten data for 1974 to 1997.
Colorado River @ NIB Gage (Q1) Copper Wasteway (Q2) Gage Pre-83 (Q4) 21 Mile Wasteway (Q6) 11 Mile Wasteway (Q5) Welton-Mohawk Main Drain (MODE) (Q7) Colorado River @ SIB (Q8)	Gage records were collected from IBWC website from 1974 to 2004. Flows were collected in cubic feet per second.
Alamo Canal Diversions (Q3)	Data was collected from the IBWC website for flows through the Alamo Canal from 1874 to 2003. Flows for 2004 were collected via email from the IBWC staff. All flows were collected in cubic meters per second and converted to cubic feet per second.

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Table A-2

Flow Names, Descriptions, and Calculations in Model

Flow Name	Description	Calculation
Mexico Order @ NIB	Daily order from Mexico placed at Imperial Dam.	Mexico scheduled flow
Water Arriving at Morelos Dam	Water arriving at Morelos Dam before any diversions.	Gage at NIB (Q1)+ Copper (Q2)
Mexico Diversion at Alamo Canal Diversion	Water diverted to Mexico through Alamo Canal.	recorded value from website [If the diversion at Alamo Canal was larger than the water arriving at Morelos Dam, it was assumed that Mexico diverted all flow arriving.]
Excess Flows Arriving at NIB (over-delivery)	Water arriving that exceeds Mexico's order.	Water Arriving at Morelos Dam – Mexico Order [This value is negative when Mexico's order is larger than its diversion]
Excess Flows Arriving Above Morelos Dam	Same flow as one above, however, calculated in another formula to eliminate negative over-deliveries.	Water Arriving at Morelos Dam – Baseflow [If the water arriving is less than or equal to the baseflow, there are no excess flows arriving above Morelos Dam. This eliminates any negative "over-deliveries."]
Mexico Excess Flows Diverted at NIB	Amount of excess flow that is diverted by Mexico above its order.	Mexico Diversion at Alamo Canal – Mexico Order @ NIB
Flow Passing Morelos Dam (Measured)	Gage reading below Morelos prior to 1983 when it was washed out. Prior to 1979, this reading includes flows from the MODE.	Gage Pre-83
Flows Passing Morelos Dam (Calculated)	Same flow as above, however, an equation is used to calculate.	Excess Flows Arriving Above Morelos Dam – Mexico Excess Flows Diverted at NIB [If Mexico diverted is less than it ordered, this value was set to 0]
Baseflow	Water arriving at Morelos Dam minus the excess arriving.	Water Arriving at Morelos Dam - Excess Flows Arriving at NIB (over delivery) [If the Excess Flows Arriving at NIB is less than zero, this value is the Water Arriving at Morelos Dam]