



5930 Summerhill Rd • Texarkana, Texas 75503 • 903-838-8533 • fax 903-832-4700

TO:	Becky Griffith, Jon Jarvis
FROM	Spandana Tummuri
SUBJECT:	Technical Memorandum on IP Analysis
PROJECT:	Sulphur River Basin Feasibility Study
DATE:	08/28/2014
CC:	Tom Gooch, Jon Albright, Robert Murray

DRAFT
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1.0 INTRODUCTION

The purpose of this technical memorandum is to summarize the impacts of strategies to develop additional water supply in the Sulphur River Basin by reallocating storage in Wright Patman Lake on the operations of the International Paper Company's Texarkana Mill (IP). IP is located near Texarkana, Texas in the lower portion of the Sulphur River Basin near the Texas/Arkansas state line. The Texarkana Plant draws its water supply from Wright Patman Lake and discharges its plant effluent into the Sulphur River immediately downstream of the Wright Patman Dam. Because of this proximity and other dependencies, modifications to Wright Patman operating parameters have the potential to impact plant operations. The purpose of this analysis is to develop an understanding of the relationship between the releases from Wright Patman and IP operations and the potential impact changes in Wright Patman releases could have on IP operations.

2.0 INTERNATIONAL PAPER OPERATIONS

The International Paper Company is a leading firm in paper and packaging industry with manufacturing operations spread across several continents. IP's Texarkana Mill is located in Queen City, Texas near the junction of Texas, Arkansas, and Louisiana. The Texarkana Mill primarily produces bleach board for packaging, drinking cups, and folding cartons. The Mill has been in operation since the late 70s and has been a significant water user in the Sulphur Basin.

2.1 IP PLANT OPERATIONS

The Texarkana Mill operations are dependent on Wright Patman Lake both as a water source for plant operations and to augment river flows to enhance effluent discharge activities. Texarkana Water Utilities (TWU) holds a right to divert water from Wright Patman Lake for municipal (up to 45,000 ac-ft.) and industrial (up to 135,000 ac-ft) uses on an annual basis. IP and TWU entered into a contract which allows IP to use approximately 67,600 ac-ft (60.3 MGD) of TWU's water annually. IP diverts raw water from an intake structure on the south side Wright Patman Lake and delivers it to a treatment plant operated by IP under contract with TWU. Currently, IP treats and delivers about 2-3 MGD of water for municipal use by Domino, Queen City, and Atlanta.

IP uses treated water for all the plant operations and generates about 28-30 MGD of effluent from the plant operations. The plant operations maximize the use of available water and recycle most of it through the manufacturing process. The effluent from various process cycles is collected in the aerated stabilization

basins. There are two aerated stabilization basins each covering an area of approximately 72 acres. After retaining the effluent in the each one of the aerated stabilization basin for two to three days, IP diverts the treated effluent to the holding pond where the effluent is held until it is released in the Sulphur River. The holding pond capacity is about 26,300 ac-ft. The pond is about 20-ft deep and it covers approximately 1,315 acres of the property.

2.2 IP DISCHARGE PERMIT

The Texas Commission on Environmental Quality (TCEQ) has issued a water quality permit to IP, which governs discharges of effluent from the holding pond into the Sulphur River. Discharges are made to a remnant channel of Baker's slough, which joins the Sulphur River below Wright Patman in segment no. 0301 of the Sulphur River Basin. IP makes discharges from a rectangular structure called Outfall 001, which contains the two pipelines used for making discharges. The capacity of each one of the pipes is approximately 323.15 MGD, thus restricting the daily maximum discharges from the Outfall 001 to 646.3 MGD. IP's discharge permit includes both water quantity and water quality requirements. The discharge permit is included in Appendix A of this memorandum.

Of the water quantity parameters, the most important one is the criterion restricting IP's ability to release flows. IP cannot make discharges from their holding pond if the flow in Sulphur River, as measured at the Wright Patman dam, is below 50 cfs. In addition to that, IP has a restriction on the daily average percentage that plant effluent may comprise of the total river flow. This percentage varies from month to month and is defined by means of the Outfall discharge conditions specified in the permit. IP has two different outfall discharge conditions permitted in the discharge permit: Outfall Condition A and Outfall Condition B. Each outfall condition consists of a variable monthly trend of percentage match of IP discharges to the Wright Patman releases. The monthly patterns for Outfall Conditions A and B are illustrated in Figure 1 below.

Outfall Condition A is the more restrictive of the two discharge conditions. IP has been operating under Outfall Condition B requirements in the recent years. The daily maximum and daily average flow of effluent shall not exceed the value listed in the Table 1 shown below for each month for each outfall discharge condition. The USGS gage used for permit compliance is located just downstream of Wright Patman dam. It can be assumed that there are no additional drainage areas contributing to the Sulphur River between Wright Patman dam and IP's discharge location.

This analysis focuses on the water quantity restrictions manifested in the water quality permit through the Outfall Condition restrictions and does not address any water quality concerns which might remain after the release quantity restrictions in the permit have been met.

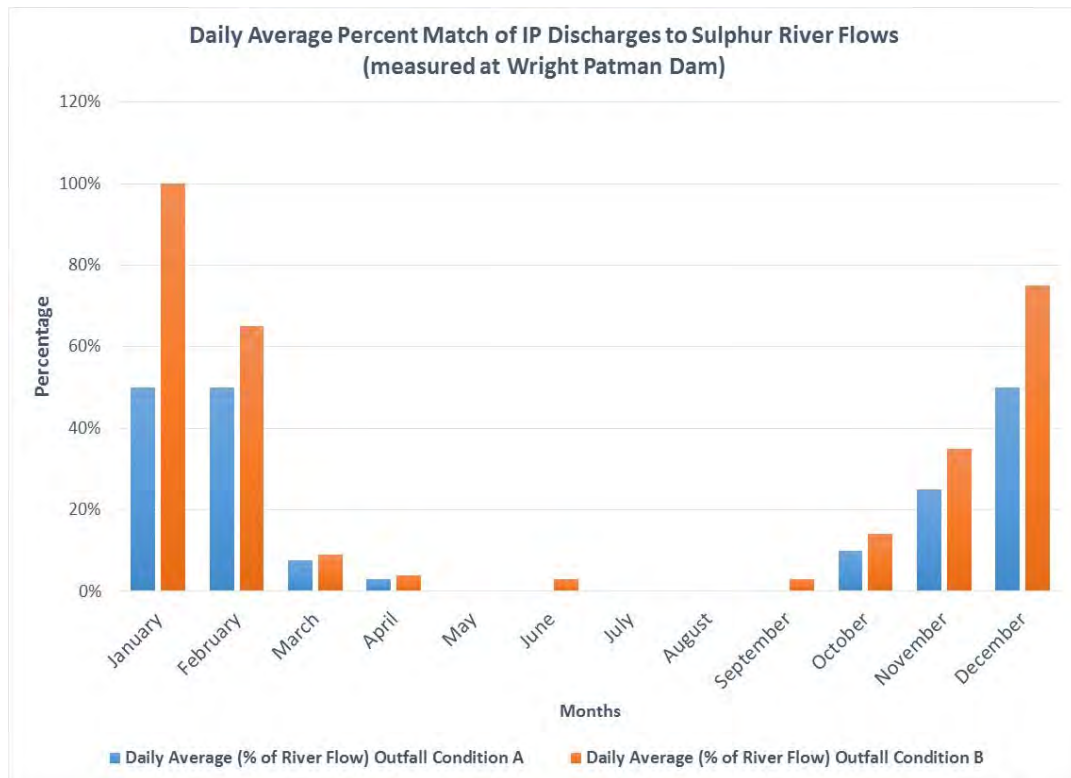


Figure 1 Illustration of the Monthly Percent Match of IP Discharges to the Sulphur River Flows

**Table 1 Summary IP Permit Requirements for
Outfall Conditions A and B**

Month		Daily Average (% of River Flow)		Daily Maximum (MGD)	
		Outfall Condition A	Outfall Condition B	Outfall Condition A	Outfall Condition B
January	1	50%	100%	646.6	646.3
February	2	50%	65%	646.3	646.3
March	3	8%	9%	646.3	646.3
April	4	3%	4%	646.3	646.3
May	5	0%	0%	0	0
June	6	0%	3%	0	646.3
July	7	0%	0%	0	0
August	8	0%	0%	0	0
September	9	0%	3%	0	646.3
October	10	10%	14%	646.3	646.3
November	11	25%	35%	646.3	646.3
December	12	50%	75%	646.3	646.3

3.0 WRIGHT PATMAN OPERATIONS

Wright Patman Lake is owned and operated by U.S. Army Corps of Engineers (USACE). The lake storage is vertically stratified into zones for sediment storage, conservation storage, and flood storage as shown in Figure 2. The volume of water available in the conservation storage is dedicated for water supply and the volume of water in the flood storage is maintained by USACE for flood operations. The City of Texarkana is the non-Federal Sponsor for the conservation storage.

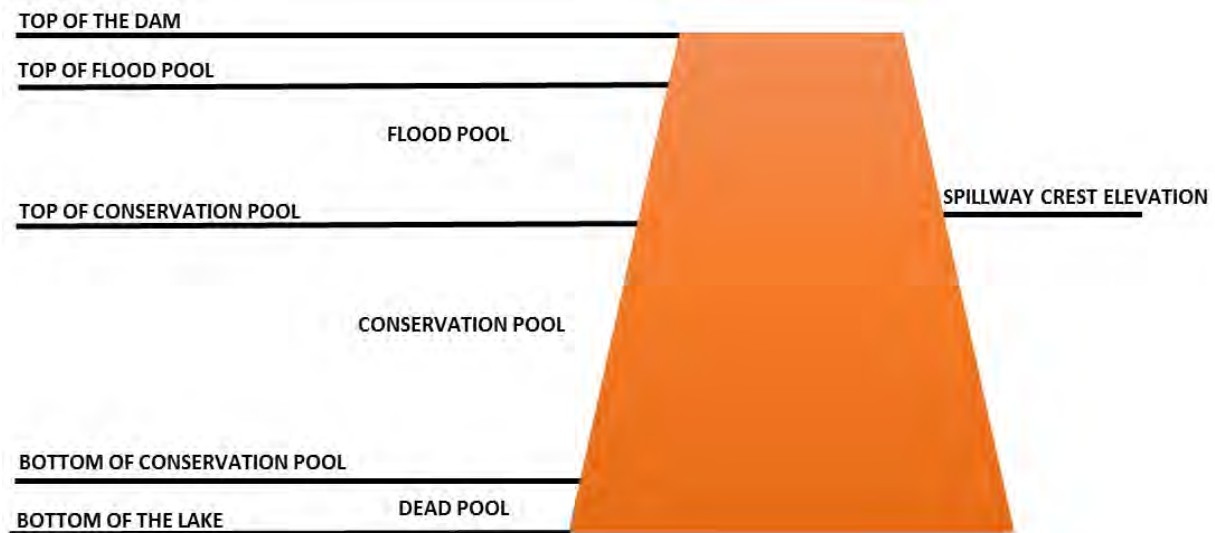


Figure 2 Illustration of a Typical Dam and Various Pools

3.1 OPERATING RULE CURVES

USACE follows a rule curve to manage the flood operations on this Lake. If the lake elevation exceeds the top of conservation pool elevation for a given month, as specified by the rule curve, USACE will release water from the outlet works until the lake is lowered to the target elevation.

The Interim rule curve governs operations until the permanent (Ultimate) contract is operationalized by USACE and the City of Texarkana. The Interim rule curve varies the top of the conservation pool between elevation 220.6 ft and 227.5 ft depending on the month. Use of the Ultimate rule curve would result in a monthly variation in the top of the conservation pool between 224.89 ft and 228.64 ft. At a future point in time, City of Texarkana and USACE may agree to change the operations from Interim to Ultimate Rule curve. Figure 3 includes an illustration of the Interim and Ultimate Rule Curves.

While TWU is operating under interim contract with USACE, IP's contract with TWU allows a maximum day diversion limit of 84 MGD and a maximum annual diversion limit of 29,400,000,000 gallons per year (80.55 MGD average day). Once Texarkana is operating under permanent or ultimate rule curve operations, IP's contract allows a maximum day diversion limit of 105.4 MGD and a maximum annual diversion limit of 36,890,000,000 gallons per year (101.07 MGD average day).

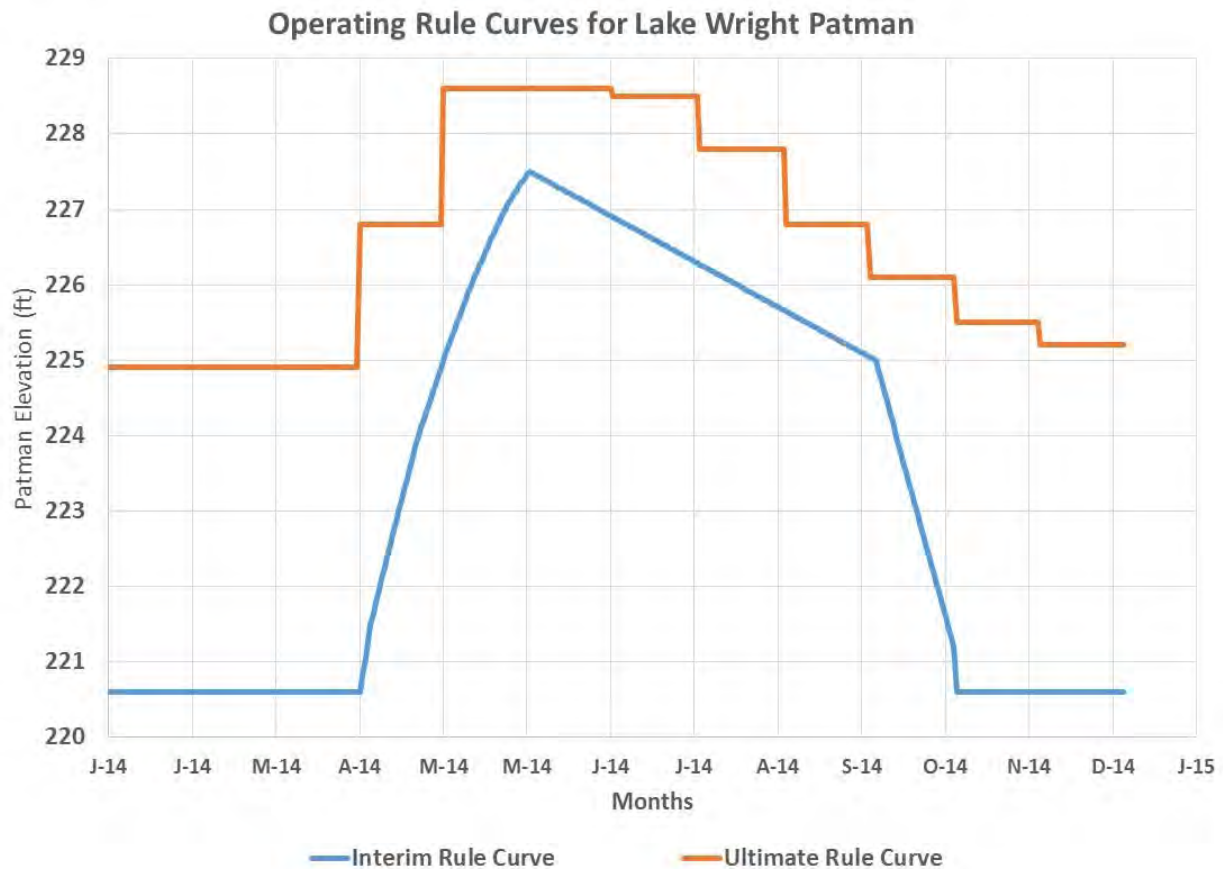


Figure 3 Interim and Ultimate Operating Rule Curves for Wright Patman Lake

3.2 REALLOCATION SCENARIOS

A reallocation of the lake would increase the amount of storage available in the conservation pool (dedicated to water supply) and thus develop additional supply that can be used to meet water needs.

While a variety of these options were analyzed as part of the Feasibility Study, three options describing a wide range of possible impacts were considered for this analysis. The three reallocation scenarios, termed as scenarios 1, 2, and 3 reflect the reallocation of the conservation pool storage to a flat elevation of 232.5 ft, 242.5 ft, and 252.5 ft respectively. Figure 4 illustrates the reallocation curves along with the interim and ultimate curves.



Figure 4 **Various Operating Rule Curves and Reallocation Scenarios for Wright Patman Lake**

4.0 MODELING APPROACH

IP's ability to release discharges from their holding pond is constrained by their permit and linked primarily to releases from Wright Patman Lake. Therefore, it was important to understand the impact of Wright Patman operations on IP's discharge process for existing rule-curve based operations. The next step was to determine the impact of Wright Patman operations on IP's discharge regime for the reallocation scenarios. A spreadsheet model was developed to represent the relationship between Wright Patman releases and allowable IP discharges.

Wright Patman releases were synthesized by the reservoir operations model developed by USACE, Fort Worth District using the Riverware software platform. Riverware has been developed by the Center for Advanced Decision Support for Water and Environmental Systems (CADSWES) at the University of Colorado, Boulder

and is the standard model for reservoir operations within the Fort Worth District. The Sulphur Basin model is based on a larger model of the Red River Basin developed by USACE to simulate flood operations. The Riverware model is a daily time-step model and it includes historical reservoir operations for a period of record of 1938-2007.

A common approach for conducting studies of this type is to use the entire hydrologic period of record data as a proxy for the full range of possible hydrologic conditions under evaluation. In this case, the daily releases from the Wright Patman Lake for the entire period of record were considered to represent all the possible hydrologic conditions (critical drought, dry, normal, and wet) impacting IP's ability to make discharges.

Effluent discharges from Outfall 1 were provided by IP for the period 2007 to 2013. Release data for the period 1938 to 2007 (to match the period of record in the Wright Patman Riverware model) were synthesized by the spreadsheet model based on operating parameters supplied by IP staff, as well as rainfall and evaporation data. Separate models were created for Wright Patman Lake operations representing the interim, ultimate, and various reallocation operational scenarios. For each of the reallocation scenarios, 80% of the additional yield available due to reallocation was assigned as a demand on the Lake. The demands used for these scenarios are shown in Figure 5 below. The remaining 20% of additional yield was assumed to be passed through the dam to meet expected environmental flow requirements.

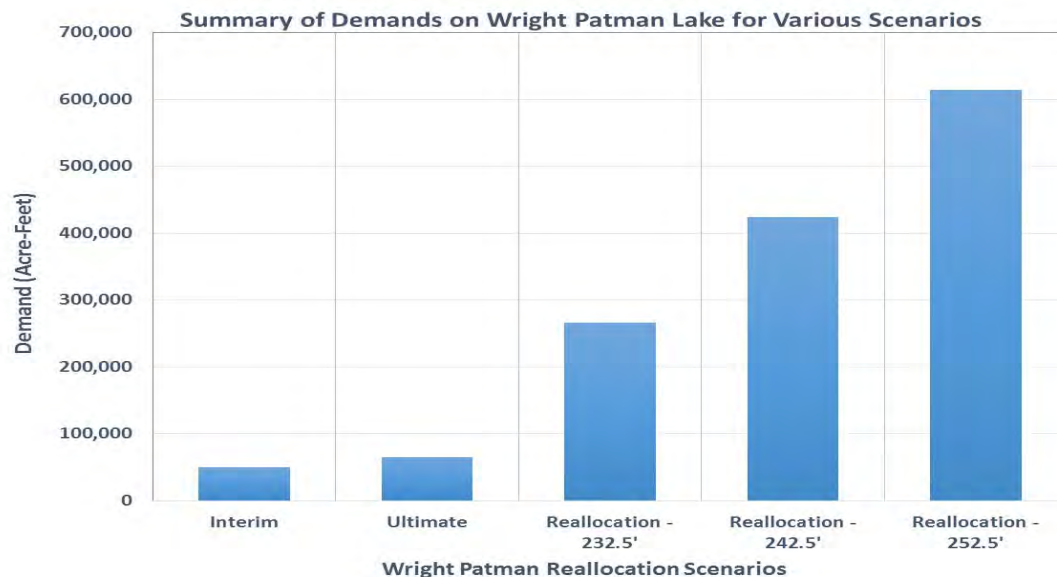


Figure 5 Summary of Demands on Wright Patman Lake for Various Operating Curve Scenarios

4.1 IMPACT ANALYSIS

The impact analysis was conducted using historical Wright Patman releases from 1938-2007 for the Interim, Ultimate, and three reallocation scenarios (232.5 ft, 242.5 ft, and 252.5 ft respectively). The analysis was based on the following assumptions:

- The operations of holding pond are based on Outfall Condition B.
- Lake Ralph Hall is considered to be in place. (Lake Ralph Hall is a proposed reservoir upstream of Wright Patman Lake that is included in the Riverware model as if it were already constructed. Preliminary analyses performed as part of this effort indicate that Lake Ralph Hall has no discernable effect on Wright Patman releases. Accordingly, the Riverware model was not modified to remove it.)
- Releases from Wright Patman Lake were limited to a maximum of 10,000 cfs per the criteria established by the Corps in the Wright Patman operating manual.
- No inflows into the Sulphur River section between the Wright Patman dam and the IP discharge location were included.

Figure 6 below includes a flow chart showing the modeling approach. The results from the Impact Analysis are discussed in Section 5.

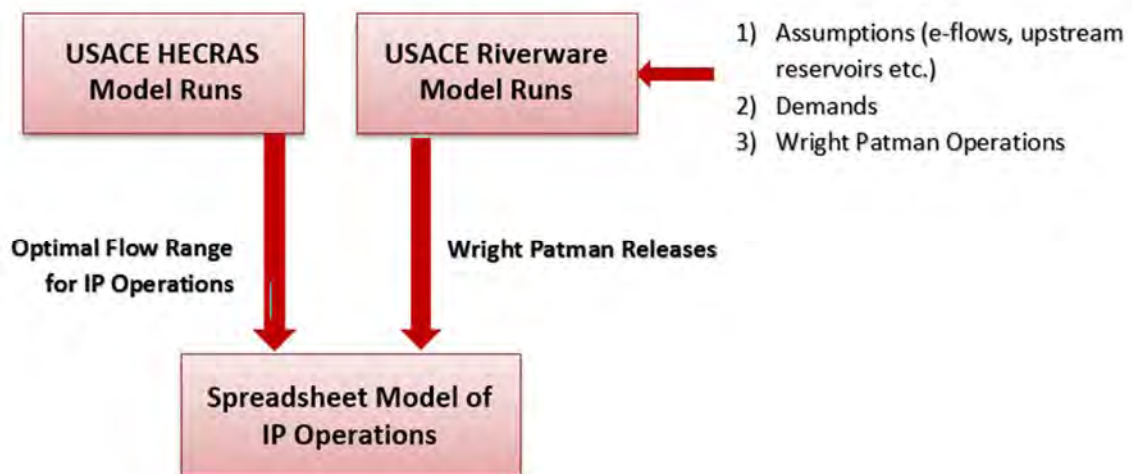


Figure 6 Flow Chart Depicting the Modeling Methodology

4.2 KEY OPERATIONAL CONCERNS

In discussions with the IP staff, following key operational concerns were identified for IP plant operations.

4.2.1 Maximize the ability to match IP discharges with Wright Patman releases

The most opportune time for IP to make the discharges, as described in the discharge permit, is during late fall and winter months. IP usually collects the discharges in the holding pond from April until August. They start making discharges in September and hope to be able to empty the holding pond by early summer. If Wright Patman releases are not favorable during the discharge season, IP cannot empty the holding pond and will have to start the next discharge cycle with leftover treated effluent from the previous discharge cycle. Any rainfall on the holding pond area adds to the pre-existing holding pond effluent volume and thus magnifies the operational issues. It was important for IP that this particular operational concern was represented in the spreadsheet model.

4.2.2 Manage IP discharges with the volume of Wright Patman releases

The discharges from IP's Outfall 001 are released into a one-mile long channel of Baker's Slough, which eventually joins the Sulphur River. When the releases from Wright Patman reach a certain volume, the Sulphur River cross-section adjacent to Baker's Slough fills up and backs into the Baker's Slough channel. During such events, IP cannot take water quality measurements, as the measuring equipment and the access points for taking measurements (as specified in the permit) are submerged by the backwater. Additionally, during backwater events, the lack of head differential between holding pond and submerged channel precludes IP from discharging flows from gravity-fed Outfall pipe. Thus high flow releases from Wright Patman pose a significant threat to IP operations and this operational concern was analyzed in this study.

4.3 BACK FLOW ANALYSIS

To quantify the extent of the back flow from the Sulphur River into Baker's Slough, a two-dimensional model was developed using USACE Hydrologic Engineering Center River Analysis System (HEC-RAS). This HEC-RAS model was developed by the Fort Worth district of USACE. The HEC-RAS model covers the entire Sulphur River Basin and includes a two-dimensional representation of Sulphur River cross-sections at regular intervals. This model was used to determine the extent of the flow dispersion and corresponding flow elevation in the river cross section near the Baker's Slough junction for flows ranging from 10 cfs to 50,000 cfs.

Figure 7 shows the Sulphur River cross-section and elevation (stage) for various releases from Wright Patman. The invert elevation for the discharge pipe in Outfall 001 is 202 feet and the outfall is approximately 20 feet high.

Based on the back flow analysis, it was determined that the optimal range of Wright Patman releases that results in a favorable discharge from IP's holding pond is 1000 – 8000 cfs. Any less than 1,000 cfs limits IP's ability to precisely calibrate their release volume to the specified percentage of Wright Patman releases. Any higher than 8,000 cfs limits IP's ability to release the discharges due to back water issues in the discharge channel. The relationship between Wright Patman releases and the elevation of the Sulphur River at the Bakers Slough cross section is displayed by the rating curve shown in Figure 8.

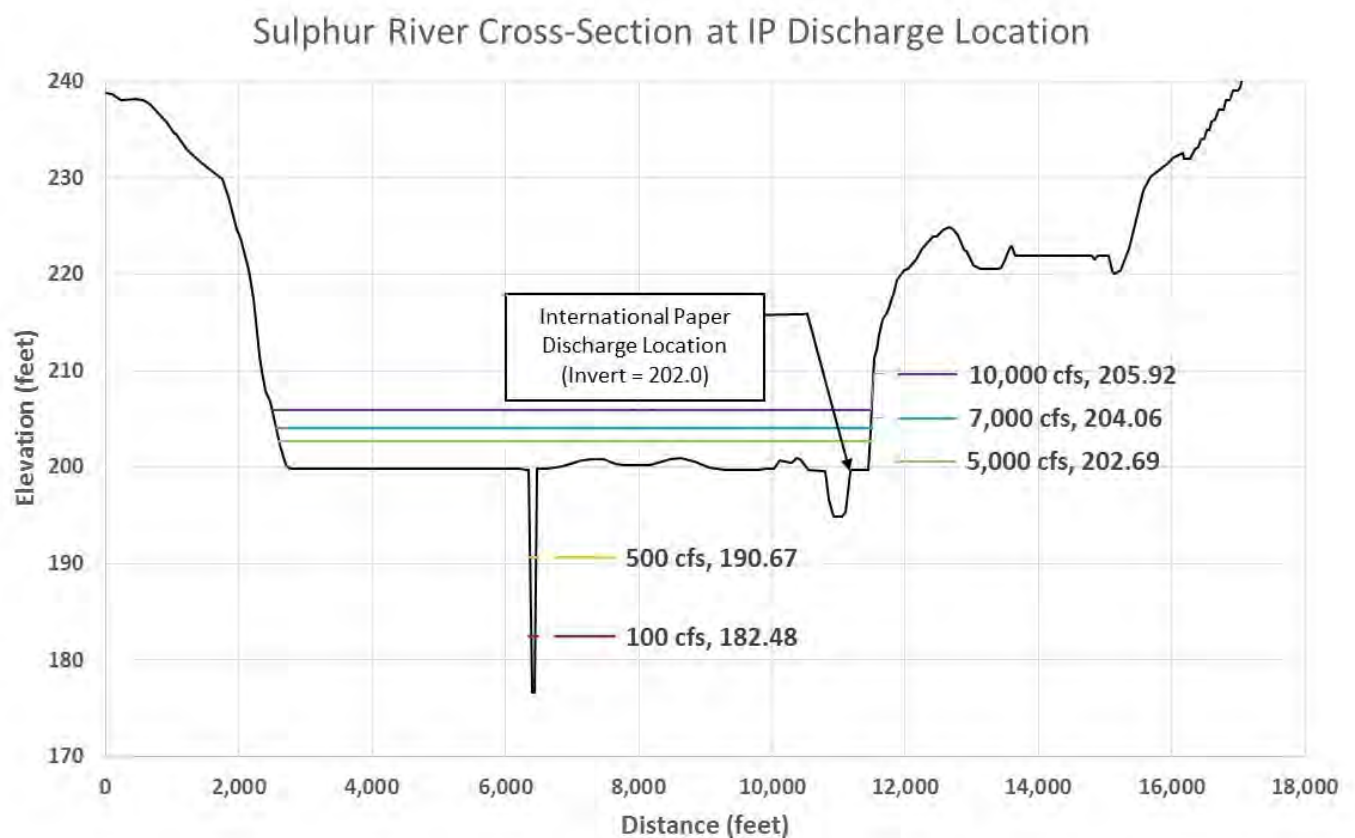


Figure 7 Sulphur River Elevations at IP Discharge Location for Various Wright Patman Releases

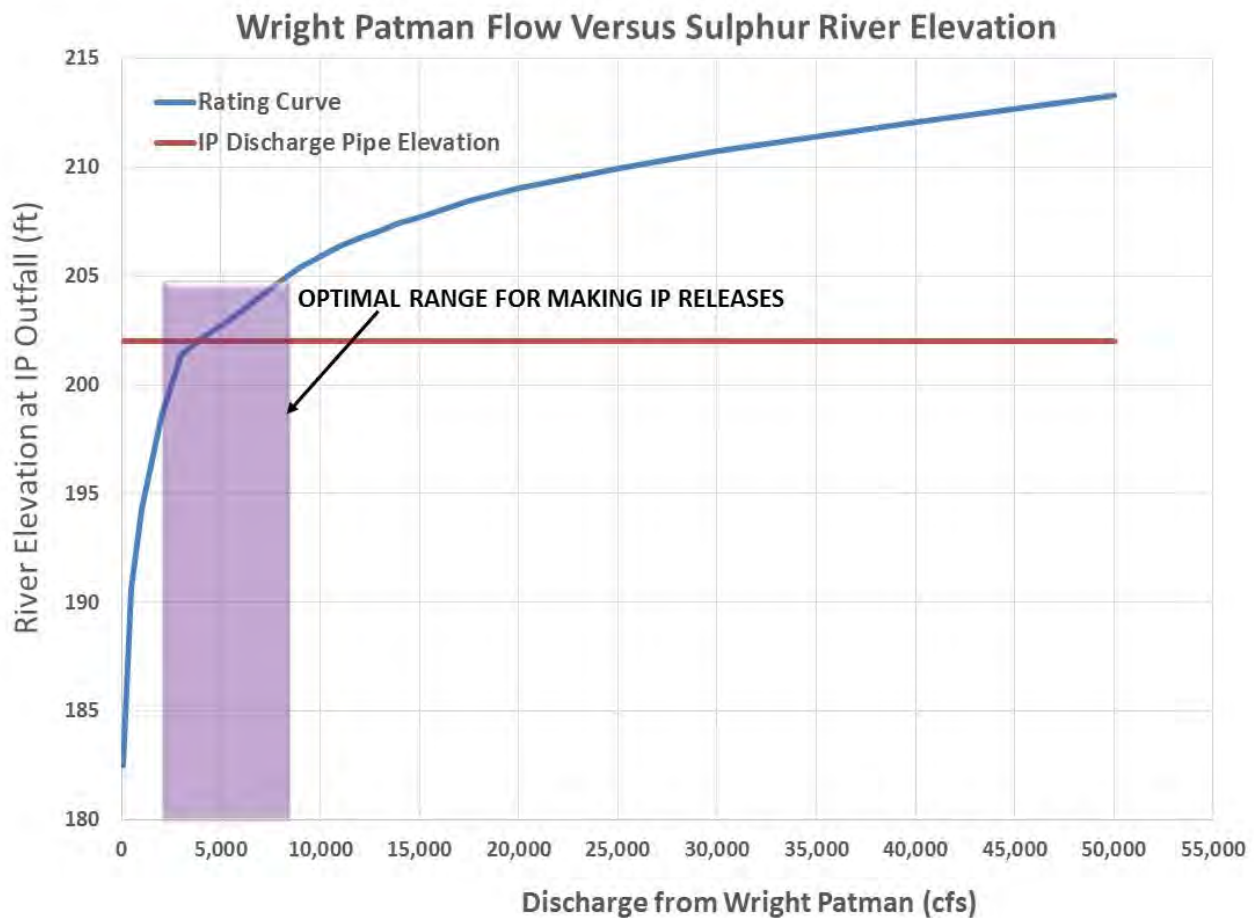


Figure 8 Plot showing Sulphur River Elevation for Various Wright Patman Releases

5.0 RESULTS AND CONCLUSIONS

Trends in Wright Patman releases for various operations are discussed below. A change in the operation scenario will result in a change in the frequency and magnitude of the flow releases. The Riverware model was run to compile the timeseries of Wright Patman releases for various operational scenarios. Each plot represents the percentage of time during the period of record (1938-2007) that releases *would have been equal to or exceed* the amount of flow shown on the vertical axis.

5.1 AVERAGE CONDITIONS

5.1.1 Interim Curve Operations

The frequency and magnitude of Wright Patman outflows for interim curve operations are shown below in Figure 9. The chart shows the frequency of the occurrence or exceedance of flows of a certain magnitude for

an entire period of record. For example, Wright Patman releases in the range of 8,000 cfs occurred about 15% of the time in daily output from 1938-2007. Similarly, it can be noted that Wright Patman releases in the range of 1,000 cfs occurred 55% of the time in the daily output from 1938-2007. It can be concluded that the favorable Wright Patman releases (1,000 – 8,000 cfs) for releasing IP discharges occurred at a frequency of 40% (Difference of 15% and 55% frequencies).

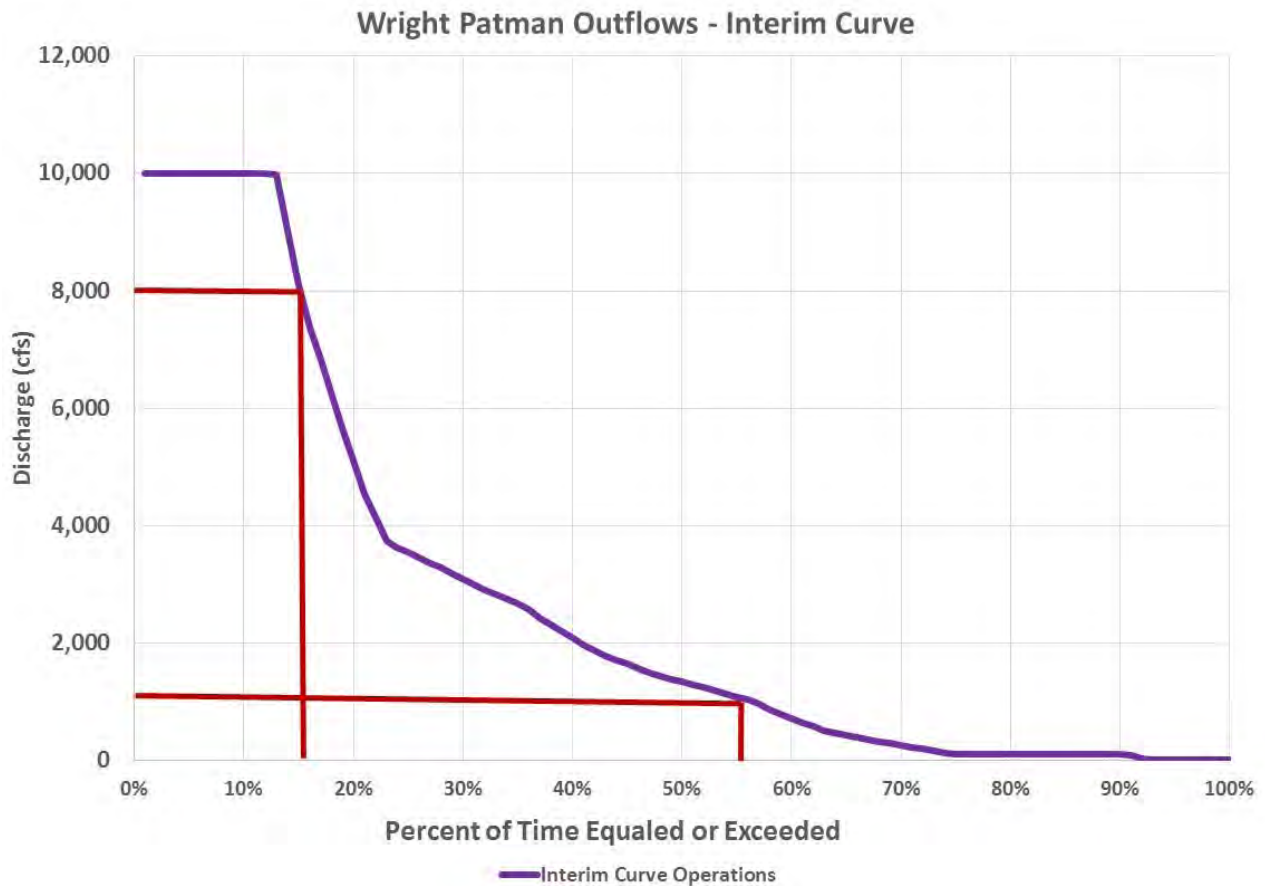


Figure 9 Flow Frequency Chart of Wright Patman Releases for Interim Curve Operations

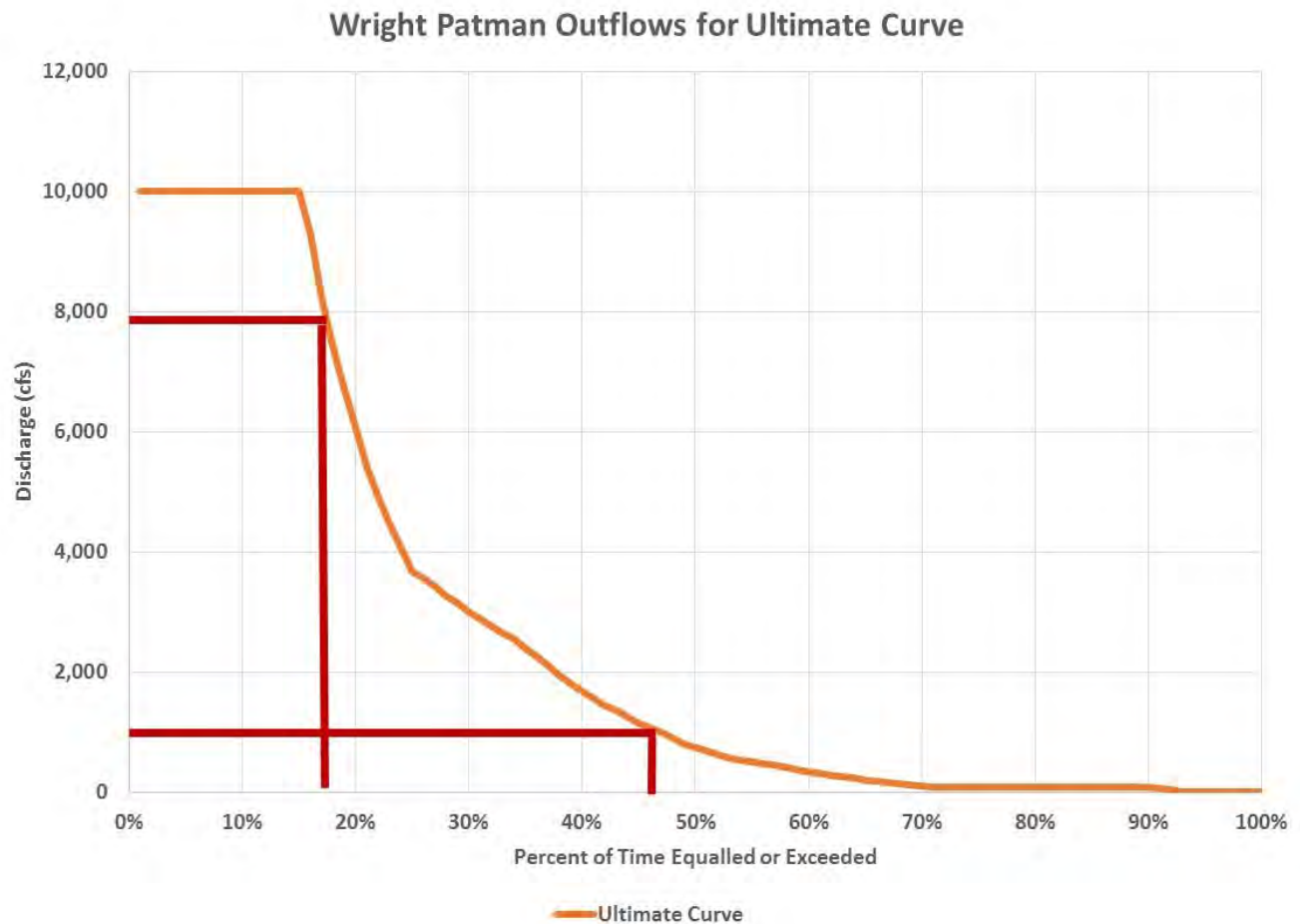


Figure 10 Flow Frequency Chart of Wright Patman Releases for Ultimate Rule Curve Operations

5.1.2 Ultimate Curve Operations

Figure 10 illustrates the flow frequency for Wright Patman Lake for Ultimate Rule Curve operations. Using the same approach described in the previous paragraph, it can be noted that flows with magnitude of 8,000 cfs occurred at a frequency of 18% and flows with magnitude of 1,000 cfs occurred at a frequency of 45%. For ultimate curve scenario, the favorable flows for making IP discharges (1,000 – 8,000 cfs) occurred at a frequency of approximately 27% (difference of 45% and 18%).

5.1.3 Reallocation Curve Operations

Figure 11 shows the flow frequency for Wright Patman Lake for various reallocation scenarios. Releases for three reallocation scenarios, 232.5 ft, 242.5 ft, and 252.5 ft and existing conditions are included in the Figure. The optimal flow range for IP discharges is highlighted on the Figure. It can be noted that the reallocation scenarios generally reduce the frequency of the favorable flows. The average flow frequency for the largest

reallocation scenarios (252.5 feet) is about 30% (difference of 10% and 40%). That is a 10% reduction from the average flow frequency for the Interim Rule Curve operations (40%).

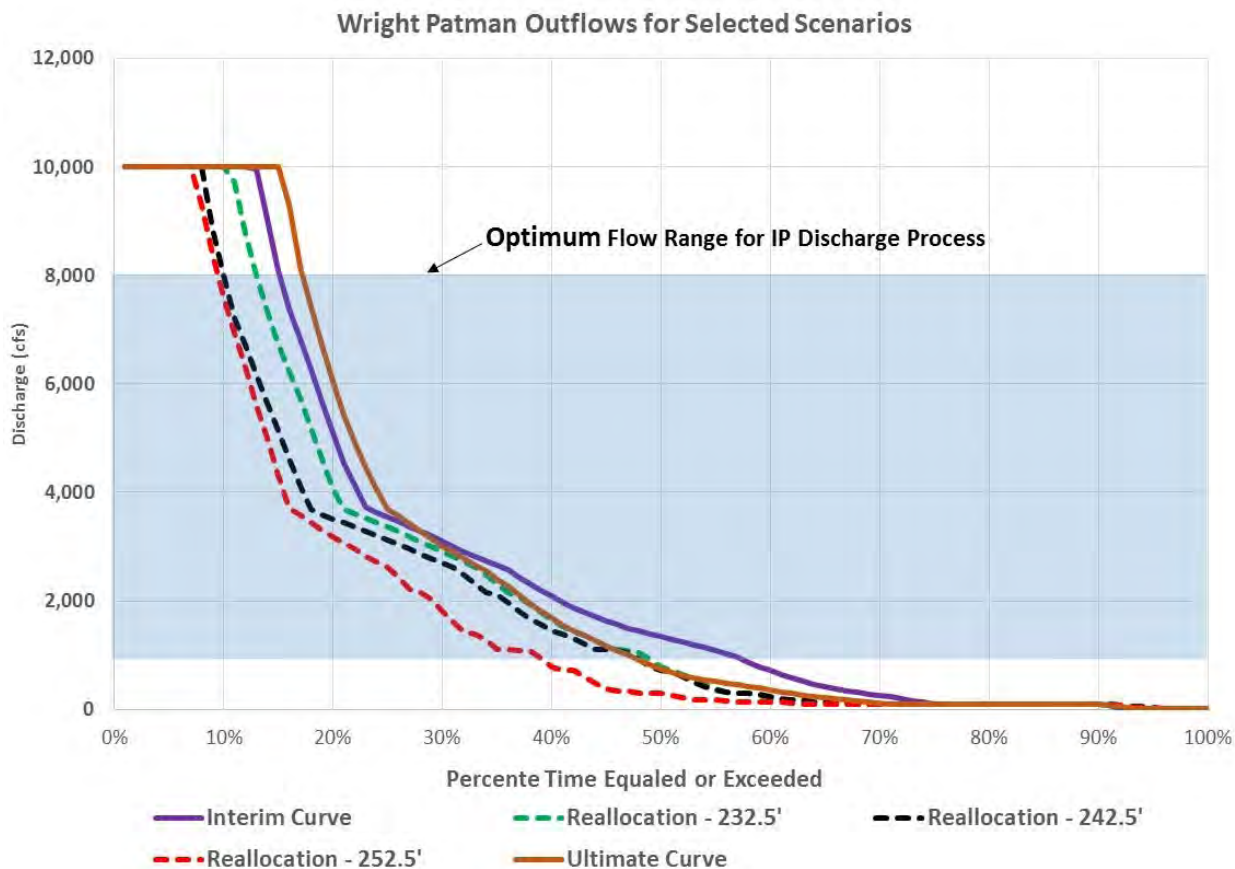


Figure 11 Flow Frequency Chart of Wright Patman Releases for Various Reallocation Scenarios

Based on the results for the comparison of average flow frequencies of various operational scenarios, it can be concluded that the reallocation scenarios render the average frequency of optimal flow range less favorable compared to the Interim rule curve scenario.

While this analysis provides a significant insight into the impact of reallocation on IP's ability to release discharges, it should also be noted that the flow frequency described in this set of results is representative of average conditions: average over all hydrologic conditions.

5.2 SEASONALITY

Another approach for summarizing the impact of Wright Patman releases on IP discharges is to focus on the seasonality. Because of the seasonal nature of the TCEQ discharge permit, it is highly relevant to quantify

the seasonal nature of the impact of Wright Patman operations on IP discharges. When revising the Wright Patman operations from Interim to one of the reallocation scenarios, the seasonal pattern of the operational curve in Interim scenario will be replaced by a flat curve in the reallocation scenarios. While the flattening of the curve is beneficial in certain months, it can be disadvantageous in other months. Special attention should be paid to the active discharge season in IP operations (Late Fall through Early Spring).

To analyze and summarize the seasonal nature of the impacts, two different sets of results were prepared. The two sets of the results are described below.

5.2.1 Seasonal Flow Frequencies

Wright Patman releases were sorted by season to identify a seasonal pattern associated with the optimal range of flows released for various Wright Patman operations. Flows were sorted by four seasons: fall (September – November), winter (December – February), spring (March – May), and summer (June – August). Plots for each one of the seasons for the period of record are included below along with the discussion of the results. Plots include a comparison of Interim Rule Curve (baseline operations) with the reallocation scenarios (proposed operations).

A. Fall (September – November)

Referring to the percentage match allowed by permit in Figure 1, it can be noted that IP's ability to release discharges starts ramping up in Fall, with the percentage match increasing from 3% in September to 35% in November. It can be noted from Figure 12 that the average frequency of Wright Patman releases in optimal range (for making IP discharges) using Interim rule curve is about 27%. The frequency of favorable releases reduces significantly when the operations on Wright Patman are changed to the reallocation scenarios. The average frequency of flows drops to 5% for the largest reallocation scenarios (252.5'), 8% for reallocation to 242.5 ft, and 9% for reallocation to 232.5 ft.

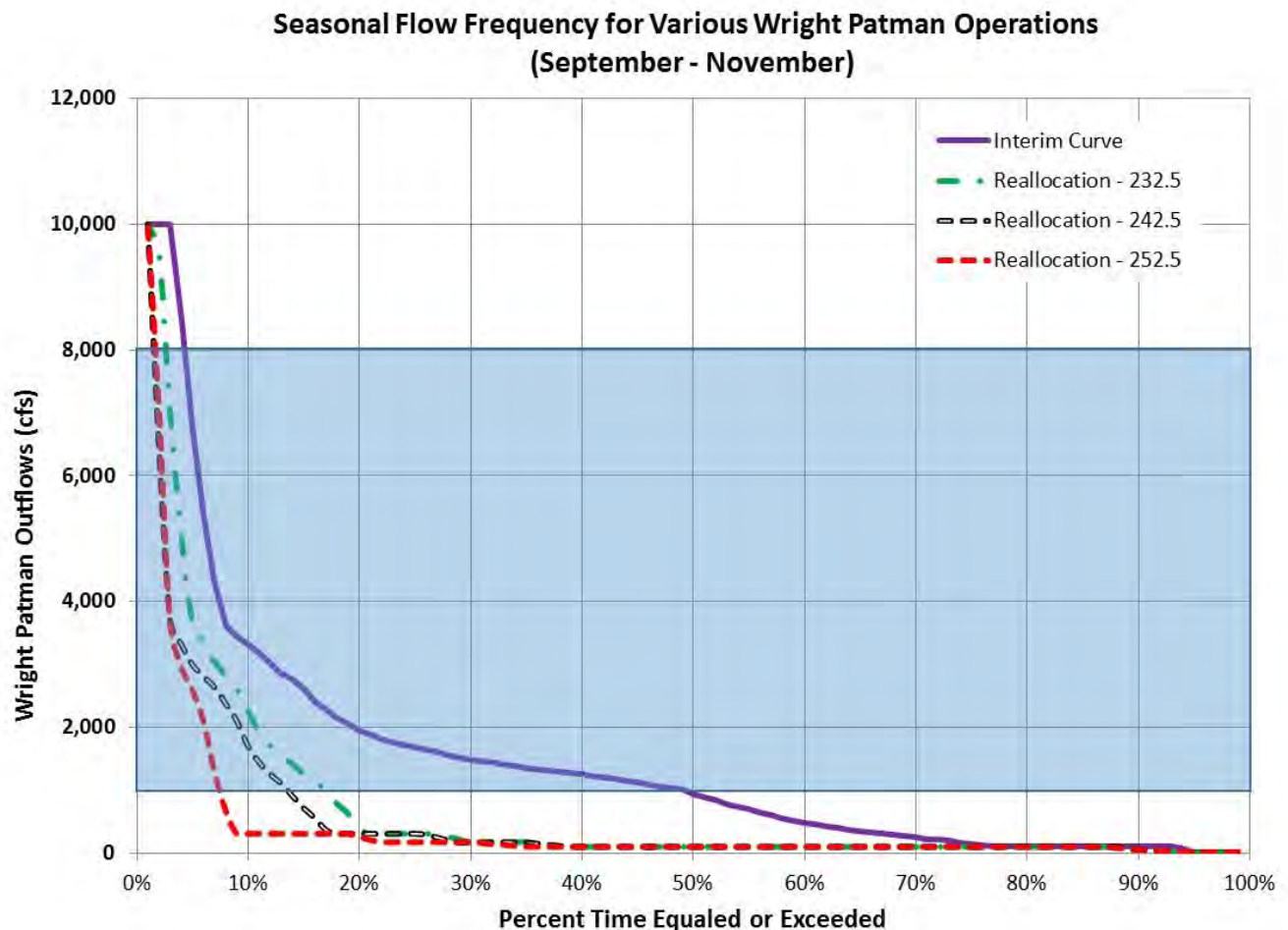


Figure 12 Frequency of Period of Record Wright Patman Outflows in Fall Season

B. Winter (December – February)

IP's discharge permits allows for maximum percentage match of IP discharges with the Sulphur River flows in the winter season. The percentage match varies from 75% to 100% from the start to the end of winter. Figure 13 includes a summary of the flow frequencies for winter season. For the period of record data, it was observed that the average flow frequency was approximately 42% for Interim rule curve operations. The frequency of optimal Wright Patman releases drops to 30% for the largest reallocation scenario (252.5') while the frequency for the other two reallocation scenarios is between 42% and 30%.

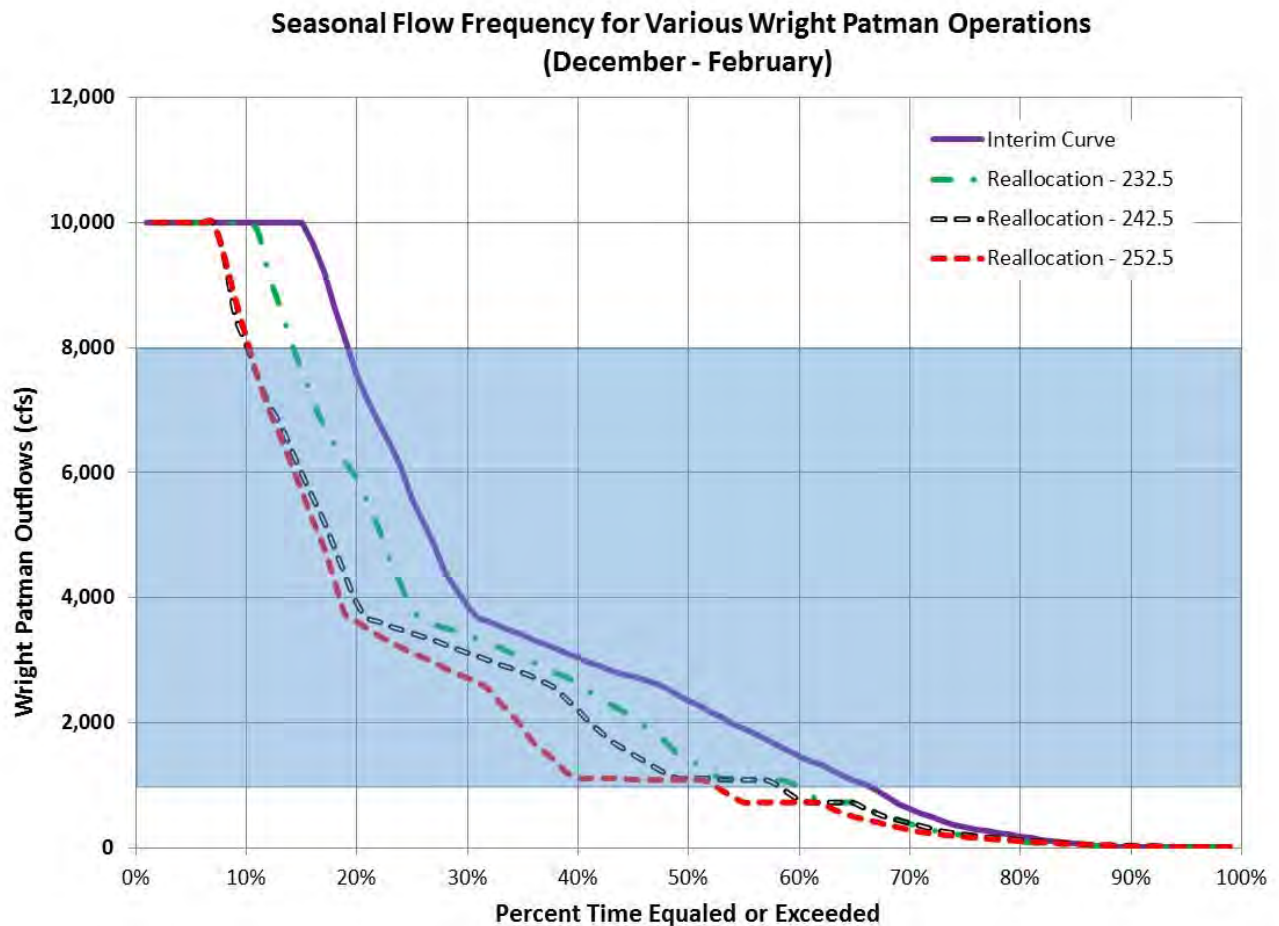


Figure 13 Frequency of Period of Record Wright Patman Outflows in Winter Season

C. Spring (March – May)

Frequencies for the spring season are summarized in Figure 14. The average frequency of Wright Patman releases in the spring season is about the same for all the operational scenarios considered for Wright Patman. The frequency (with a few percent points difference) for all scenarios is about 45%. It should be noted that the releases from Wright Patman are fairly significant in the spring season and they are also not significantly impacted by the change in the lake operations. However, IP's discharge permit does not allow them to take advantage of this favorable season as the discharge permit only allows up to 3% match in the spring season.

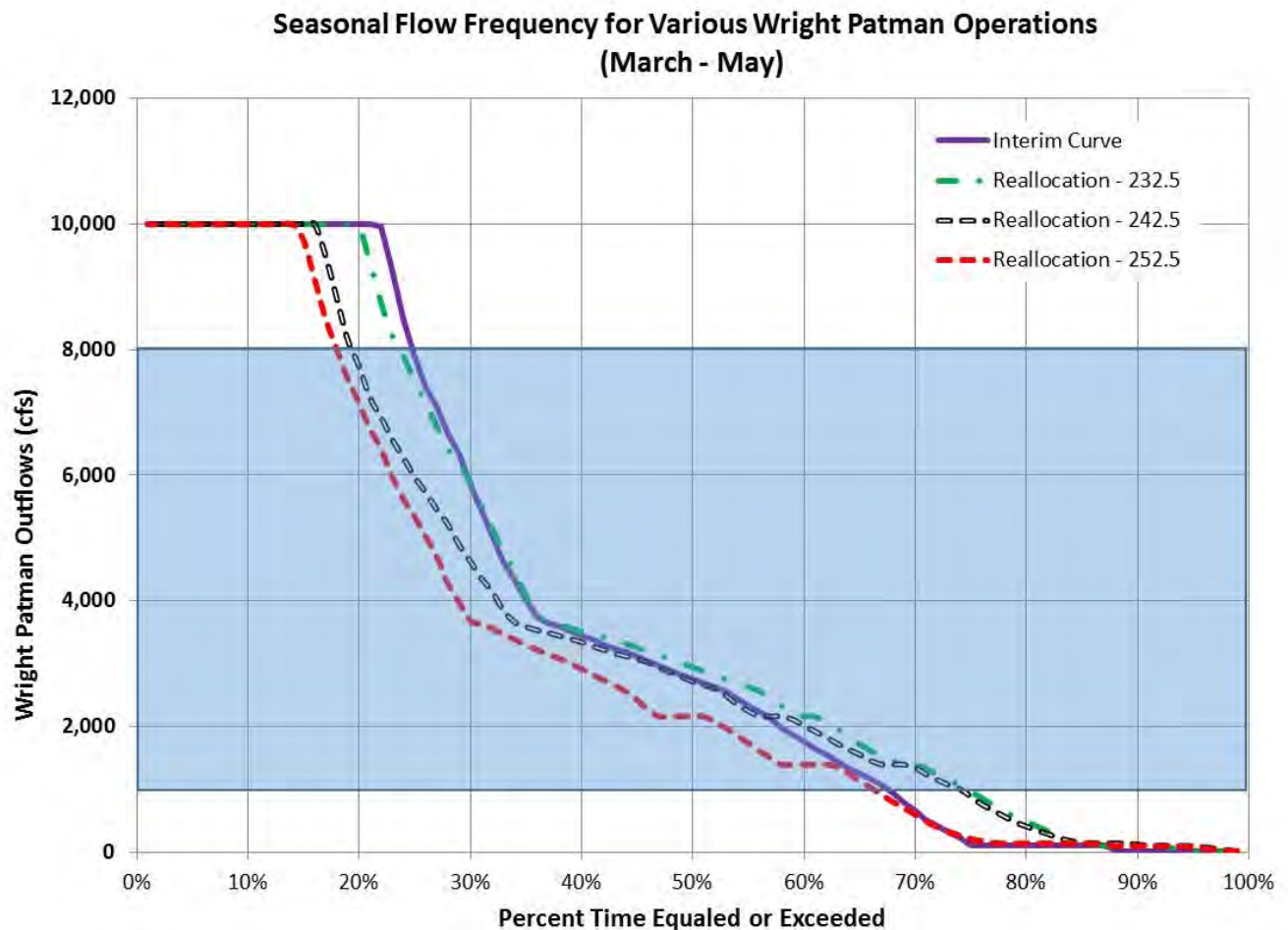


Figure 14 Frequency of Period of Record Wright Patman Outflows in Spring Season

D. Summer (June – August)

The average frequency of favorable Wright Patman releases is presented in Figure 15. It should be noted that the average frequency is approximately 27% for interim rule curve and the two smaller reallocation scenarios. The average frequency drops down for the largest reallocation scenario to approximately 20%. However, IP cannot make any discharges in the summer season because their discharge permit does not allow for any percentage match with the Sulphur river flows, so the change in the frequency of favorable flows is relatively meaningless.

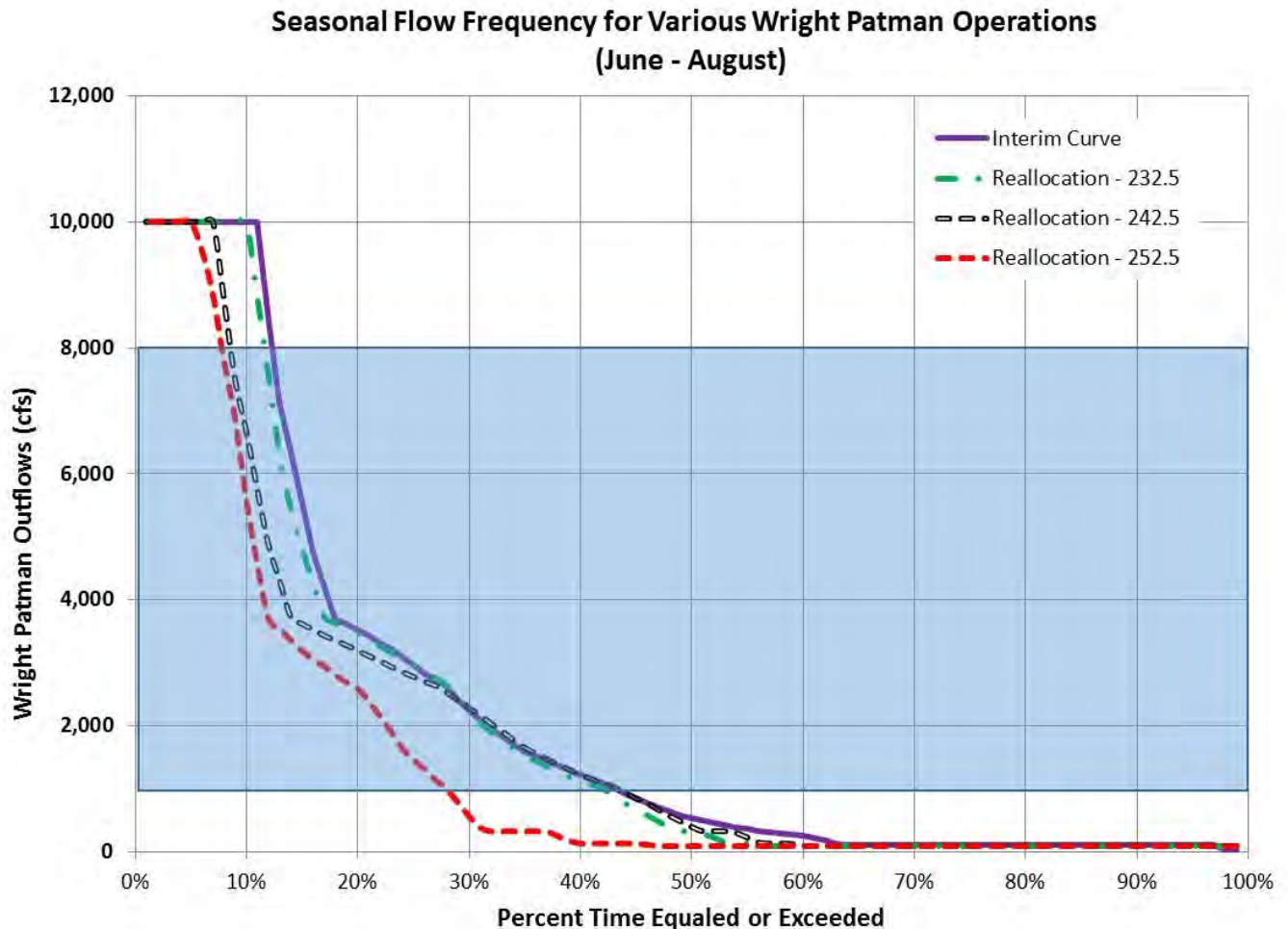


Figure 15 Frequency of Period of Record Wright Patman Outflows in Summer Season

5.2.2 Count Analysis

One of the metrics that was used to summarize the Wright Patman releases in this analysis was the “Count” of days when the releases were within the optimal range (1,000 cfs – 8,000 cfs) for IP discharges. The count of favorable days for each month of each year in the period of record were computed and tabulated. This tabulation was developed for all Wright Patman operational scenarios (interim, ultimate, and three reallocations). Table 2 shown below is an example of the “Count” summaries for the various months and years for Interim Curve operations. Count summaries for the remaining operational scenarios are included in Appendix A. The purpose of the Count metric was to better grasp the seasonal nature of the impact of changes to Wright Patman operations on IP discharges. The best way to interpret the information in Table 2 is to focus on one column at a time and determine the number of times favorable flows occurred in that given month. The greater the number for a given month, the more favorable that month is for releasing IP discharges. A

month with greater than 50% days with favorable flows was highlighted in green and those with less than 50% days having favorable flows were highlighted in red. For example, in the table below October is a favorable month for releasing IP discharges in all years while September is the least favorable.

Table 2 Table showing the Number of Times Favorable Flows had occurred in a given month (Count)

	Count											
	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec
1938	1	0	0	0	0	0	1	25	0	23	5	0
1939	0	15	20	25	15	0	0	0	0	15	5	0
1940	0	0	0	21	31	30	26	18	0	23	22	13
1941	18	28	19	21	0	0	21	30	0	25	23	29
1942	17	8	29	3	0	0	26	0	0	24	6	4
1943	29	0	18	26	0	20	18	0	0	23	8	0
1944	22	21	13	22	3	11	15	0	0	23	15	31
1945	21	22	0	0	0	0	0	0	26	15	29	0
1946	9	6	6	30	18	0	16	11	0	24	7	0
1947	31	13	19	30	25	29	0	0	0	24	18	18
1948	18	22	15	15	2	22	5	0	0	22	6	0
1949	3	0	10	27	31	16	7	0	0	20	15	17
1950	14	0	0	17	3	26	14	23	4	21	12	0
1951	11	13	23	0	0	13	31	1	0	27	13	13
1952	28	23	31	15	11	30	3	0	0	20	12	26
1953	31	28	29	21	0	19	17	1	0	23	6	20
1954	22	28	15	0	4	27	0	0	0	19	30	0
1955	0	22	11	30	8	0	0	0	1	31	8	0
1956	0	26	21	0	0	0	0	0	0	6	11	0
1957	1	28	18	4	0	0	0	3	30	31	4	6
1958	20	23	31	26	0	0	5	31	9	31	20	16
1959	0	15	31	18	5	3	31	24	0	27	24	6
1960	10	29	31	6	0	0	18	5	4	31	20	3
1961	9	28	29	13	4	5	31	8	0	26	14	29
1962	31	21	24	20	24	3	19	0	24	31	30	31
1963	31	2	25	2	0	0	0	0	0	20	5	0
1964	0	0	16	4	24	0	0	0	13	31	17	19
1965	22	11	23	1	15	30	5	0	0	23	5	0
1966	0	18	5	1	0	0	23	4	0	27	8	4
1967	17	3	0	13	15	15	28	0	0	24	30	17
1968	31	29	13	18	15	25	31	16	14	31	13	31
1969	31	0	0	20	7	21	5	0	0	19	9	2
1970	22	26	5	24	16	0	0	0	0	27	27	0
1971	0	10	11	0	0	0	0	0	0	7	26	8
1972	0	23	0	0	0	0	0	0	0	0	29	31
1973	31	25	8	6	8	20	18	0	23	30	0	0
1974	10	23	9	0	17	5	24	0	23	31	1	0
1975	26	1	6	30	29	30	21	0	0	23	5	0
1976	0	0	22	7	31	29	23	18	0	26	11	23
1977	20	19	17	4	18	0	0	0	0	18	20	0
1978	7	22	31	11	0	0	0	0	0	0	0	0
1979	30	28	21	15	18	18	25	22	10	31	10	9
1980	24	22	23	14	19	22	0	0	0	28	8	16
1981	0	0	13	0	11	4	28	5	0	14	10	12
1982	0	27	27	0	3	0	22	15	0	24	13	1
1983	18	27	12	16	0	0	18	0	0	22	6	0
1984	0	16	28	20	9	0	0	0	0	20	17	22
1985	27	26	14	21	31	30	5	0	0	23	23	18
1986	19	16	26	22	31	30	31	1	0	25	30	31
1987	31	28	9	14	0	0	0	0	0	14	20	10
1988	0	20	31	18	0	0	0	0	0	10	25	19
1989	31	16	3	18	11	0	1	31	2	23	5	0
1990	12	16	7	0	0	0	13	17	0	26	30	31
1991	13	26	22	10	13	30	4	0	0	25	22	1
1992	0	23	0	15	10	30	19	12	30	31	18	16
1993	2	26	0	26	30	0	0	0	0	17	21	4
1994	30	27	9	11	20	30	22	24	0	25	16	15
1995	12	19	31	26	6	28	11	0	0	24	6	0
1996	0	0	0	0	0	0	0	31	20	31	24	0
1997	27	15	0	0	2	30	21	0	0	24	11	31
1998	0	0	13	15	0	0	0	0	0	27	30	10
1999	24	28	25	26	0	10	0	0	0	25	7	0
2000	0	2	31	22	26	19	19	7	0	23	15	13
2001	0	0	0	0	0	18	20	0	27	31	21	15
2002	0	9	20	0	29	5	0	0	0	24	27	18
2003	31	17	31	6	0	0	0	0	0	12	5	0
2004	0	25	26	0	0	13	18	0	0	24	15	24
2005	28	28	16	3	0	0	0	0	0	0	0	0
2006	0	0	9	16	0	0	0	0	0	1	0	0
2007	17	28	2	3	0	14	5	30	6	24	7	3

Comparison of the monthly Count for various operational scenarios is presented in Figure 16. The purpose of this illustration was to determine how the reallocations scenarios were performing versus the Interim Rule Curve operations. Figures 16, 17 and 18 show the comparison of the January Count for the Interim, Ultimate, and three reallocation scenarios for years 1938 - 2007.

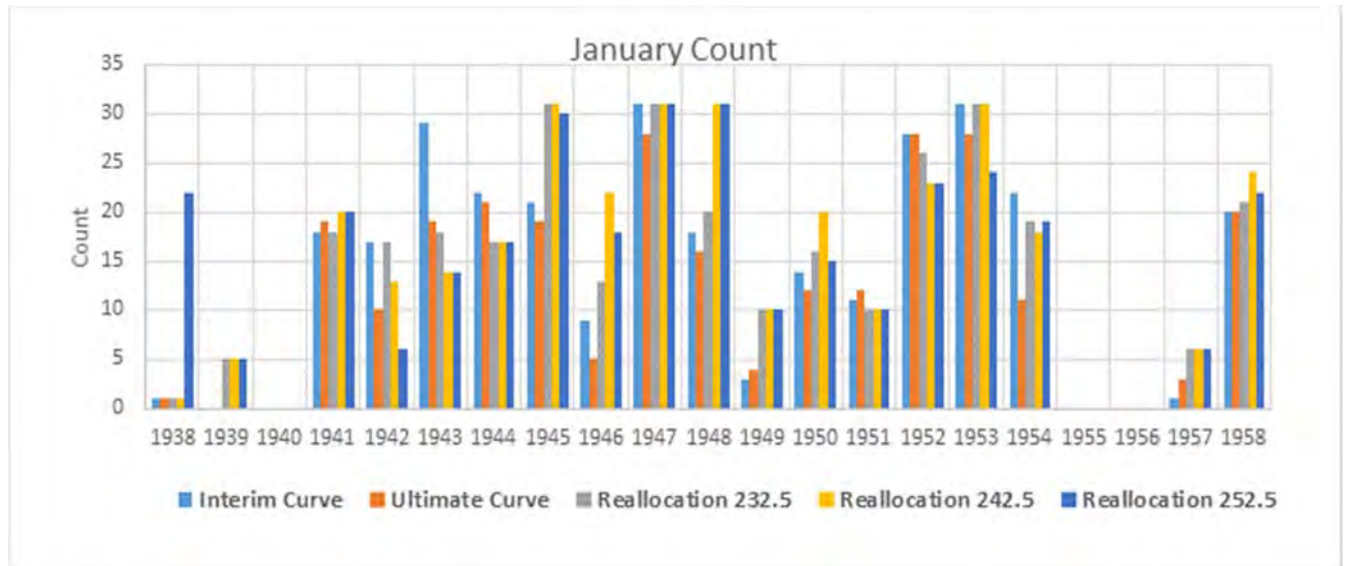


Figure 16 Comparison of January Count for Various Operational Scenarios (1938-1958)

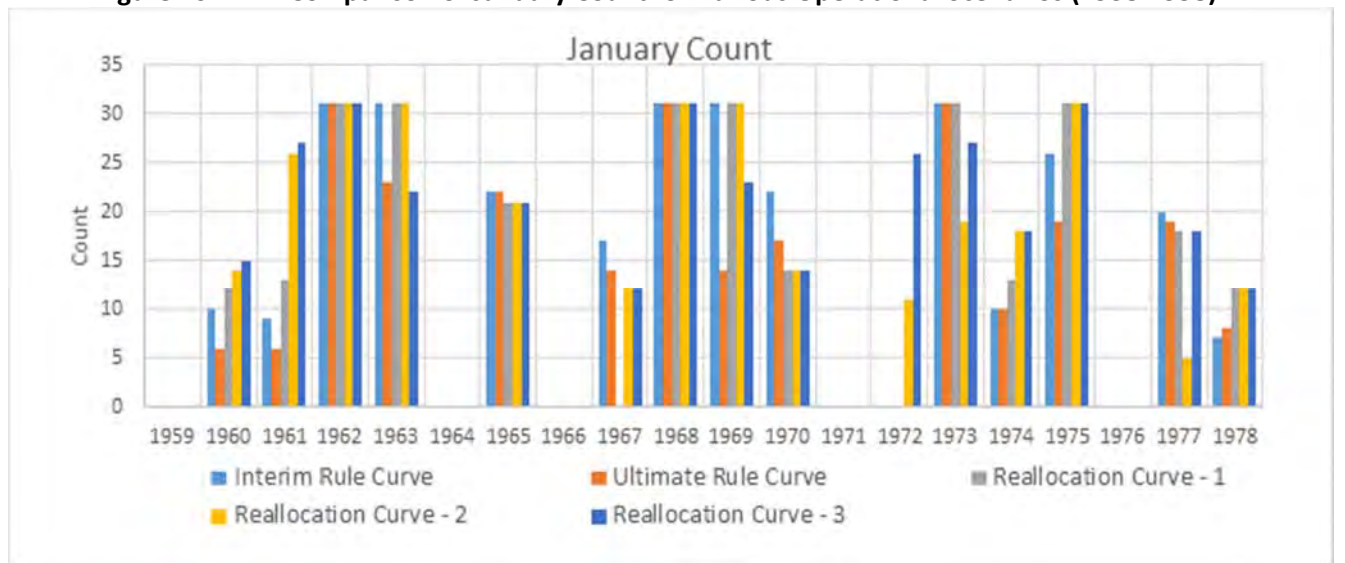


Figure 17 Comparison of January Count for Various Operational Scenarios (1959-1978)

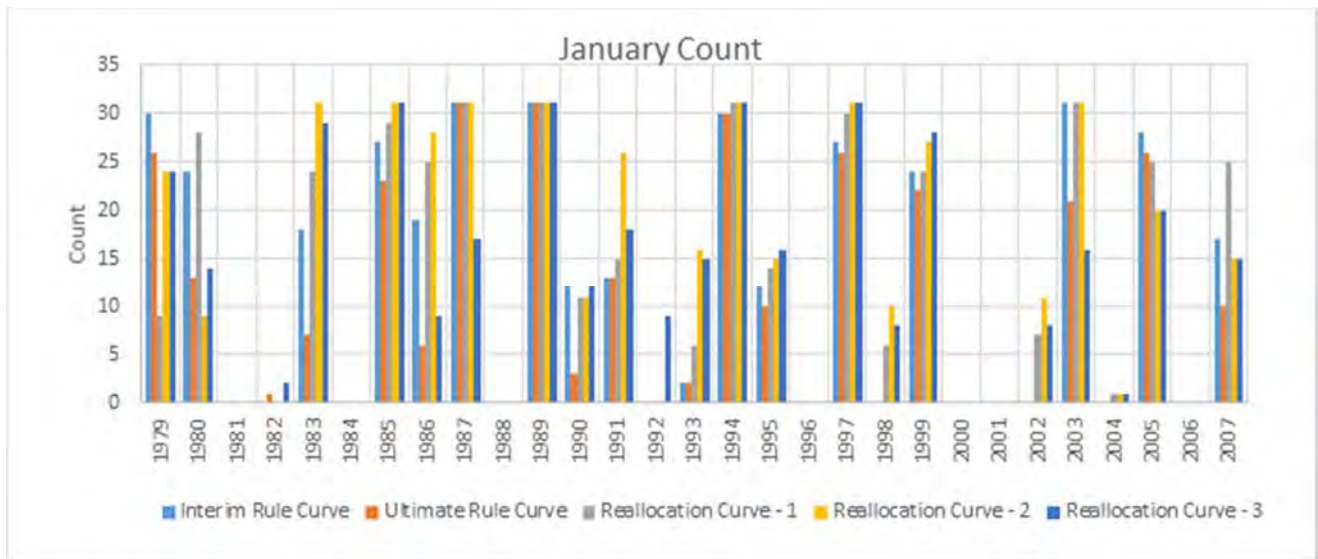


Figure 18 Comparison of January Count for Various Operational Scenarios (1979-2007)

It is difficult to identify a pattern of impact of Wright Patman operations on the monthly Count. A detailed review indicated that this is most likely because overall weather patterns for that month and year were obscuring the effect of reservoir operations. Figure 19 below, indicates the comparison of Count among the various scenarios for six years from the period of record generally considered to be "wet" months.

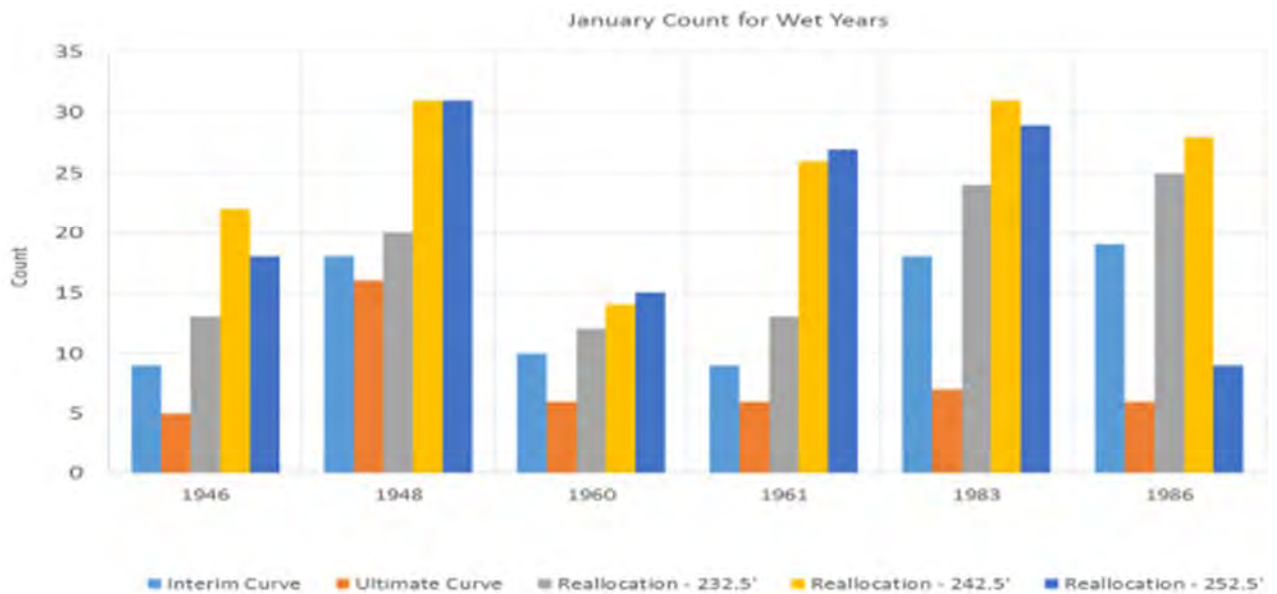


Figure 19 Comparison of January Count for Various Operational Scenarios in Wet Hydrologic Years

Figure 19 shows that there is indeed a reasonable pattern to the impact of Wright Patman operations on the monthly Count. Count is higher for the reallocation scenarios when compared to the interim curve operations indicating that in wet Januaries, IP's ability to make discharges is enhanced by the reallocation scenarios as compared to the baseline conditions.

Wright Patman releases are closely related to the weather conditions because in wet years, reallocation scenarios allow for greater volumes of water to be held in the Lake (because of the increase in conservation storage), thus releasing less flows downstream of the Sulphur River towards IP's discharge location. This reduction of frequency of high flow releases in turn results in an increase in the number of days Wright Patman releases are in the optimal range for IP discharges.

A review of the seasonal analyses demonstrates that seasonality in flow availability is a critical concept for IP operations. It is critical that optimal range of Wright Patman releases occur in the appropriate season so that IP can take maximum advantage of the discharge permit to make discharges. In that sense, the impact of Wright Patman operations on the Count metric for months between October – March (active months with significant match with Wright Patman releases) is much more significant than the impact in other months where the discharge permit does not allow significant match.

5.3 SIMULATED HOLDING POND OPERATIONS

An alternative way of examining the impact to IP discharges of changes to Wright Patman releases is to track the holding pond operations for the period of record. IP's holding pond was simulated in the spreadsheet model as if it was operational for the entire period of record, based on the information provided by the IP staff. The holding pond has a capacity of 26,300 ac-ft, a surface area of 1,315 acres and depth of 20 feet. Inflows into the holding pond from the IP plant are based on the average of 2007-2014 historical inflows provided by IP staff. Rainfall and evaporation at the Wright Patman gage were used as a proxy for the rainfall and evaporation over the holding pond. The holding pond was emptied by means of the guidelines provided in the discharge permit. The daily volumes in the holding pond volume for the entire period of record, as driven by various Wright Patman operational scenarios are discussed in this section.

5.3.1 Interim Curve Operations

Figure 20 is a summary of the historical trend in the Holding Pond volume for Interim Curve operations at Wright Patman Lake. The blue line tracks the daily volume of the holding pond for the period of record (1938-

2007) of the analysis. The figure also includes an orange line representing the maximum holding pond volume. Times when the holding pond volume extends above the orange line represent occasions when the volume of effluent produced by the plant would have exceeded the available storage, necessitating either an emergency discharge or a permit violation. As indicated in Figure 20 there would have been four occurrences of this nature during the period of record in the operational model. Two of the occurrences are strictly hypothetical, as the IP plant was not operating during the critical drought of the 1950's. However, the other two occurrences synthesized by the model for 2006 and 2007 actually occurred. Because of the lack of sufficient inflows during those years, IP was not able to match substantial flows and had to make a special request to TCEQ for a permit variance in order to make an emergency discharge and avoid plant closure.

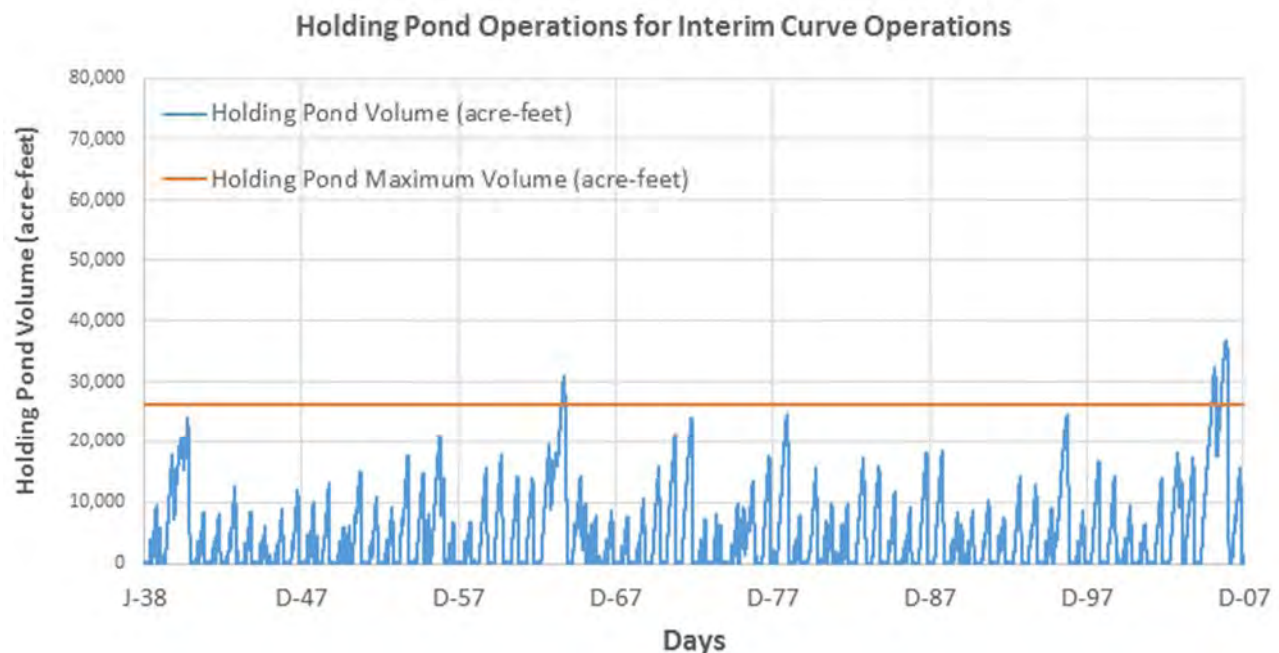


Figure 20 Holding Pond Simulations for Interim Curve Operations

5.3.2 Ultimate Curve Operations

Figure 21 is a summary of the holding pond volume for the period of record of the analysis using Ultimate Rule curve operations at Wright Patman. It can be noted that the number of instances in which the holding pond volume exceeded the maximum volume is greater for this scenario compared to the Interim curve scenario. Increasing the conservation pool elevation results in more flows being held in the Lake compared to the Interim Curve. As a result of this, less releases are observed in the ultimate rule curve scenario compared to the interim rule curve. That in turn increases the number of times holding pond volumes exceed available storage.

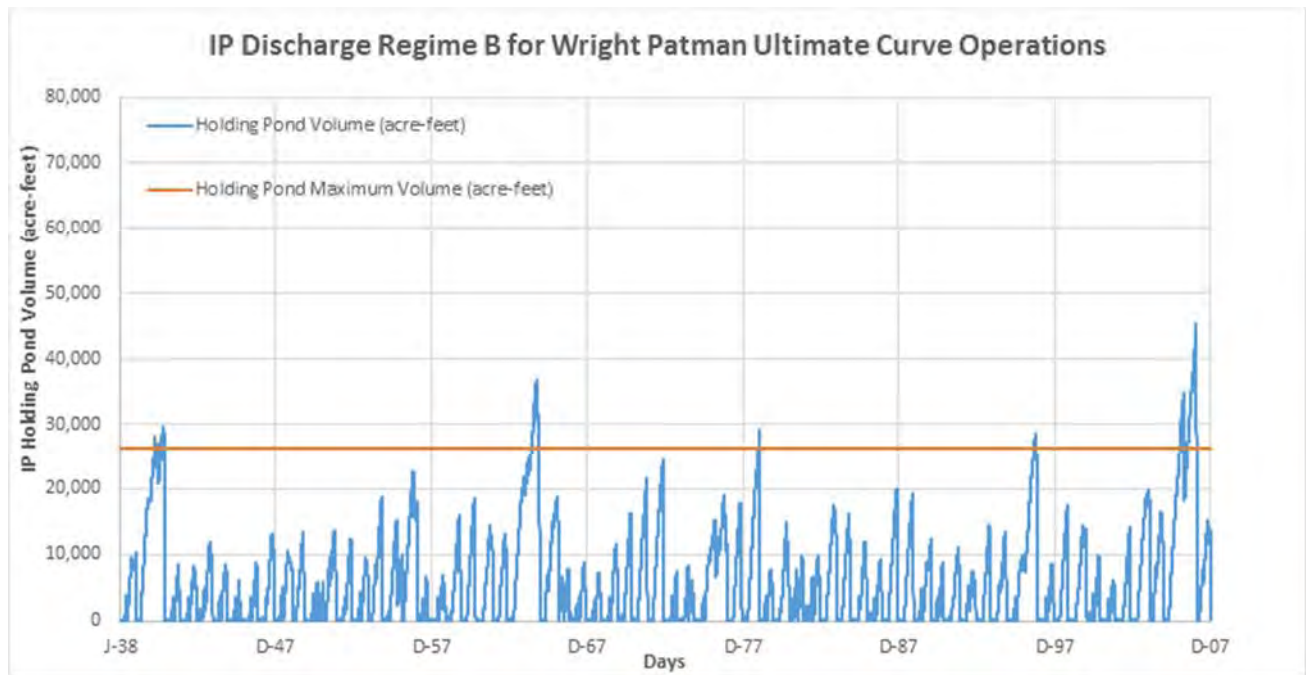


Figure 21 Holding Pond Simulations for Ultimate Rule Curve Operations

5.3.3 Reallocation Scenarios

Figures 22, 23, and 24 represent the holding pond volume for the three reallocation scenarios analyzed (232.5 ft, 242.5 ft, and 252.5 ft). The frequency of holding pond volume exceedance was higher for the 232.5 reallocation as compared to the Interim or Ultimate Rule curves. The frequency of exceedance remained same for all reallocation scenarios but the magnitude of holding pond volume exceedance was less for 242.5 and 252.5 ft than 232.5 ft. The higher conservation pool in 242.5' and 252.5' scenarios resulted in greater amounts of environmental flow releases through the dam. This in turn allowed for additional discharges from the holding pond, thus reducing the volume in the holding pond.

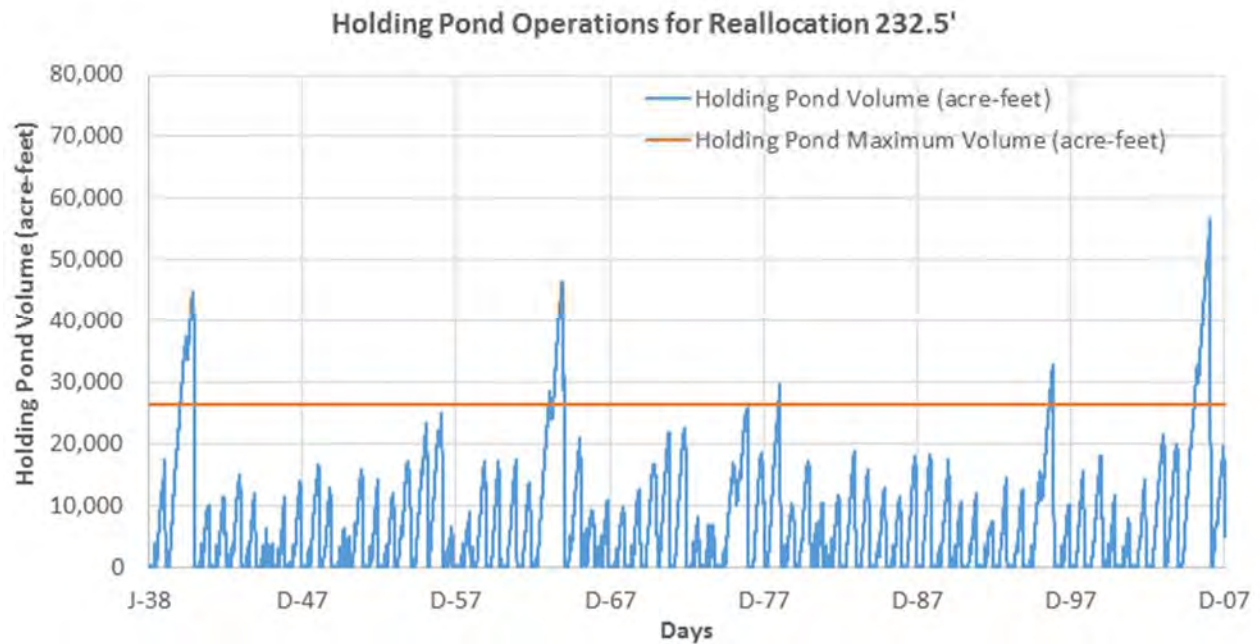


Figure 22 Holding Pond Simulations for Reallocation Scenario 1 – 232.5 Feet

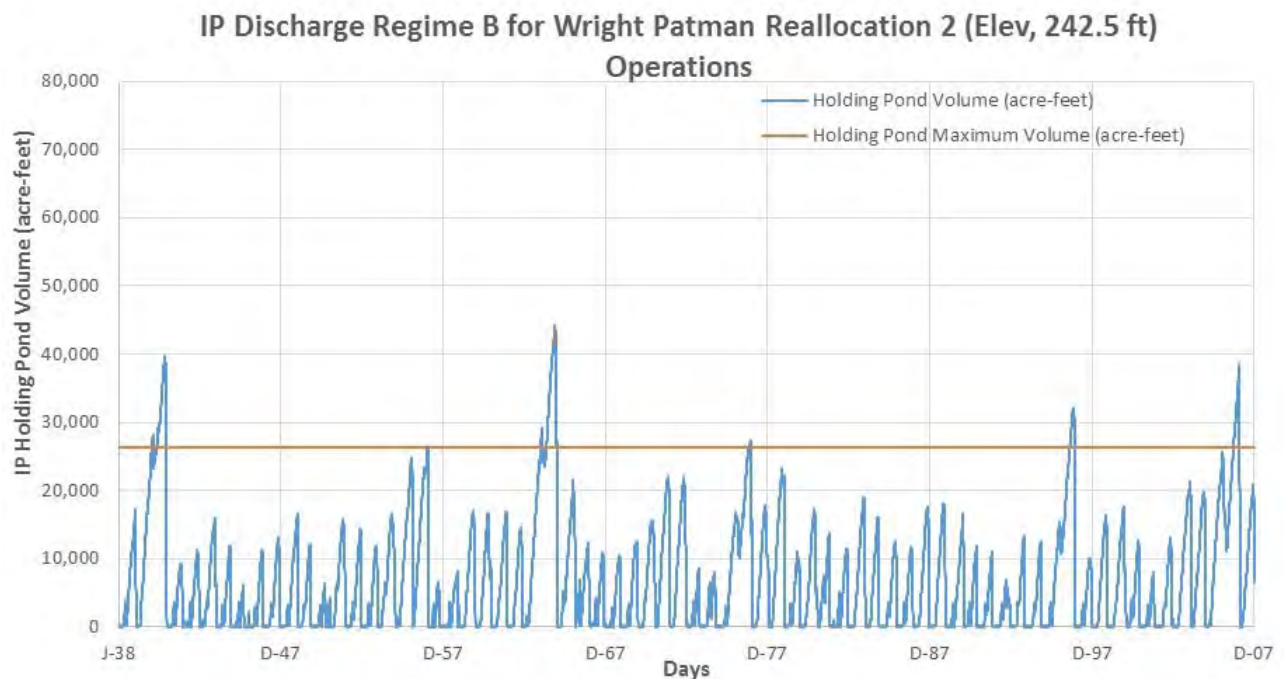


Figure 23 Holding Pond Simulations for Reallocation Scenario 2 – 242.5 Feet

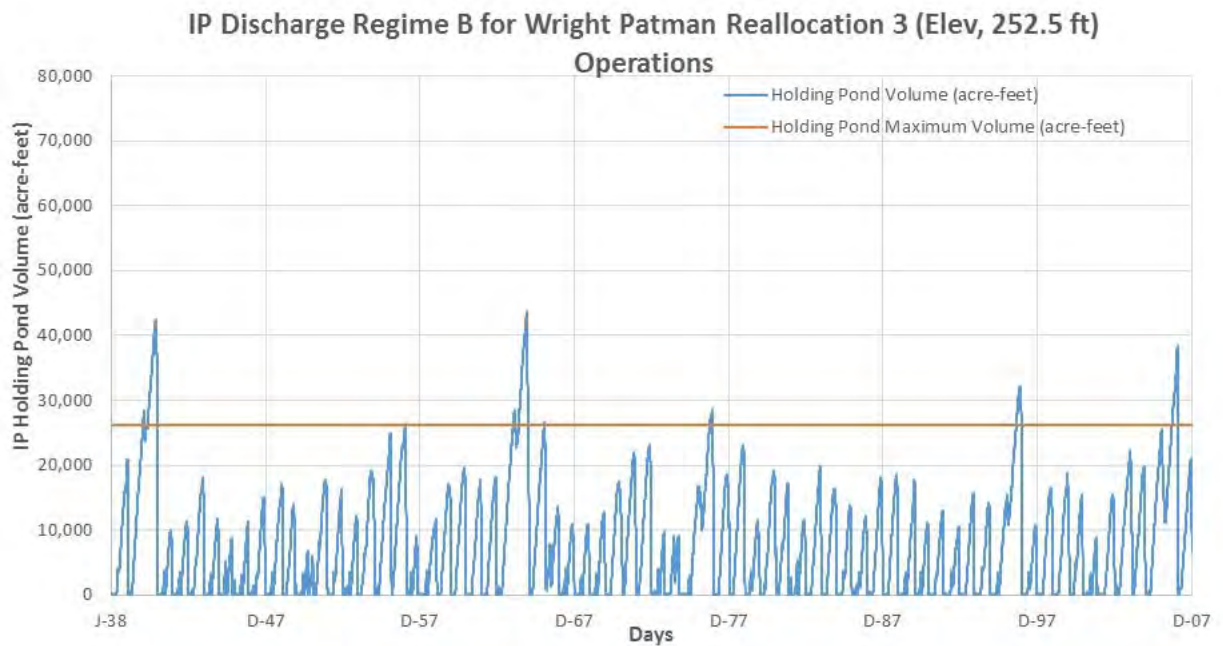


Figure 24 Holding Pond Simulations for Reallocation Scenario 3 – 252.5 Feet

5.4 HOLDING POND REMAINING VOLUME

Because essentially no discharges are allowed by the TCEQ permit during the summer months, IP's operating protocol is to empty the holding ponds by 30 April of each year in order to maximize the storage available during those no-discharge months. Effluent volume remaining in the holding ponds on 30 April represents an increased risk that plant operations could be affected during the coming year if weather and Wright Patman releases are not advantageous. Tracking the number and magnitude of instances when IP would not have been able to empty their holding ponds is another way to look at potential impacts.

Figure 25 shows the cumulative trace of the remaining holding pond volumes for the entire period of record. In other words, this is the sum of the remaining volume in the holding pond for all the instances in the period of record analysis when IP could not have emptied the holding pond. It can be noted that reallocation scenario 232.5 ft results in the maximum holding pond volume. The additional environmental releases in reallocation scenarios 242.5 ft and 252.5 ft help relieve some of the holding pond volume and thus results in less cumulative volume than 232.5 ft. Bar charts showing the incremental remaining holding pond volumes for various Wright Patman operational scenarios are included in Appendix B.

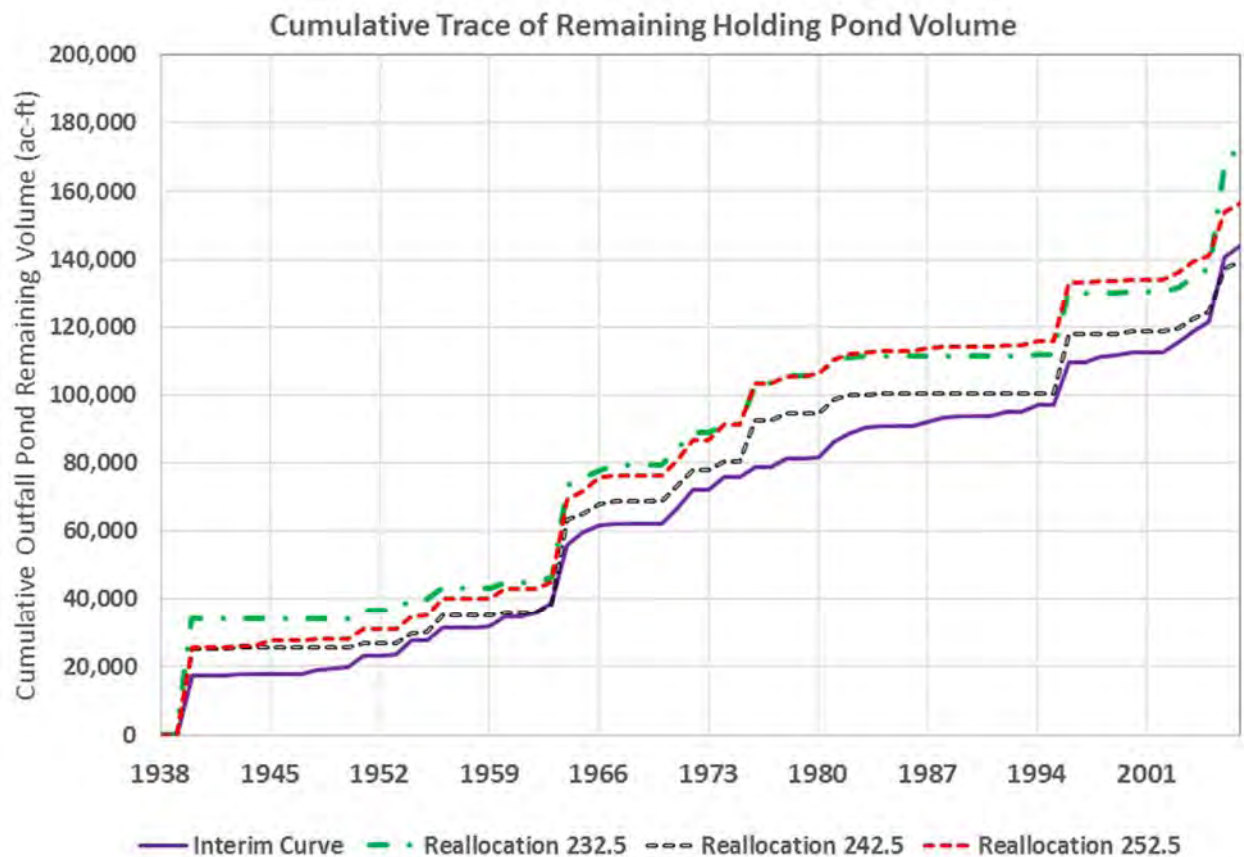


Figure 25 Cumulative Trace of Remaining Volume of Effluent in the Holding Pond

5.5 CONCLUSIONS

The primary objective of this study was to develop a tool that simulated the relationship between Wright Patman releases and IP effluent management system. This tool was then used to analyze various “what if” scenarios associated with Wright Patman releases. The following conclusions were developed based on the analysis discussed in the previous sections.

Wright Patman Releases - The most optimal range of Wright Patman releases for effective management of IP discharge system is 1,000 cfs – 8,000 cfs. Any less than 1,000 cfs limits IP’s ability to precisely calibrate their release volume to the specified percentage of Wright Patman releases. Releases higher than 8,000 cfs result in back flow of Sulphur River into their discharge channel, thus limiting their ability to release discharges from the gravity fed system.

Average Conditions – A review of average conditions over the period of record revealed that reallocation scenarios render the average frequency of optimal Wright Patman releases less favorable compared to the baseline conditions. While this analysis provides a significant insight into the impact of reallocation on IP's ability to make discharges, it should also be noted that the flow frequency described in this set of results is representative of average conditions.

Seasonality – Seasonality analyses appear to provide a better metric for tracking the impact of Wright Patman operations on IP discharges. IP's discharge permit allows for a higher percentage match in October – March compared to the remaining months. A detailed review of the seasonal nature of the Wright Patman releases depicted that the reallocation scenarios reduced IP's ability to make discharges in the favorable months (October – March). It would be advantageous for IP to explore the flow regime for spring season further and identify potential opportunities for optimizing the flows available in the season.

Count – Another important metric developed to summarize effects to IP was the “count” of days when flows were within the optimal range of 1,000-8,000 cfs. The count of favorable days was computed for each month of each year and analyzed in detail. It was difficult to discern a pattern from the results summarized for various months and year. The “Count” metric is influenced not just by the changes in the Wright Patman operations but also by the hydrologic conditions for that month and year. A review of the “Count” metric for wet hydrologic conditions indicated that the “Count” is higher under the reallocation scenarios than under existing conditions, i.e., in certain months, reallocation tends to favor IP discharges as compared to the existing condition. The reallocation scenarios provide opportunity to hold back greater amounts of water in wet years (because of the increase in conservation storage) thus releasing less water through the outlet works. This in turn results in greater number of days with releases in optimal range for making IP discharges. Converse of this was noticed in the dry years, thus making the overall assessment of Count metric for the period of record problematic.

Holding Pond Volume – Holding pond volumes were simulated over the period of record for baseline and reallocation scenarios. This analysis identifies instances when the holding pond volume would have exceeded the available storage due to lack of favorable discharge conditions in the preceding portion of the discharge cycle. The frequency and magnitude of this type occurrence appears to be impacted by reallocation of storage at Wright Patman. Cumulatively, the “remaining” holding pond volume is increased under reallocation scenarios.

Based on the analysis, it can be generally concluded that reallocation would have a discernable impact on the IP effluent management system. This screening level analysis should be refined to understand and quantify this impact better.

6.0 RECOMMENDATIONS

It was noted that the results from the analysis were significantly varied with the changes in the assumptions. Therefore, it is important to refine the assumptions that reflect the most probable operating conditions for Wright Patman. A detailed analysis to refine the assumptions and the approach is recommended as a follow-up to this study. The next level of analysis should also look at the impact of Wright Patman in association with other upstream reservoirs. After a detailed study of the impacts, the future studies should include an assessment of the strategies to mitigate the potential impact on the IP plant operations.

Following assumptions can be analyzed and refined in the next phase of studies:

1. Timing of diversions for water supply
2. Environmental Flow simulations
3. Alternative mechanisms to reduce/mitigate impacts
 - Increased releases using existing water right under low flow conditions
 - Modified discharge structure to increase the range of flows under which discharges could occur
4. Impacts of potential upstream reservoirs on WP operations/discharges and IP system