Memorandum

To: Martin Doyle, City Engineer
From: City of Clayton Hydrologists
Date: November 17th, 2021
Re: City of Clayton Pump Station Capacity

The City of Clayton, located downstream of Falls Lake Dam, relies on the Neuse River for water. Since the last hydrologic and hydraulic assessment of the Neuse in 2000, there has been uncertainty regarding the predictability of the Neuse due to 1) Changing precipitation characteristics. 2) Removal of low-head dams and the effects of potential restoration on the floodplain depth during floods. These changes may have significant influences on the minimum and maximum water elevation that is needed to sustain the water intake system. Based on changes since the last assessment, **City of Clayton Hydrologists recommend that the ring levee be raised to a minimum of 7.5 ft, along with minimal restoration of the channel.**

Presuming no riverbed erosion, the levee must be raised at least 3.5 ft to ensure the pump station is not inundated at the current Q50 flood. Under current conditions the ring levee will only withstand the Q25 event, so it must be raised regardless of restoration. Minimal and substantial restoration will cause the Q50 to reach 7.5 ft and 8.7ft, respectively. Differing restoration efforts will influence the channel roughness, slowing the velocity of water in the channel and increasing depth. Erosion is not considered here to provide a more conservative prediction in terms of flood levels by considering the highest bed level and therefore highest water levels. Ensuring the pump station is operable is very important in protecting Clayton's water supply.

Accounting for 0.5 ft of erosion, minimal or substantial restoration will be required to keep the intake pipe submerged. Without restoration the 7Q10 flow will no longer submerge the intake pipe. The intake infrastructure needs a minimum depth of water to keep it fully submerged and operational. The 7Q10 flows are used as a minimum flow benchmark, where the intake infrastructure must be fully submerged. Since 2000, there have been some estimates of the riverbed dropping by 0.5ft. Erosion is considered to have occurred to provide a conservative prediction of intake inundation by working from the lowest flows we can predict.

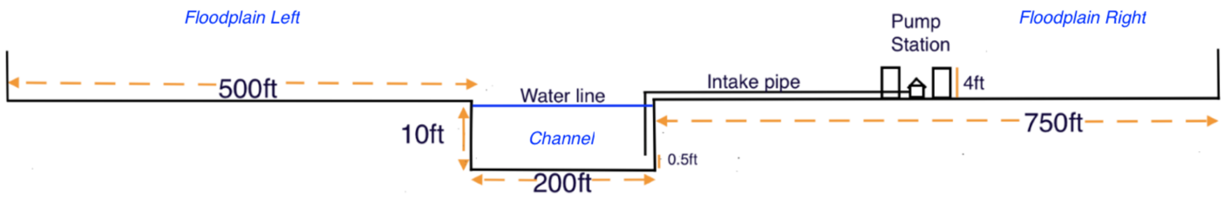
The City of Clayton should increase the height of the levee by at least 3.5ft and invest in minimal or substantial restoration. Raising the ring levee warrants adequate protection against current Q50 storms, as well as an opportunity for at least minimal restoration to be performed in the channel. Minimal or substantial restoration will be required to ensure the intake pipe is fully inundated and will benefit the federally listed species in this reach of the river, including the freshwater mussel. Minimal restoration guarantees the 7Q10 base flows fully cover the intake pipe as well as requiring the lowest investment into to the ring levee around the pump station.

Appendix A: Floodplain Description

Assumption:

- The slope of the channel is 0.0006

Model A.1:



Model A.1. Shows the cross section of the Neuse River near Clayton. Figure not drawn to scale.

Appendix B: Q50 Calculations

Assumptions:

- Pearson Type III equation is assumed to be best fit for Neuse River (near Clayton) stream discharge data.
- Mean daily discharge data is used in Pearson Type III equation instead of max daily discharge.
- The pre-pump station time span was 1982-2000
- The post-pump station time span was 2001-2020
- The 30 largest storms were input for each time span to best represent the Q50 value. 30 events were selected for each time span in order to account for the possibility of multiple big storm events occurring in a single year (which could be overlooked if only the largest storm per year was considered).

Pearson's Type III equation was used to estimate the peak discharge and their recurrence interval of the Neuse River near Clayton (1982-2000; 2001-2020). The Log-Pearson spreadsheet developed by Dr Steven Yochum of the NRCS was used.

Table B.1

OUTPUT TABLES (The spreadsheet is configured so that only the area in these boxes will be printed.)

Log-Pearson Frequency Analysis Spreadsheet, Version 2.5, 6/2014 *Page 1 of 3*

Project: *0*
Streamgage: *USGS 02087500 NEUSE RIVER NEAR CLAYTON, NC*
Date: *11/11/21* **Performed By:** *Taro Katayama*

Without Generalized Skew

Average: 9.1183
Standard Deviation: 0.266328871
Skew Coefficient[1]: 1.860394418

Length of systematic record: 30
Number of historic peaks: 0
Length of Data Record: 30
Length of Historic Record:[5] ----

With Weighted Generalized Skew

Generalized Skew Coefficient[3]:
Variance of Generalized Skew[3]:
A: 0.038118
B: 0.550000
station skew: 1.860394
MSE Station Skew: 0.596625258
Weighted skew coefficient[1]: 0

Recurrence Interval[2] (years)	Percent Chance	K-Value	Peak[4] Discharge (cfs)	95% Confidence Limits Upper (cfs)	Lower (cfs)
500	0.2	5.065	35,100	51,500	27,400
200	0.5	4.193	27,900	38,400	22,600
100	1	3.532	23,400	30,700	19,500
50	2	2.868	19,600	24,600	16,800
25	4	2.201	16,400	19,700	14,400
10	10	1.313	12,900	14,800	11,700
5	20	0.633	10,800	11,900	9,950
2	50	-0.289	8,440	9,150	7,740
1.25	80	-0.792	7,390	8,040	6,650
1.05	95	-0.998	6,990	7,640	6,230
500	0.2	2.878	----	----	----
200	0.5	2.576	----	----	----
100	1	2.326	----	----	----
50	2	2.054	----	----	----
25	4	1.751	----	----	----
10	10	1.282	----	----	----
5	20	0.842	----	----	----
2	50	0.000	----	----	----
1.25	80	-0.842	----	----	----
1.05	95	-1.645	----	----	----

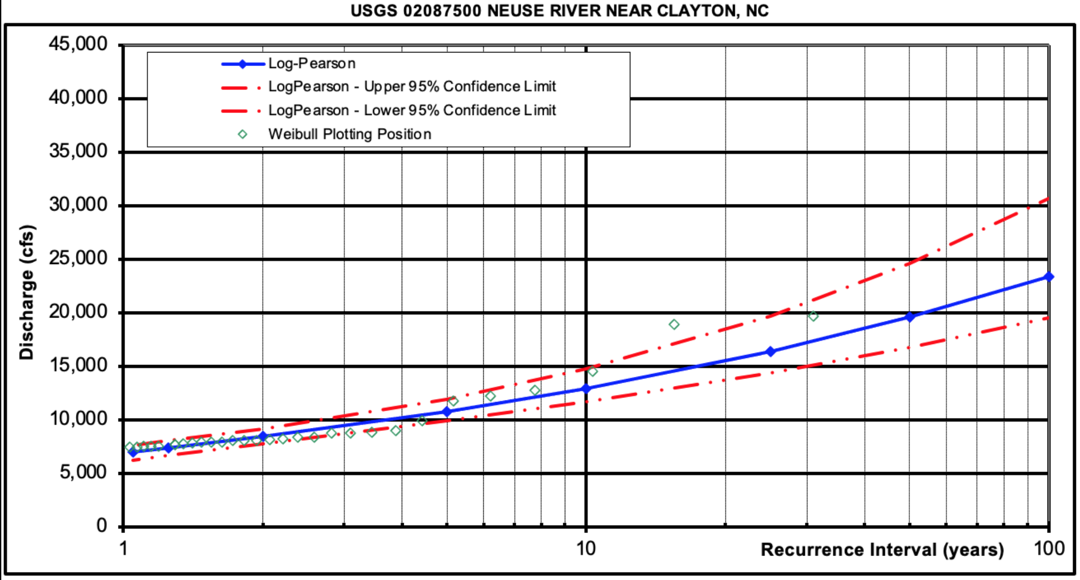
Table B.1 shows the Log-Pearson Frequency for the pre-pump station time span.

Graph B.1

Log-Pearson Frequency Analysis Spreadsheet, Version 2.5, 6/2014 *Page 3 of 3*

Project: *0*
Streamgage: *USGS 02087500 NEUSE RIVER NEAR CLAYTON, NC*
Date: *11/11/21* **Performed By:** *Taro Katayama*

Discharge-Frequency, with Gage Skew
USGS 02087500 NEUSE RIVER NEAR CLAYTON, NC



Graph B.1 shows the discharge frequency with upper and lower confidence intervals for the pre-pump station time span. Note that the x-axis was logged.

Table B.2

OUTPUT TABLES (The spreadsheet is configured so that only the area in these boxes will be printed.)

Log-Pearson Frequency Analysis Spreadsheet, Version 2.5, 6/2014 *Page 1 of 3*

Project: *0*
Streamgage: *0*
Date: *1/0/00* **Performed By:** *0*

Without Generalized Skew

Average:	9.1663
Standard Deviation:	0.343664368
Skew Coefficient(1):	0.960300038
Length of systematic record:	30
Number of historic peaks:	0
Length of Data Record:	30
Length of Historic Record:(5)	----

With Weighted Generalized Skew

Generalized Skew Coefficient(3):	
Variance of Generalized Skew(3):	
A:	-0.231910
B:	0.690322
station skew:	0.960300
MSE Station Skew:	0.274614027
Weighted skew coefficient(1):	0

Recurrence Interval(2) (years)	Percent Chance	K-Value	Peak(4) Discharge (cfs)	95% Confidence Limits Upper (cfs)	Lower (cfs)
500	0.2	4.041	38,400	57,200	29,500
200	0.5	3.454	31,400	44,400	24,900
100	1	2.996	26,800	36,400	21,800
50	2	2.525	22,800	29,700	19,000
25	4	2.033	19,200	24,100	16,500
10	10	1.340	15,200	18,000	13,400
5	20	0.762	12,400	14,200	11,200
2	50	-0.158	9,060	10,100	8,130
1.25	80	-0.853	7,140	7,970	6,210
1.05	95	-1.331	6,060	6,870	5,110
500	0.2	2.878	----	----	----
200	0.5	2.576	----	----	----
100	1	2.326	----	----	----
50	2	2.054	----	----	----
25	4	1.751	----	----	----
10	10	1.282	----	----	----
5	20	0.842	----	----	----
2	50	0.000	----	----	----
1.25	80	-0.842	----	----	----
1.05	95	-1.645	----	----	----

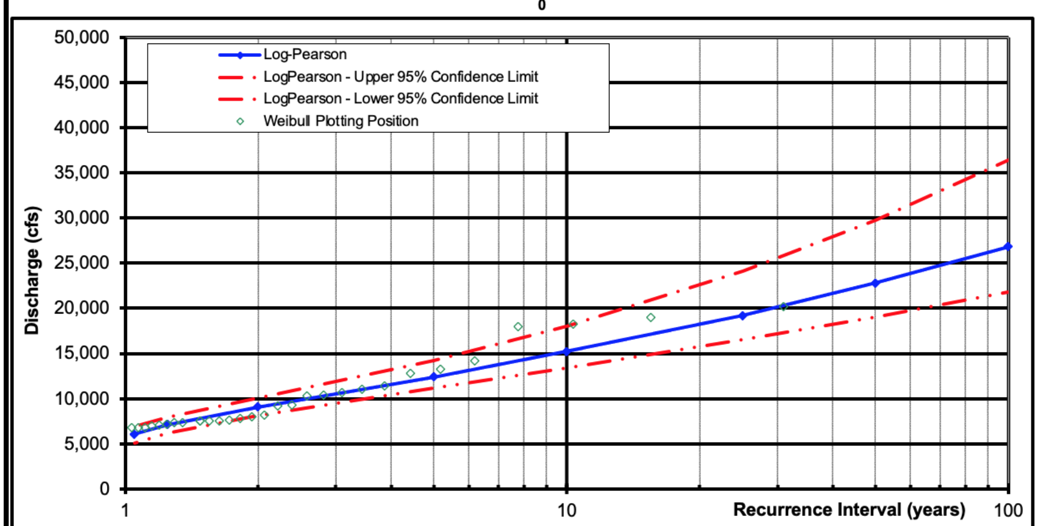
Table B.2 shows the Log-Pearson Frequency for the post-pump station time span.

Graph B.2

Log-Pearson Frequency Analysis Spreadsheet, Version 2.5, 6/2014 *Page 3 of 3*

Project: *0*
Streamgage: *0*
Date: *1/0/00* **Performed By:** *0*

Discharge-Frequency, with Gage Skew
0



Graph B.2 shows the discharge frequency with upper and lower confidence intervals for the post-pump station time span. Note that the x-axis was logged.

Note: Since the last assessment (2000), the Q50 (discharge at 50yr event) has increased from 19,600 cfs to 22,800 cfs.

Appendix C: 7Q10 Calculations

Assumptions:

- Pre-dam 7Q10 based on years 1942-1980
- Post-dam 7Q10 based on years 1982-2020

The average daily discharge data taken from the USGS streamgage on the Neuse River near Clayton was used in the 7Q10 calculations. Initially the 7Q1 was calculated, which resulted in the lowest 7-day average of that particular year. Next, 7Q10 was calculated by finding the minimum 7-day average within 10 years. The 7Q10s were then averaged amongst the pre dam range and the post dam range to see how the construction of the dam influenced the 7Q10.

Table C.1

7Q10 Pre Dam	Year Range	7Q10 Post Dam	Year Range
78.14	1942-1951	116.57	1982-1991
78.14	1943-1952	116.57	1983-1992
64.29	1944-1953	116.57	1984-1993
55.57	1945-1954	116.57	1985-1994
55.57	1946-1955	166.86	1986-1995
55.57	1947-1956	166.86	1987-1996
55.57	1948-1957	166.86	1988-1997
55.57	1949-1958	166.86	1989-1998
55.57	1950-1959	166.86	1990-1999
55.57	1951-1960	166.86	1991-2000
55.57	1952-1961	184.29	1992-2001
55.57	1953-1962	184.29	1993-2002
55.57	1954-1963	184.29	1994-2003
90.71	1955-1964	193.86	1995-2004
90.71	1956-1965	193.86	1996-2005
90.71	1957-1966	193.86	1997-2006
115.57	1958-1967	190.14	1998-2007
65.14	1969-1968	190.14	1999-2008
65.14	1970-1969	190.14	2000-2009
65.14	1971-1970	190.14	2001-2010
65.14	1972-1971	176.86	2002-2011
65.14	1973-1972	176.86	2003-2012

65.14	1974-1973	176.86	2004-2013
65.14	1975-1974	176.86	2005-2014
65.14	1976-1975	176.86	2006-2015
65.14	1977-1976	176.86	2007-2016
65.14	1978-1977	176.71	2008-2017
69.14	1979-1978	176.71	2009-2018
69.14	1980-1979	176.71	2010-2019
69.14	1981-1980	176.71	2011-2020

Average 7Q10 Pre dam 38yr span	Average 7Q10 Post dam 38yr span
67.43	171.01

Table C.1 shows the 7Q10s for varying year ranges for pre- and post-dam time spans. The 7Q10s were averaged for the 38-year periods before and after the dam was built.

Appendix D: Manning's n Assumptions and Calculations

Manning's n values were taken from table D.1 below. The "Major streams" category was used because the channel width is greater than 100ft. The "irregular and rough sections" sub-category was selected due to restoration efforts in the channel. An n value of 0.035 was selected for calculations without channel restoration. An n value of 0.1 was selected for the substantial restoration calculations, and an average of the two prior n values (n=0.0675) was used for the minimal restoration calculations. The n value for the floodplain was kept constant (at n=0.12) throughout the calculations since the restoration only occurred in the channel.

Table D.1

TABLE 7.1
Manning's *n* Roughness Coefficient (continued)

Type of Channel and Description	Minimum	Normal	Maximum
Brush			
Scattered brush, heavy weeds	0.035	0.05	0.07
Light brush and trees	0.035	0.06	0.07
Medium-to-dense brush, in winter	0.045	0.07	0.11
Medium-to-dense brush, in summer	0.07	0.1	0.16
Trees			
Dense willows, summer, straight	0.11	0.15	0.2
Cleared land with tree stumps, no sprouts	0.03	0.04	0.05
Same as above, but with heavy growth of sprouts	0.05	0.06	0.07
Heavy stand of timber, a few down trees, little undergrowth, flood stage below branches	0.07	0.1	0.12
Same as above, but with flood stage reaching branches	0.1	0.12	0.16
Major streams (top width at flood stage more than 100 ft)			
Regular section with no boulders or brush	0.025		0.06
Irregular and rough sections	0.035		0.1

Source: From Chow, V.T., *Open-Channel Hydraulics*, McGraw-Hill, New York, 1959. With permission.

Table D.1 shows the resource used to select Manning's n values for all channel calculations. The category "Major streams" was used because the channel in our calculations has a width larger than 100ft.

Table D.2: Manning's n values

	Pre-dam	Post-dam, No Restoration	Post-dam, Minimal Restoration	Post-dam, Substantial Restoration
Channel	0.035	0.035	0.0675	0.1
Floodplain	0.12	0.12	0.12	0.12

Table D.2 shows the Manning's n values that were used for all future calculations.

Manning's n calculations:
Total discharge was calculated for the left floodplain, right floodplain, and channel (see Appendix A). These three values were then added together to get the total discharge for the system.

Equation D.1: Hydraulic Radius

$$R=A/P$$

R= Hydraulic Radius
A=Area
P=Perimeter

Equation D.2: Velocity

$$V= (1.49/n)*(R^{(2/3)})*(S^{(1/2)})$$

n = Manning's n
V= Velocity
R=Hydraulic Radius
S=Slope
*1.49 is used because units are in feet

Equation D.3: Total Discharge

$$Q=V*A$$

Q=Total Discharge
V= Velocity
A=Area

Appendix E: Pump Station Calculations

Assumptions:

- Total discharge based on pre- and post-pump station Q50 values (Appendix B)
- See appendix D for Manning's n assumptions

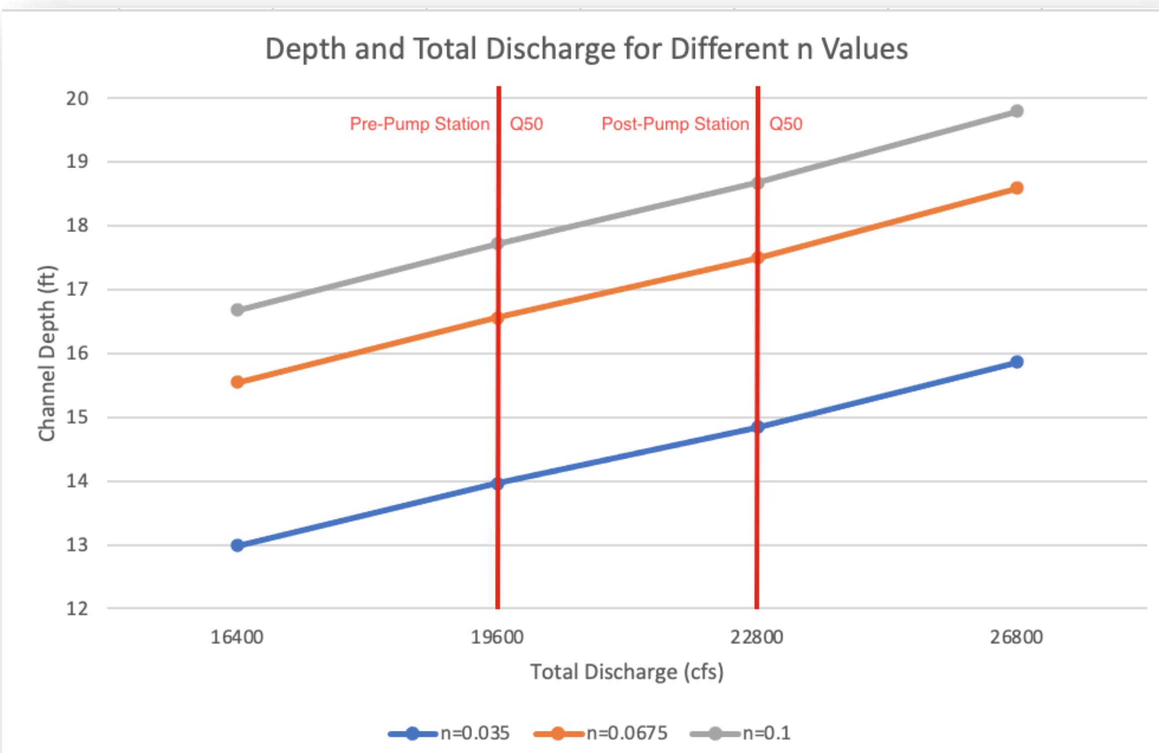
- Manning's N gives accurate predictive channel and floodplain depth.
- There was no 0.5 ft drop in the bed of the channel due to erosion predicted by the geologist (providing a more conservative analysis for potential pump station inundation).

Table E.1:

	Pre-Pump Station	Post-Pump Station		
	No Restoration	No Restoration	Minimal Restoration	Substantial Restoration
Channel Depth (ft)	13.962	14.846	17.497	18.675
Floodplain Depth (ft)	3.962	4.846	7.497	8.675
Total Discharge (cfs)	19,600.0	22,800.2	22,798.8	22,801.6

Table E.1 shows the channel/floodplain depths and total discharges for the pre-pump station and post-pump station (with levels of restoration) scenarios.

In both pre- and post-pump station scenarios the Q50 was held constant and using Manning's equation, channel and floodplain depths were determined. For the post-pump calculations, the Q was held constant, but Manning's n coefficient was altered based on varying degrees of restoration resulting from varying levels of channel roughness.



Graph E.1 shows the depths and total discharges for the three different Manning's n values that were used. The red vertical lines represent the 7Q10 values for pre- and post-dam.

Appendix F: Intake Pipe Calculations

Assumptions

- Total discharge based on pre- and post-dam 7Q10 values (Appendix C)
- See appendix D for Manning's n assumptions
- There was a 0.5 ft drop in the bed of the channel due to erosion predicted by the geologist (providing a more conservative analysis for potential intake pipe inundation).

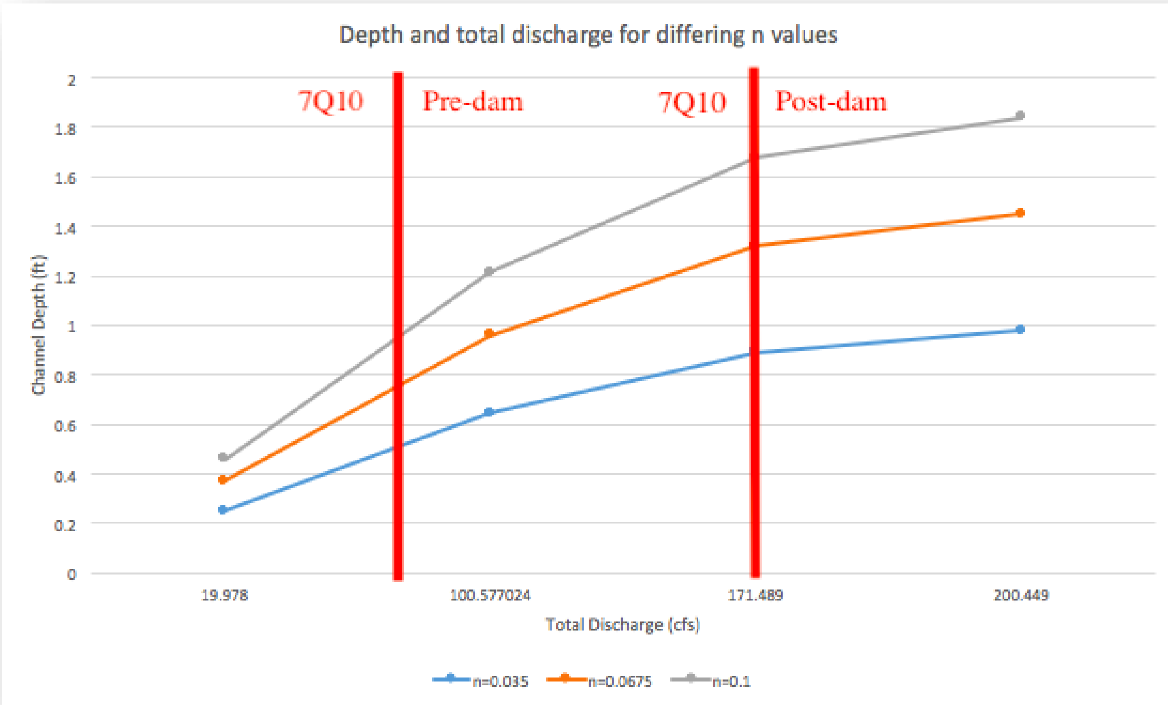
Table F.1:

	Pre-Dam	Post-Dam		
	No Restoration	No Restoration	Minimal Restoration	Substantial Restoration
Channel Depth (ft)	0.507	0.890	1.320	1.675
Floodplain Depth (ft)	0.000	0.000	0.000	0.000
Total Discharge (cfs)	67.118	171.233	171.017	171.489

Table F.1 shows the channel depths and total discharges for the pre-dam and post-dam (with levels of restoration) scenarios.

Note: The final channel depth was determined by changing values of depth until the desired 7Q10 was reached for total discharge (using the equations in appendix D).

Graph F.1:



Graph F.1 shows the depths and total discharges for the three different Manning's n values that were used. The red vertical lines represent the 7Q10 values for pre- and post-dam.