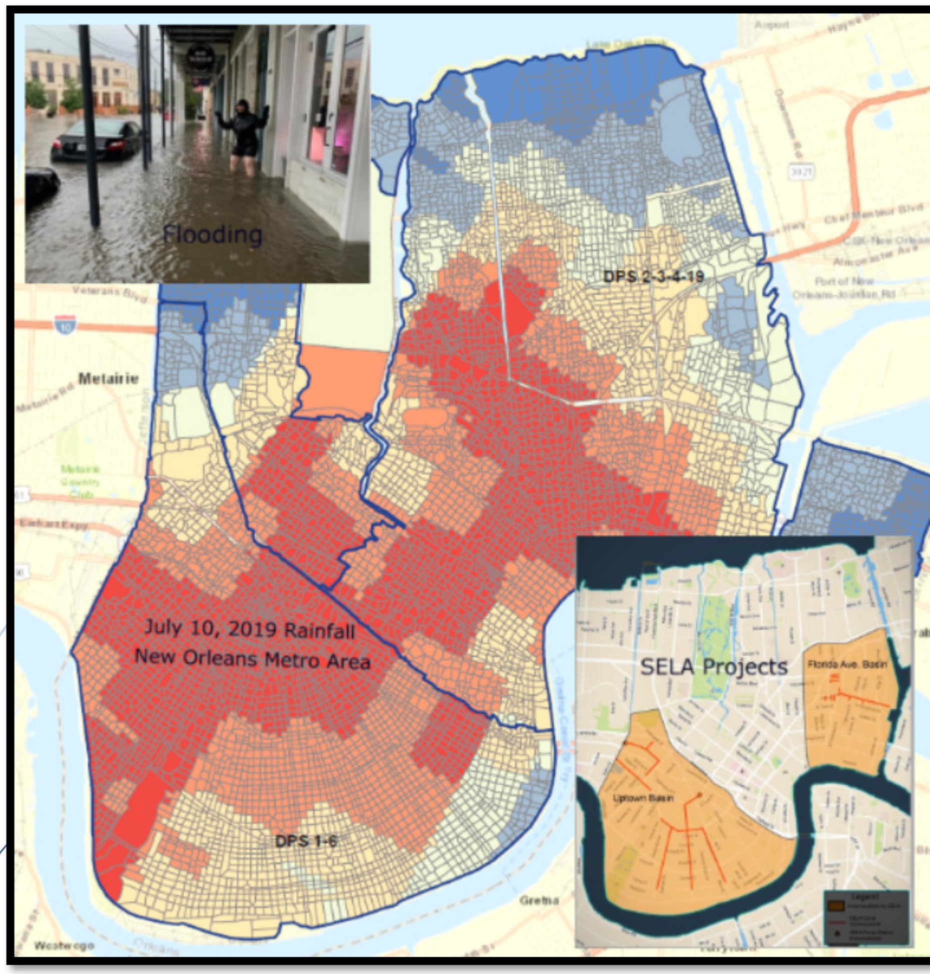
Sewerage & Water Board of New Orleans

Comprehensive S&WB-City of New Orleans Stormwater Management Model (SWMM)

July 10, 2019 Rainfall Event Modeling and Mapping



Ardurra

September, 2019

ARDURRA

Contents

List of Figures

List of Tables

Appendices

1. Executive Summary

The Sewerage and Water Board of New Orleans (SWBNO) requested that Ardurra model the July 10, 2019 rainfall event using the comprehensive S&WBNO Stormwater Management Model (SWMM) to evaluate the flooding in the City. On the morning of July 10th, the city of New Orleans experienced a heavy rainfall of up to 9 inches of rain in 3 hours in some areas. The intense rainfall event caused significant flooding and some areas remained flooded for a period of several hours. This brought unexpected hardship and inconvenience to residents and disrupted commerce.

SWBNO, along with its federal partner, the United States Army Corps of Engineers (USACE), is in the final stages of the East Bank portion of a massive construction project, the Southeast Louisiana Urban Flood Control Program (SELA). SELA was designed to lower the risk of flooding in several low-lying areas historically prone to property damage from rain-induced flood events. One reason for this modeling study was to show whether SELA had provided expected flood-reduction benefits or had adversely impacted other areas of the City.

Ardurra utilized the SWMM software to perform this analysis. SWMM is a state-of-the-art modeling software that is widely used throughout the world to evaluate drainage challenges. Ardurra has worked closely with the City of New Orleans, SWBNO and the USACE in the development of the SELA program and the SWMM model.

The data from the July 10th rainfall event were entered into the model and the results were compared with collected information on observed flood conditions. This exercise showed the model provided an accurate representation of the rainfall event that occurred. The information on flood conditions, along with the data collected on the amount of rainfall, support that this storm exceeded a 100-year rainfall event in different parts of the city. Most of the current drainage system was designed to manage a 2-year rain event. SELA provides an upgrade to parts of the system, primarily major canals and pump stations, to handle a 10-year event. The rainfall experienced on the morning of July 10, 2019 greatly exceeded the improved capacity of the entire drainage system . Areas that had SELA construction projects have seen an increase in their drainage capacity. Areas outside of SELA have not had significant increases in drainage capacity. All areas, regardless of whether they have benefitted from SELA construction or not, do not have the drainage capacity to handle a 100-year flood event like the July 10 event.

The drainage system has 24 drainage pumping stations that have a combined capacity of over 50,000 cubic feet per second (cfs), which is nearly 400,000 gallons per second. Pumping this volume of water allows the drainage system to handle a ten-year rain event. A ten-year event in the City of New Orleans is expected to deliver about 4.7” of rain in three hours . The July 10 event clearly exceeded those totals in much of the City.

The drainage system, which is comprised of drainage pipes and catch basins maintained by the City of New Orleans, as well as SWBNO’s canals and pumping stations, would benefit from an improved preventive maintenance program. Going forward, this enhanced program should include more frequent inspection of drainage canals, debris and trash removal from along the canal banks, inspection and maintenance of street drainage, increased green infrastructure projects, greater enforcement of the City's Developer Policy in the area of private runoff onto public rights of way, as well as identification of any potential storage locations that can be utilized for temporary storage during large rainfall events.

2. July 10, 2019 Storm

New Orleans received nearly 9 inches of rainfall in some areas, most of which occurred between 6:30 AM and 9:30 AM, on July 10, 2019. The daily rainfall totals measured by SWBNO on the East Bank varied from 2.5 inches at DPS 12 near the lakefront to a high of 8.62 inches at Station A near Armstrong Park. Of the 16 rain gauges on the East Bank in Orleans Parish, 10 of them recorded over 4 inches of rainfall in 3 hours. Compared to the storms earlier this year on April 4th and May 12th, the rainfall intensity was much higher, and it occurred in the entire metropolitan area. The intense rainfall occurring over a short period of time caused severe street flooding in various parts of New Orleans. Streets were inundated in certain areas of Downtown, Broadmoor, Mid-City, the Lower 9th Ward, and Gentilly. As water levels rose, many streets and underpasses became impassable; cars were partly submerged underwater, and some residential homes and businesses were flooded. As the rainfall stopped, the flooding subsided in a relatively short time as all the pump stations caught up with the rain event. Some of the pictures with street flooding due to this storm and information can be found in Appendix B. The locations of these places were tentatively identified and mapped in Figure 1. It is anticipated that there were additional flooding locations that did not have published photos available for our review and inclusion.

Figure 1 Rain gauges (Total Daily Rainfall) & Flood Locations

The average total rainfall amount in the subbasins in the study area is color-coded and mapped in Figure 2. The rainfall amount was calculated using radar data and calibrated using real-time data collected by the SWBNO in PCSWMM software. NEXRAD Level-III Instantaneous Precipitation Rate (Dual Pol.) (256 Level/230 KM) radar product was obtained for the KLIX-New Orleans, LA from the National Centers for Environmental Information, National Oceanic and Atmospheric Administration (NOAA) online database. NEXRAD is comprised of high-resolution Doppler weather radars that detect precipitation to track weather events. The radar files obtained from NEXRAD were then processed to generate a time series of precipitation for each subbasin to use for SWMM modeling. Since the rainfall intensity and duration can vary significantly within a short distance and there are only a few reliable rain gauges in the basins, it would be almost impossible to get this level of accuracy without radar data. As shown in Figure 2, the average rainfall varied from less than 2 inches to more than 8 inches within the study area.

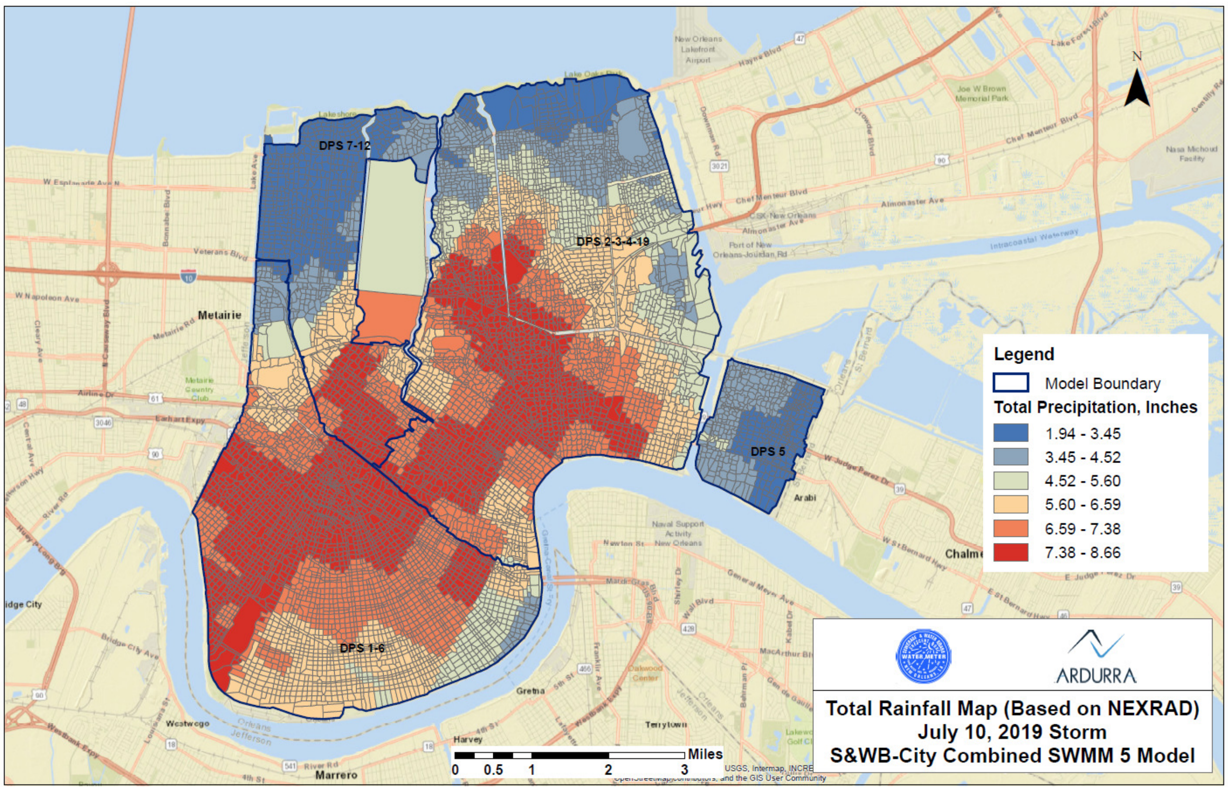


Figure 2 Rainfall Distribution on July 10, 2019

The rain gauges shown in Figure 1 were used for the calibration of Radar rainfall. Daily total rainfall at S&WB gauges on July 10,2019 is shown in Table 1 below.

Table 1 Total Rainfall on July 10, 2019

Station	Rainfall	Station	Rainfall	Station	Rainfall
Central	7.12	DPS-05	4.96	DPS-14	2.69
Station A	8.62	DPS-06	4.43	DPS-16	3.82
WBPC	6.50	DPS-07	5.46	DPS-17	6.70

DPS-01	7.52	DPS-10	4.01	DPS-19	6.83
DPS-02	7.21	DPS-11	0.87	DPS-20	4.58
DPS-03	6.96	DPS-12	2.50		
DPS-04	5.99	DPS-13	1.18		

A typical graph of rainfall intensity and cumulative rainfall in a subbasin is shown in Figure 3. Most of the rainfall occurred within just three hours, which was one of the primary causes of flooding due to that storm. The rainfall simply exceeded the capacity of the drainage system.

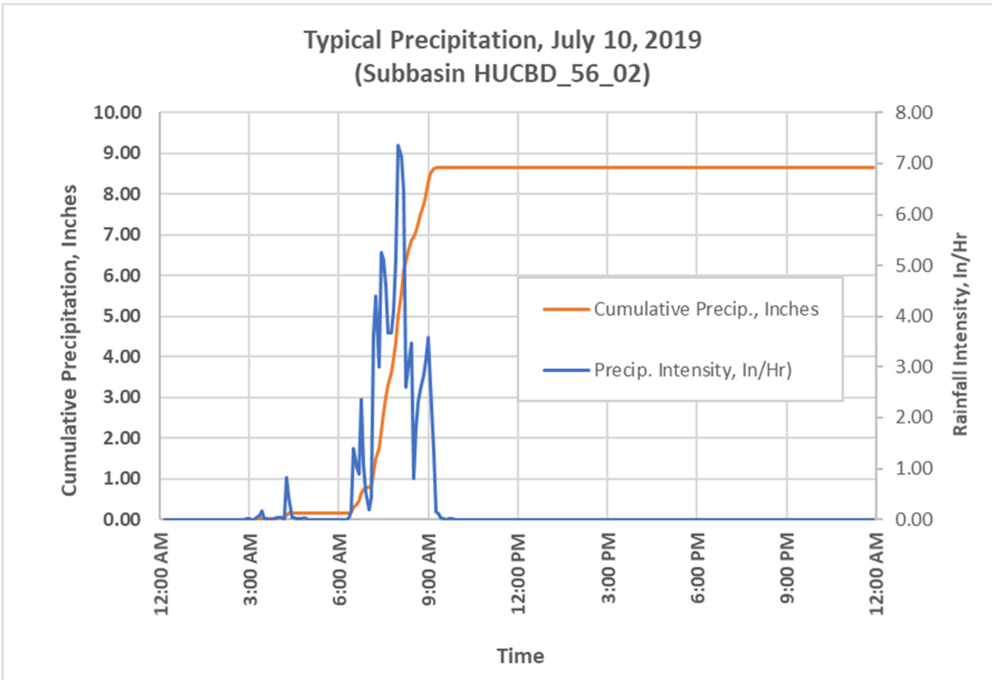


Figure 3 A Typical Precipitation Hyetograph

A substantial part of the city experienced a rainfall that was greater than the average monthly rainfall in this area. The average annual normal precipitation for the project area, based on National Climatic Data Center records at Audubon Park, and Louis Armstrong International Airport over the period 1985-2014, is 60.6 inches shown in Table 2. Monthly and annual averages are given below for the same period. The heaviest rainfall usually occurs during the summer, with June being the wettest month in the metro area with an average normal of 7.6 inches at Audubon Park. As we can see, the amount of rainfall in on July 10 exceeded the expectations for monthly rainfall based on historical records.

Table 2 Monthly and Annual Precipitation (Inches)

Month	Audubon	Armstrong	Average
January	5.3	5.0	5.1
February	4.8	4.2	4.5
March	4.8	4.6	4.7
April	4.5	4.1	4.3
May	4.4	4.4	4.4
June	7.6	6.8	7.2
July	6.4	7.2	6.8
August	6.3	6.0	6.1
September	5.4	5.9	5.7
October	3.3	3.6	3.4
November	3.9	3.9	3.9
December	4.8	3.9	4.4
Annual totals	**61.5**	**59.7**	**60.6**

(Data: National Climatic Center)

The frequency based hyetographs for the 2-, 5-, 10-, 25-, 50- and 100-YR rainfalls developed from the temporal based rainfall distributions provided in the National Weather Service Technical Papers Hydro-35 and No. 40 (see Table 3) shows that the rainfall that occurred on July 10th was equivalent to a storm that occurs less frequently than a typical 50-year or even a 100-year storm, in terms of producing runoff in most of the areas that experienced flooding. Table 3 gives the accumulated rainfall amount for the New Orleans areas for the 1-, 3-, 6-, and 24-hour periods, without adjustment for aerial size.

Table 3 Frequency based rainfall distributions

Hours	2-YR	5-YR	10-YR	25-YR	50-YR	100-YR
1	2.4	3.0	3.3	3.8	4.1	4.4
3	3.3	4.1	4.7	5.5	6.1	6.8
6	4.1	5.3	6.2	7.1	7.9	8.9
24	6.0	7.6	9.2	10.4	11.6	13.2

It's important to note that many recent observations/studies suggest an increase in the intensity as well as the frequency of precipitation extremes. A recent study by a team of researchers at LSU (Brown et al., 2019) revealed that due to the change in global climate in the last few decades the hourly rainfall intensity significantly increased in the Southeastern area of the United States. The average duration of the rainfall has shortened as the global climate has gotten warmer. At this point, there is not enough data to determine if this is a long-term trend or to assess the exact impact of climate change on the precipitation and its duration. But it is apparent that flooding risks are increased in rainfall events like the one on July 10th, 2019, which appear to be occurring more often.

3. Southeast Louisiana Urban Flood Control (SELA)

In response to frequent flooding events in the late 70s through the mid 90s the Southeast Louisiana Urban Flood Control Program (SELA) was created. The program is federally funded and intended to reduce flood damages in New Orleans and surrounding parishes in areas hardest hit with repetitive flood loss and damage claims against the federally funded flood insurance program. To alleviate the flooding during these types of events, and to reduce claims against the national flood insurance program, the federal government, through the US Army Corps of Engineers, has spent over $1.5 billion on drainage construction projects.

Selected projects were carefully vetted to ensure the completion of the project would not cause or exacerbate any flooding conditions in another area. The possibility of negatively impacting an area was considered grounds for eliminating the area from SELA eligibility. It has been a priority of all agencies involved that SELA construction address and solve these types of problems rather than simply moving them to another area.

Several of the areas that experienced a significant amount of rain were areas that do not benefit from the completed East Bank SELA construction projects as shown on the SELA basin map below (Figure 4).

Figure 4 SELA Orleans Project

Areas served by DPS 7 and DPS 12 in the Lakeview area did not have the historical flood loss claims necessary to justify the federal assistance supplied by the SELA program. Additionally, the CBD area, the Ninth Ward and the area around the St. Louis Canal were not judged as eligible for SELA construction. In these areas, SELA has had no impact. There have been no SELA projects to alleviate flooding, nor is it possible for SELA projects in other areas of the City to increase flooding because these areas are not hydraulically connected to the area where the SELA projects were performed.

Claims that SELA has caused flooding in certain areas of the City are unfounded. Some residents are saying that they never experienced flooding like this prior to the completion of SELA. The fact is that the City has not experienced a rainfall event equivalent to the recent events since 1995. In 1995, flooding in the SELA improved areas of Uptown was significantly more severe than in recent rain events.

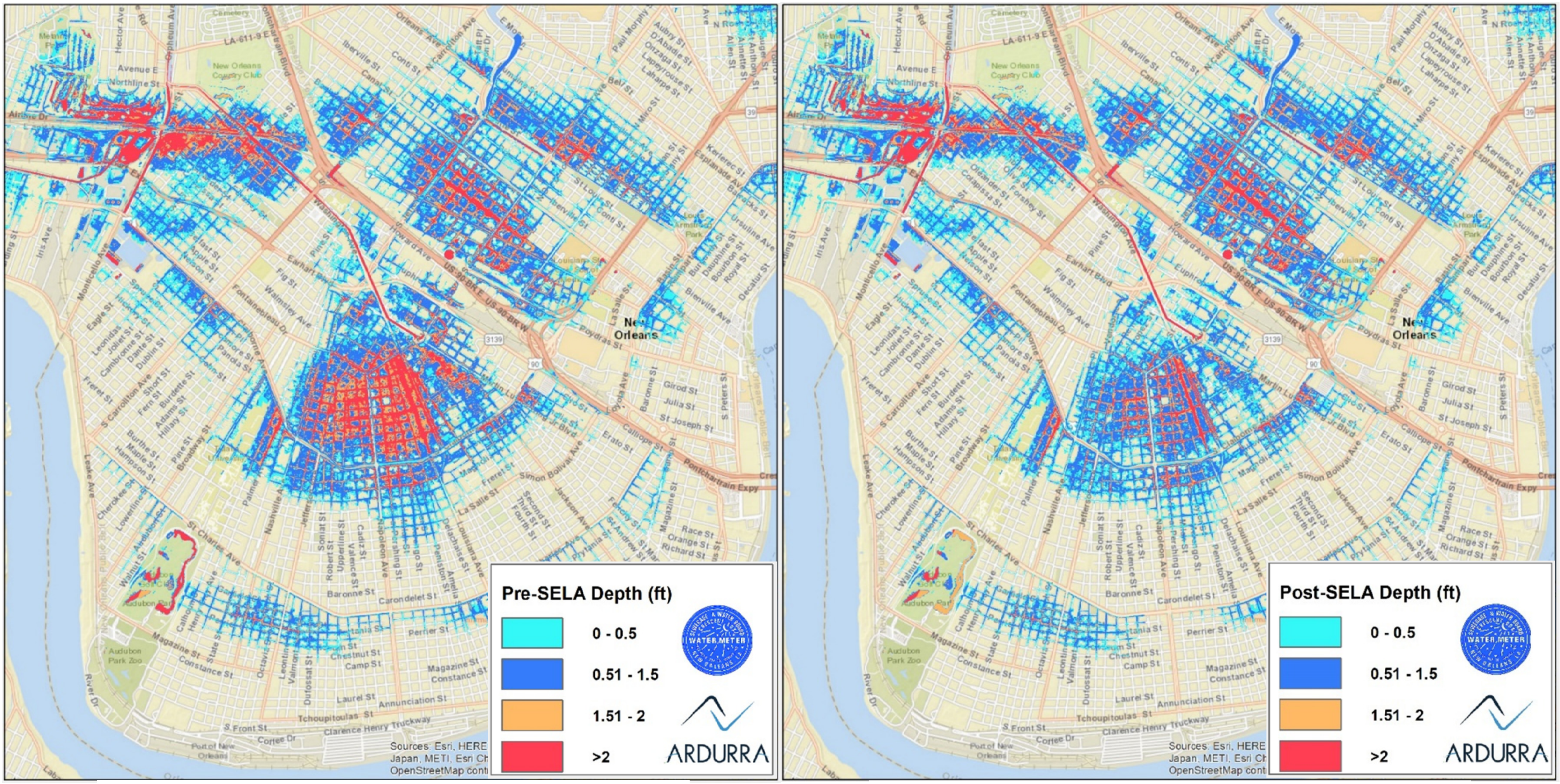
Using the SWMM model and the same rain event, we can analyze and compare flooding that would have occurred without SELA to the results with SELA completed. Figure 5 shows the results of these two model runs. Both analyses used the July 10, 2019 rainfall event.

The red areas indicate flood levels in excess of 2 feet. The pre-SELA analysis shows extensive flooding in the Broadmoor and Hollygrove areas. The post-SELA analysis shows that there is still some flooding in these areas. As previously noted, the July 10 rainfall event far exceeded the design capacity of the SELA improvements, so some flooding during this event should be expected, but the extent of the flooding is significantly reduced.

It also should be noted that there are no areas where flooding is worse in the post-SELA analysis than it was in the pre-SELA analysis. The conclusion from these two analyses is that the SELA projects have significantly reduced flooding in the Uptown and Hollygrove areas, without inducing additional flooding in other areas.

Comparison of Pre-SELA to Post-SELA Conditions

(Major Drainage System Only)



Pre-SELA Overflow Map of July 10, 2019 Storm

Post-SELA Overflow Map of July 10, 2019 Storm

Figure 5 Pre and Post SELA Flooding Scenario with July 10th Storm

4. Comprehensive SWBNO-City SWMM Model

The model that was used to analyze the July 10 storm is a recently developed comprehensive stormwater drainage model using the SWMM5 modeling program, developed by the United States Environmental Protection Agency (EPA). The EPA Storm Water Management Model (SWMM) is a sophisticated model that is widely used throughout the engineering industry for modeling both single events and long-term simulations of rain fall events. This model incorporates precise information on the existing drainage system as well as rainfall inputs including duration, intensity and quantity. Because this software program is the industry standard, it can include data that are collected from a wide variety of sources, making it ideal for the collection of information and rapid updating of the model to accurately reflect existing conditions and to provide the most accurate predictions available for future storm events.

This current model for New Orleans is the culmination of decades of model development, by several different agencies and engineering firms. This model dates back to the 1980's when the SWBNO hired the Engineering firm of Daniel, Mann, Johnson and Mendenhall (DMJM) to develop the first computer model of the New Orleans drainage system. This model was later converted to a HEC-RAS model by the USACE and expanded and improved. The SWBNO then hired BCG Engineering and Consulting (BCG, now Ardurra) to convert the USACE HEC-RAS model to a SWMM model. This SWBNO model included only the major canals and pump stations.

After Hurricane Katrina, the City of New Orleans Department of Public Works, separately from the SWBNO, contracted with the engineering firm of CDM-Smith to develop a SWMM model of the subsurface drainage pipes under the City's Streets. While the SWBNO model included the major drainage canals and pump stations, the City's model included smaller pipes that are part of the City's subsurface drainage system (less than 36" diameter pipes). The City's model did not include major drainage canals and pump stations. The City's models utilized boundary conditions that represented the downstream SWBNO system in lieu of actual dynamic connection to the SWBNOB system. These models were primarily built to size the drain lines as part of the City's ongoing Street Capital Improvement Program. The backwater effect of the outfalls (the ability of the outfall canals to accommodate the flow coming from the City's drainage system) was not considered in these models.

As a part of developing the master drainage plan of New Orleans, the SWBNO contracted with BCG (now Ardurra) to update the existing SWBNO's SWMM model with SELA improvements and to combine that model with the City's SWMM model of local drainage to form a single comprehensive, dynamic model of the entire drainage system that includes virtually all pipes, from the small local drainage, through the major canals and pump stations.

While, we refer to this model as "The Comprehensive Drainage Model", it is actually a series of separate geographic models that cover the Orleans parish drainage. Areas like Algiers, English Turn, The Lower Ninth Ward and New Orleans East are totally separate from the remainder of the city's drainage system and these act as totally standalone models. The East Bank of Orleans Parish, west of the Industrial Canal, is in fact 4 separate drainage basins with limited interaction with the other basins. These models are separate but have dynamic boundary conditions where the adjacent drainage basin is represented by the major canals and pump stations from the original SWBNO SWMM Model, with SELA improvements. Since these areas are basically separate drainage basins, separating the models has no negative consequences. While these models for the individual areas are separate, they have been programmed with dynamic boundary conditions that allows for the limited interactions between the drainage basins to be accurately represented. This separation of the models allows faster run times while maintaining the dynamic connections between the adjacent drainage basins.

These comprehensive models have been utilized and reviewed at the federal, state and local level over the years and they represent the most detailed and accurate model of the New Orleans Drainage System that has ever existed. These models include all the SELA improvements that have been implemented over the past 25 years.

5. SWMM Model results July 10, 2019 Storm

The SWMM model was run for July 10th storm event using Radar rain gauges created for each subcatchment in PCSWMM software (a commercial third-party software program that utilizes the EPA SWMM analysis engine but includes pre- and post-processors to simplify data entry and analysis). Initial water levels at junctions and storage nodes were estimated based on observed water surface elevations at SWBNO gauges. Pump control rules were created to adjust the on and off timing of the pumps to mimic the pumping operation during the storm. The boundary conditions for each model were provided by the water level at Lake Pontchartrain.

SWMM model results for July 10 storm were compared with observed water levels collected by SWBNO as well as by Ardurra. While all the SWBNO gauges were either at suction side or at discharge side of the pump stations, Ardurra, under contract to the S&WB, maintains up to 30 gauges that are deployed in a variety of locations throughout the major and minor drainage system. These gauges are portable and could be located within facilities as small as individual catch basins to as large as major canals far from the drainage pump stations. The SWMM model results for the July 10 event closely match the recorded water levels on July 10. These results are within expected ranges when comparing a model to actual field results. Charts comparing the recorded flows and water levels at various locations with those from the SWMM model are presented in Appendix A. The overflow map of the study area due to July 10 storm is presented in Figure 6.

SELA construction on the East Bank has been focused in the areas of Uptown, Hollygrove, the Florida Triangle and Dwyer Rd. A great deal of the flooding that occurred as a result of the July 10 rainfall occurred outside of the boundaries of those SELA construction projects. The CBD and the Ninth Ward are areas outside of the SELA construction basins and would not see any benefits from the SELA construction projects. With the completion of the construction projects in the Uptown area, flooding events would be dramatically reduced during events that more closely resemble a 10-year event.

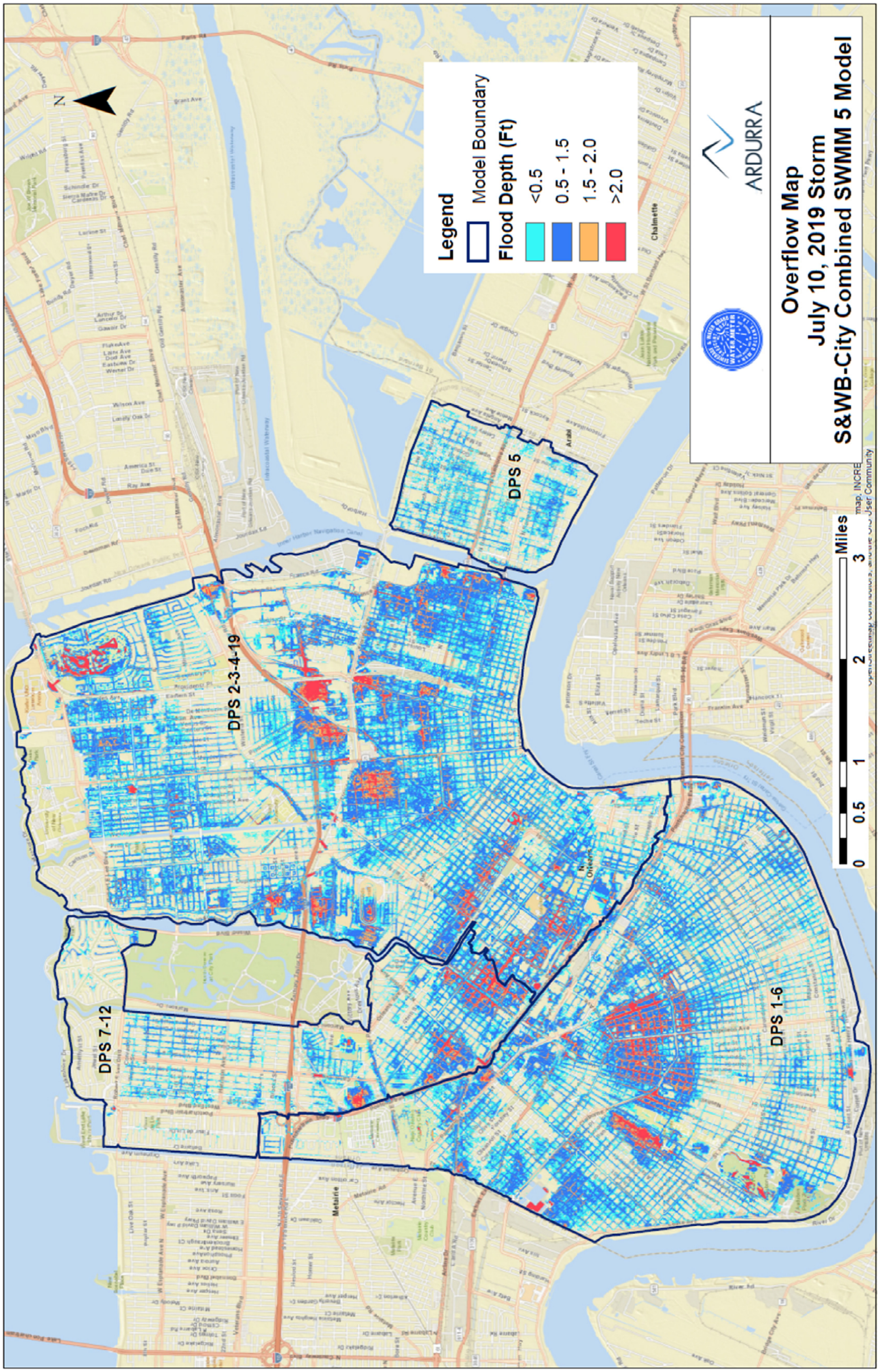


Figure 6 Overflow Map of the Study Area (July 10, 2019 Storm)
(Major and Minor Systems)

The SELA construction has expanded the drainage pumping capacities of stations to meet 10-year design storm standards and has increased the drainage canal capacities to both transport more flow to the massive drainage pumping stations and to increase below ground storage rather than relying on above ground storage during large rain events. The East Bank SELA construction projects were in areas that had experienced a high degree of repetitive flood loss claims under the Federal Flood Assistance Program.

In the areas that have had SELA construction projects there has been a marked reduction in flooding during events that approximate the 10-year design storm. SELA has proven effective at reducing flood damage claims and is an important part of the Hurricane Risk Reduction System that was implemented after Katrina.

6. Conclusions

The SWMM Model results are very close to the recorded data and generally agree with the observations.

The rainfall event of July 10, 2019 was greater than a 100-year event. The SELA construction projects are bringing the major drainage system to a 10-year design storm. The secondary and tertiary drainage system that flows into the major drainage system is at a 2-year design storm, and in some areas, does not even meet that criteria. The pumping system and the major conveyance system were not designed to handle the rainfall that occurred on July 10. These secondary and tertiary systems were not designed to handle this type of event. If the hundreds of millions of dollars were identified to bring those minor systems up to a 10-year design storm, they still would not have been close to being able to handle this high intensity, 100-year storm event.

The SELA improvements have had a dramatic impact on the drainage system in the areas where there has been SELA construction. Those improvements will be further enhanced when the secondary and tertiary systems are brought to the same standards as the SELA construction. At no point will a drainage system designed to handle a 10-year storm event be able to withstand a 100-year storm without incurring some flooding.

The drainage system would benefit from a preventive maintenance program that resembles the aggressive Preventative Maintenance schedule the SWB utilizes for the sanitary sewer system. This could include:

- Scheduling regular inspections of major drainage canals. From these inspections, preventive maintenance can be scheduled which could include removal of debris from covered and open canals. Earthen canals can be compared to their original design and can be reshaped to ensure that they will be able to handle the flows required.
- Regular inspections of canal banks to remove debris dumped on canal rights-of-way and vigilant effort to remove trash from street rights-of-way to lower the amount of debris that could impact drainage operations during these intense rain events.
- Inspection and maintenance of secondary and tertiary drainage systems, to include cleaning of drain catch basin and catch basin leads. Residents can be encouraged to monitor the gutter

bottom areas in front of their homes and provide debris removal to the best of their ability and to report conditions that are beyond their capability to repair.

- Increase green infrastructure projects that will provide rainwater a beneficial reuse rather than a system that forces rainwater into the drainage system as rapidly as possible.
- Enforcement of a Developers Policy towards reducing storm water runoff from large private developments and into the public right of way.
- Identification of any potential storage locations that can be pumped into during high intensity events.

7. References

Brown, V.M. Keim, B.D., Black, A.W. 2019, “Climatology and Trends in Hourly Precipitation for the Southeast United States”, Journal of Hydrometeorology

Appendices

A. Comparison of observed water levels with the model results

B. Photos with Street Flooding

C. Modelers Involved

A. Comparison of observed vs modeled water levels

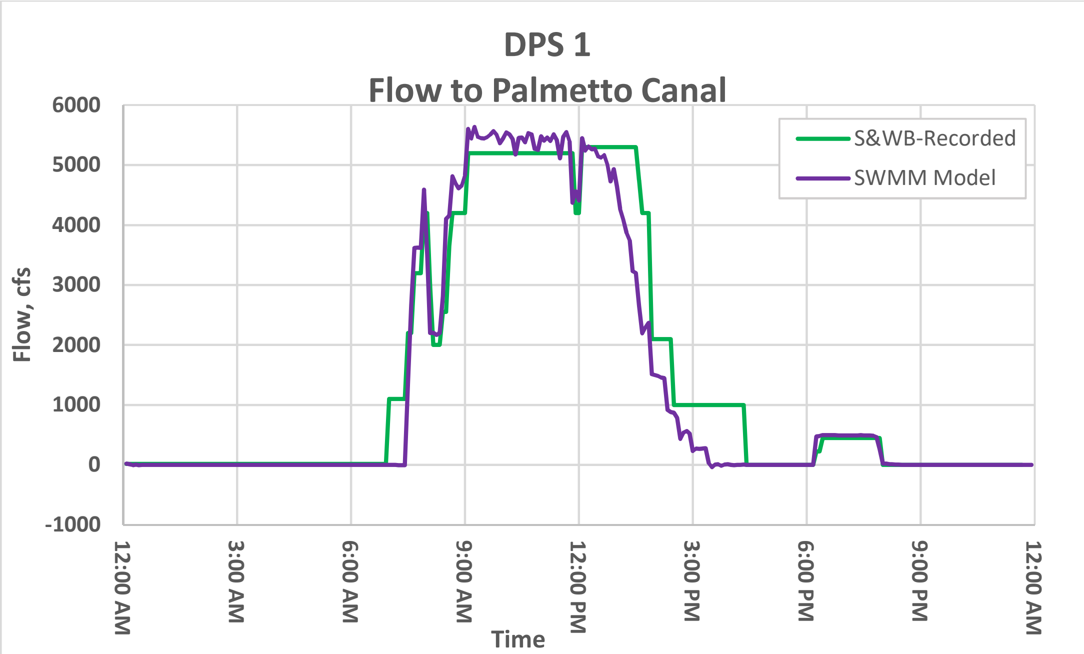


Figure A - 1 DPS 1 Flow to Palmetto Canal

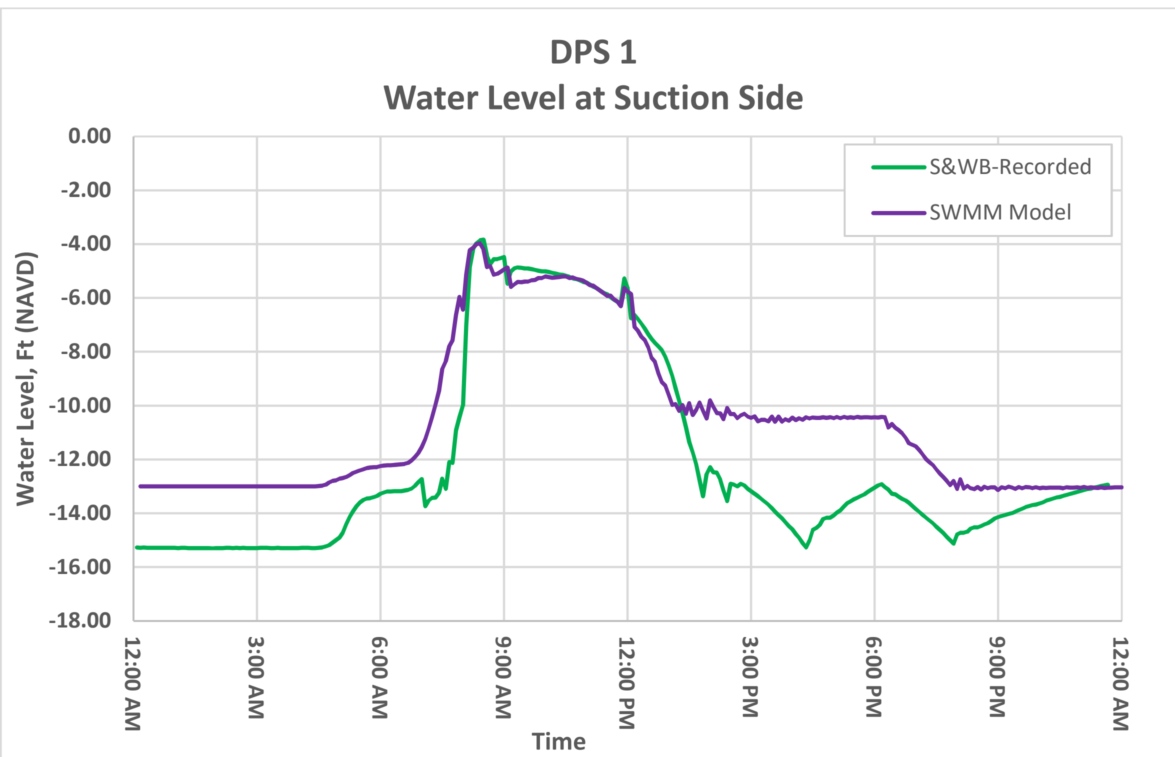


Figure A - 2 DPS 1 Water Level at Suction Side

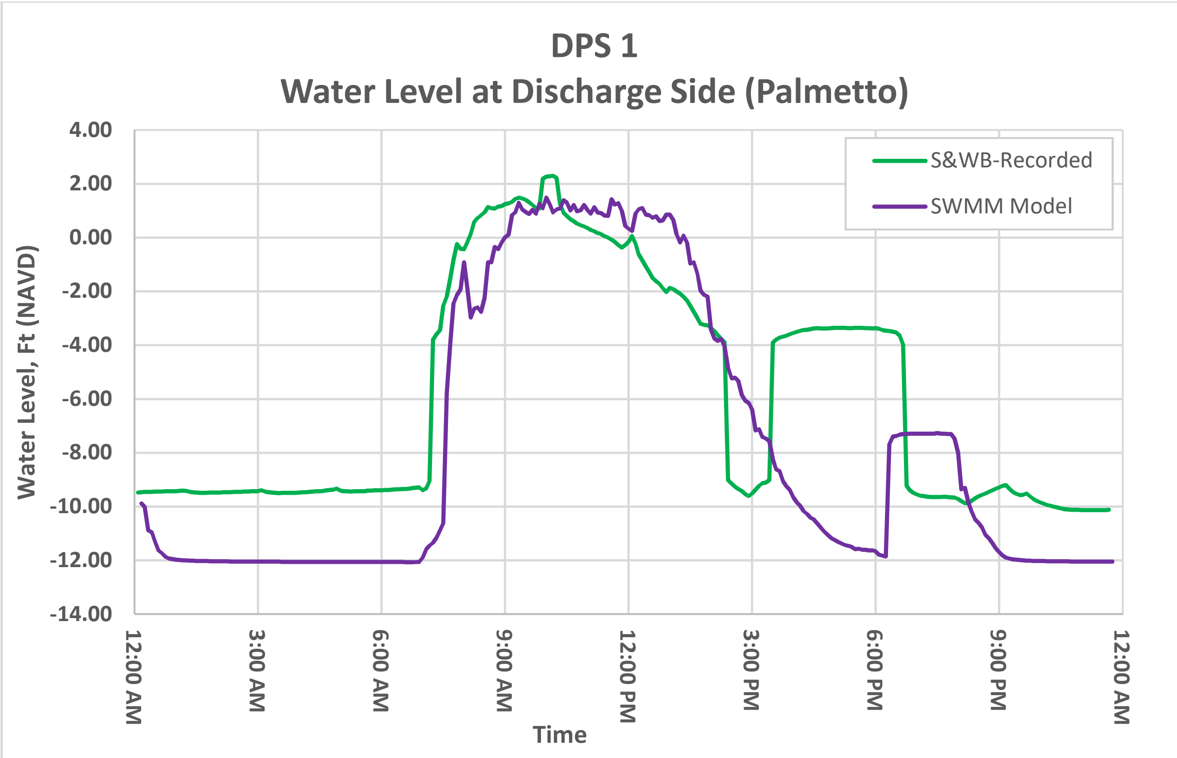


Figure A - 3 DPS 1 Water Level at Discharge Side (Palmetto)

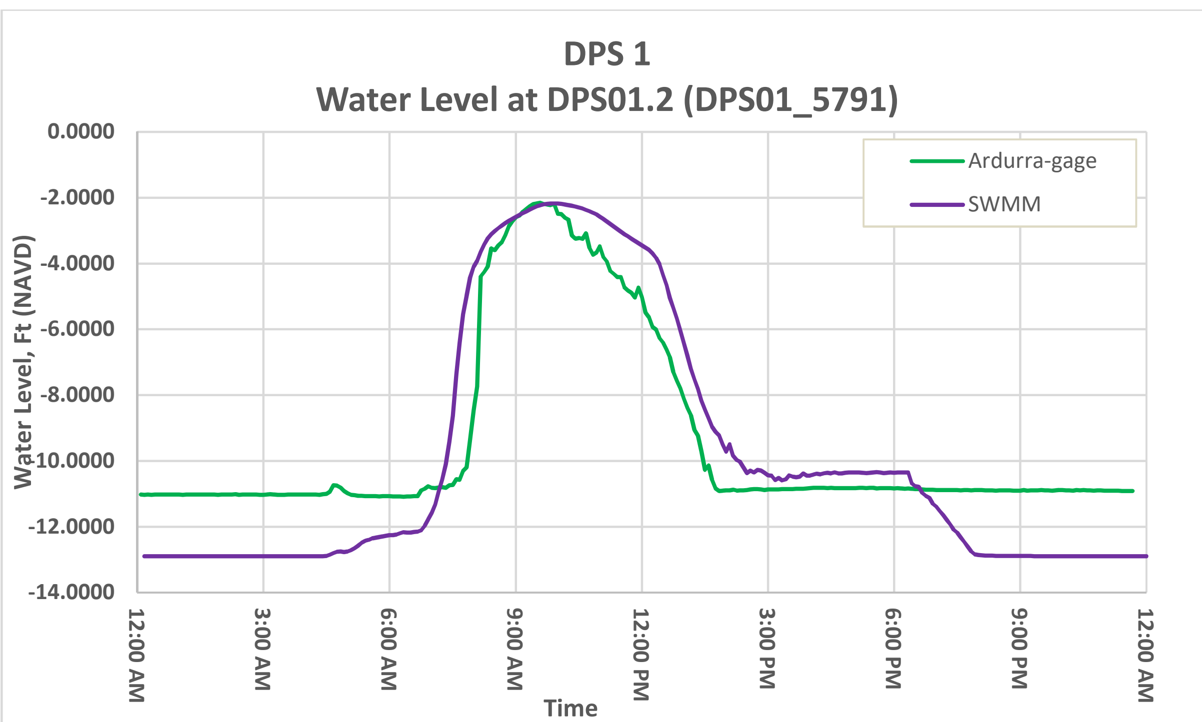


Figure A - 4 DPS 1 Water Level at DPS01.2 (DPS01_5791)

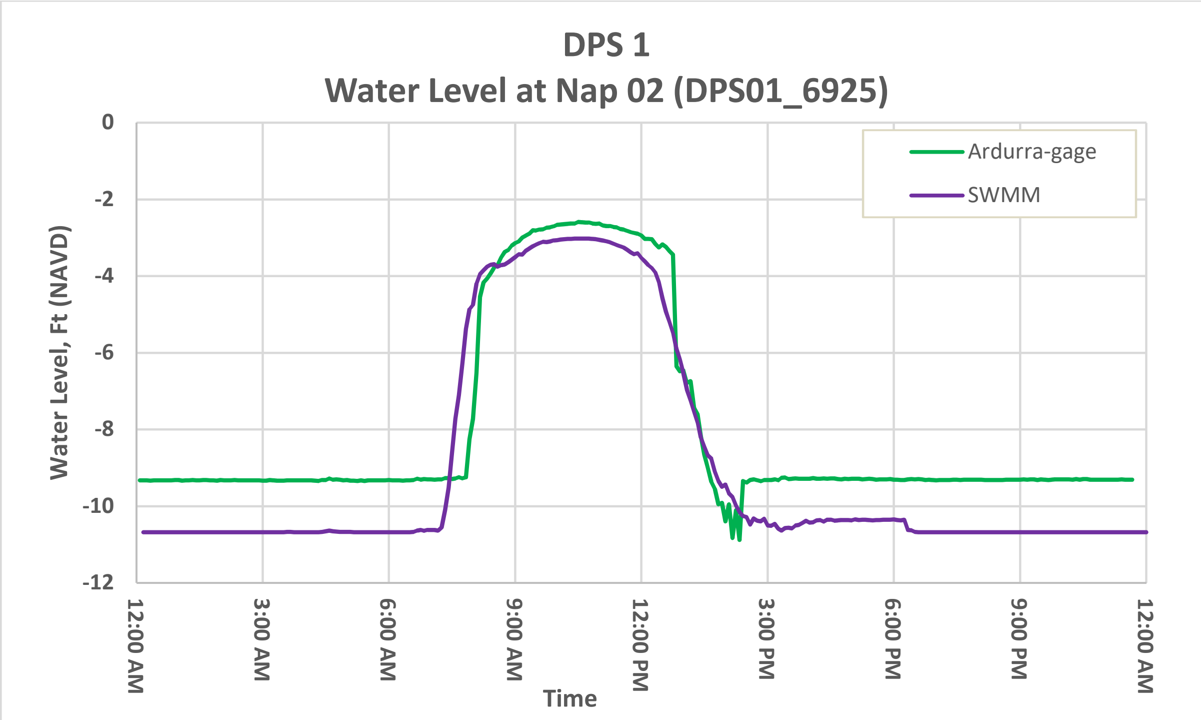


Figure A - 5 DPS 1 Water Level at Nap 02 (DPS01_6925)

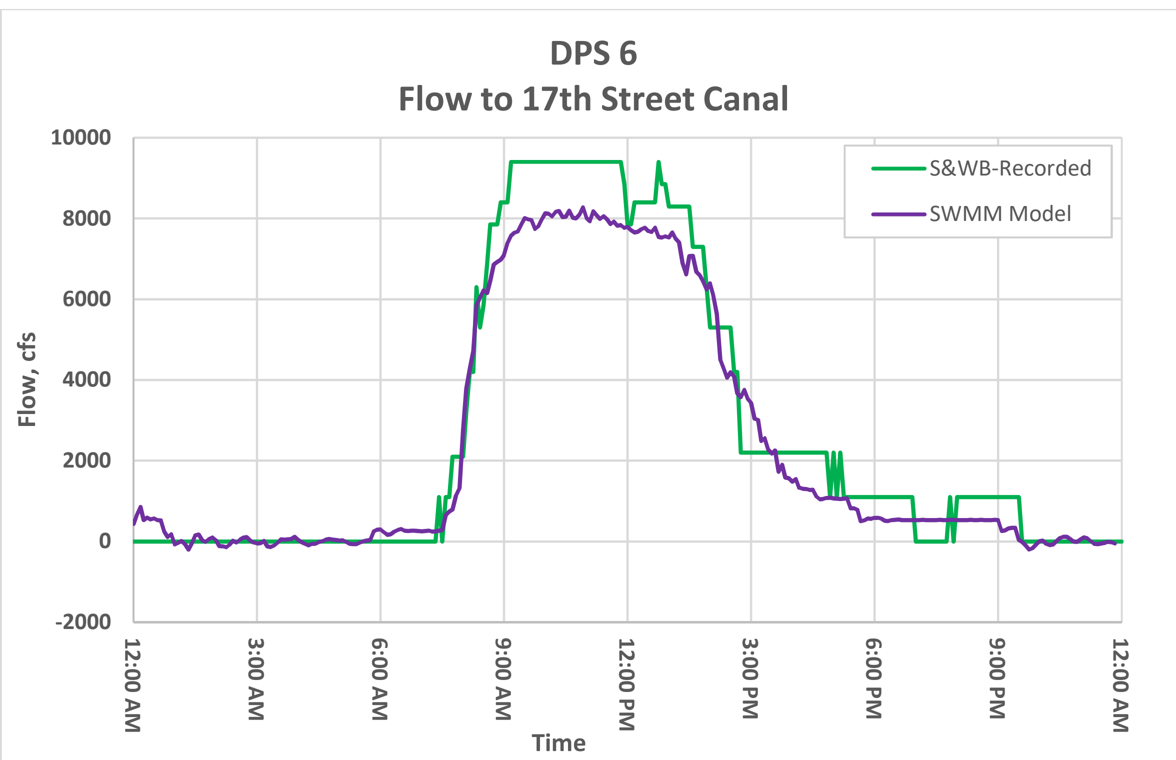


Figure A - 6 DPS 6 Flow to 17th Street Canal

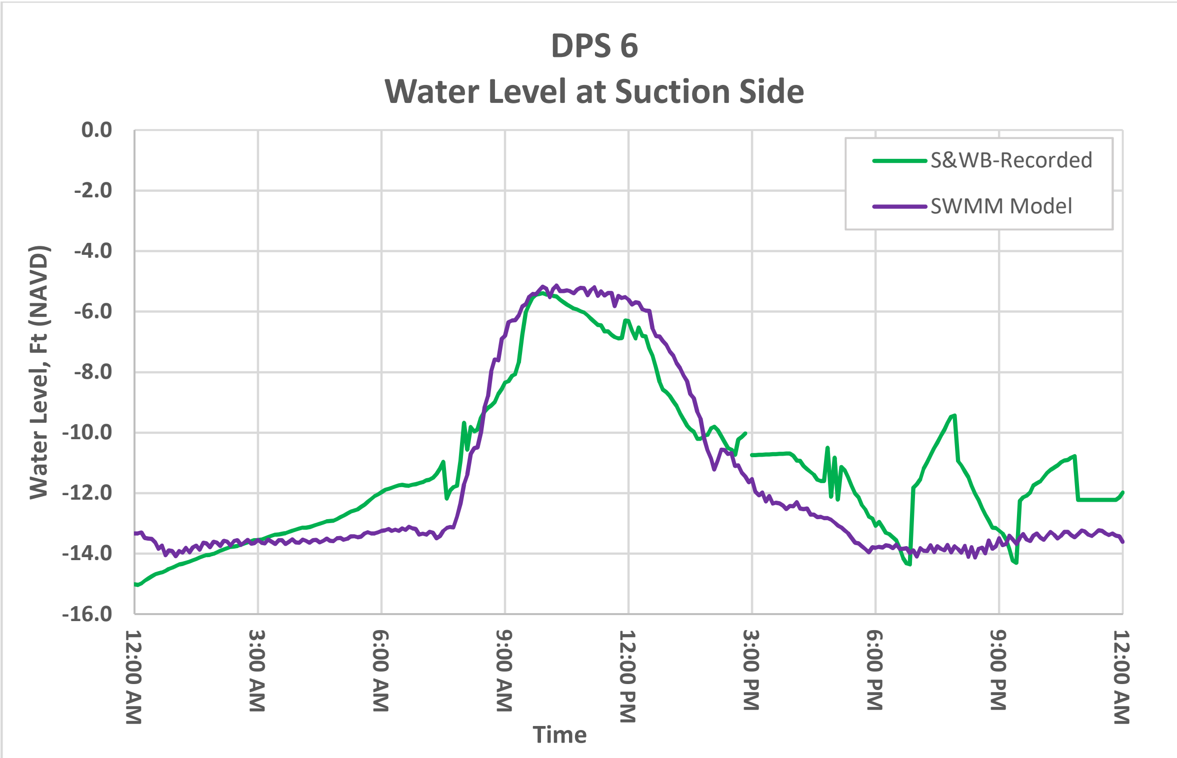


Figure A - 7 DPS 6 Water Level at Suction Side

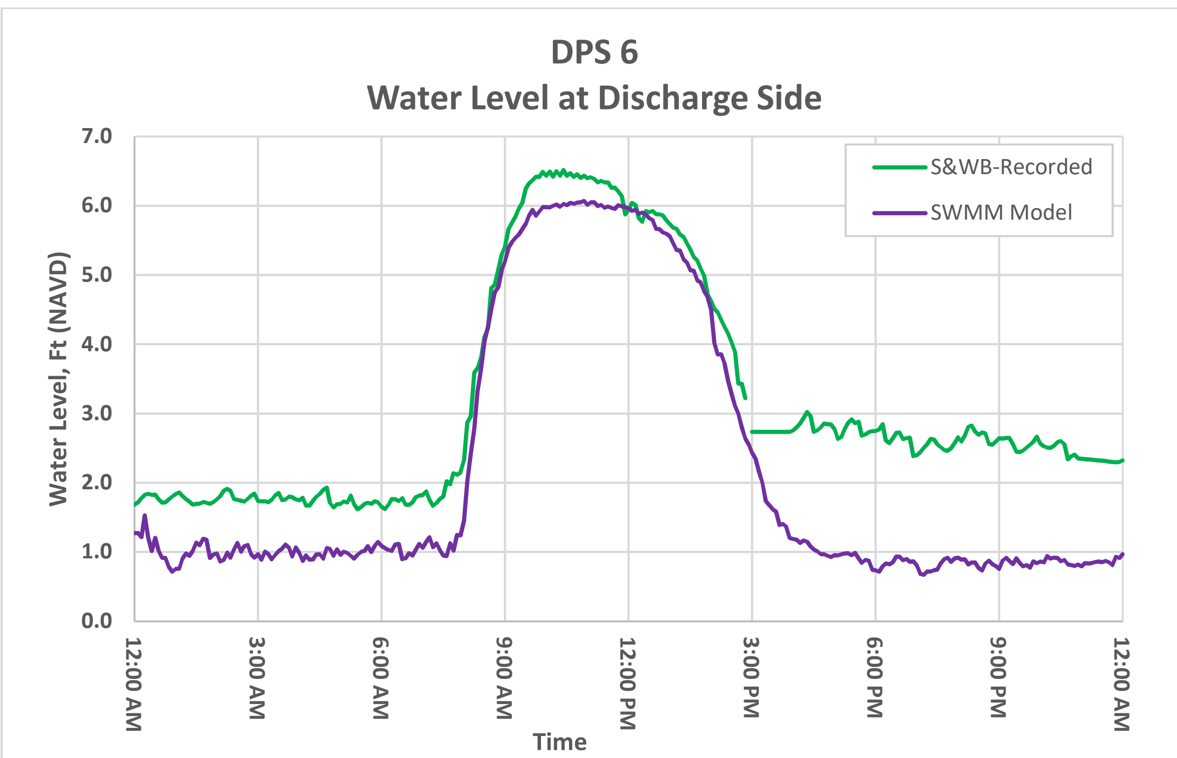


Figure A - 8 DPS 6 Water Level at Discharge Side

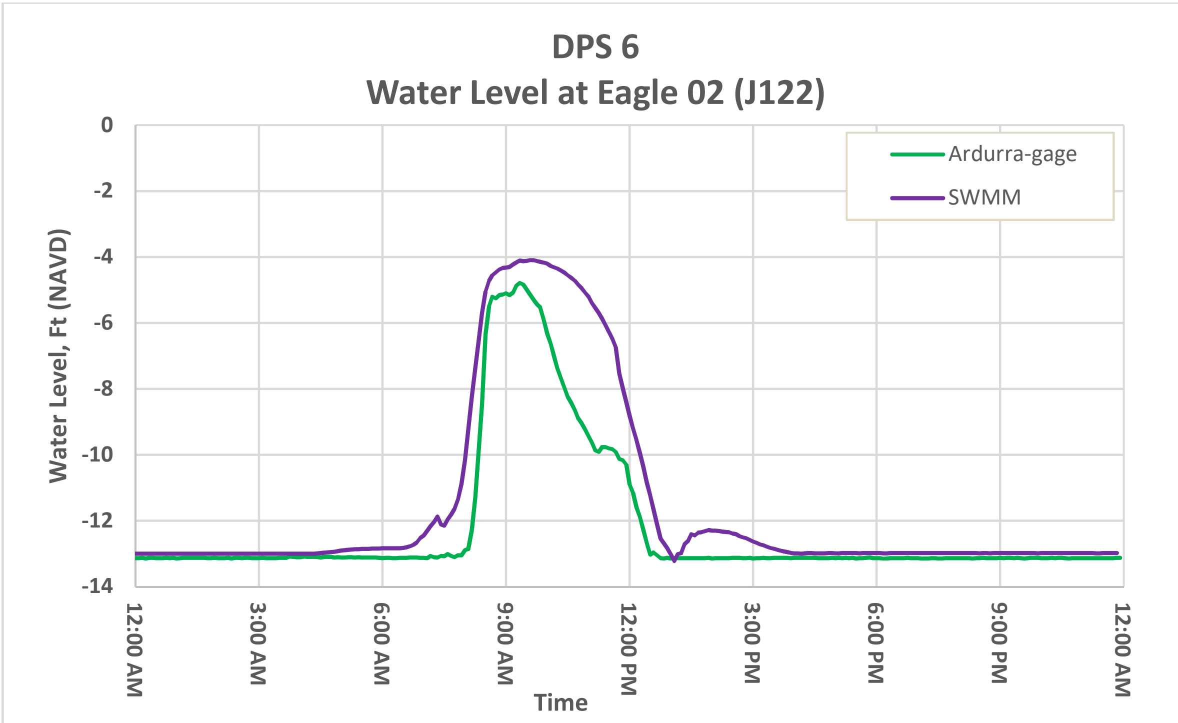


Figure A - 9 DPS 6 Water Level at Eagle 02 (J122)

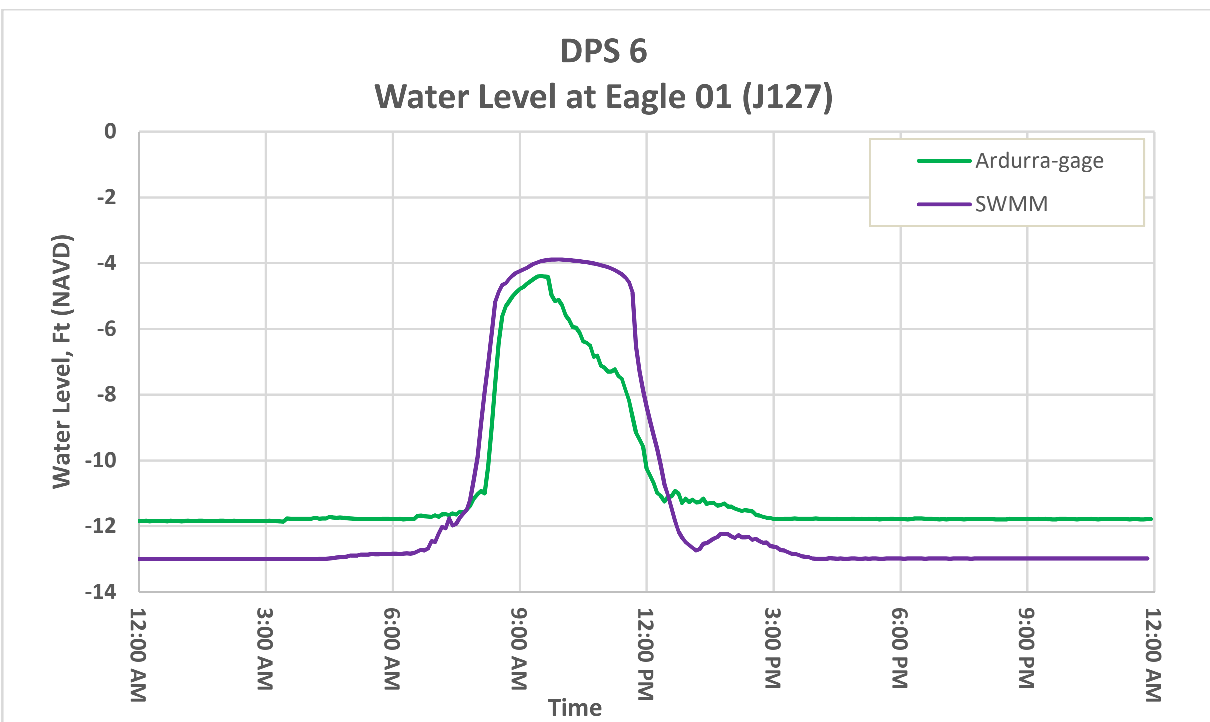


Figure A - 10 DPS 6 Water Level at Eagle 01 (J127)

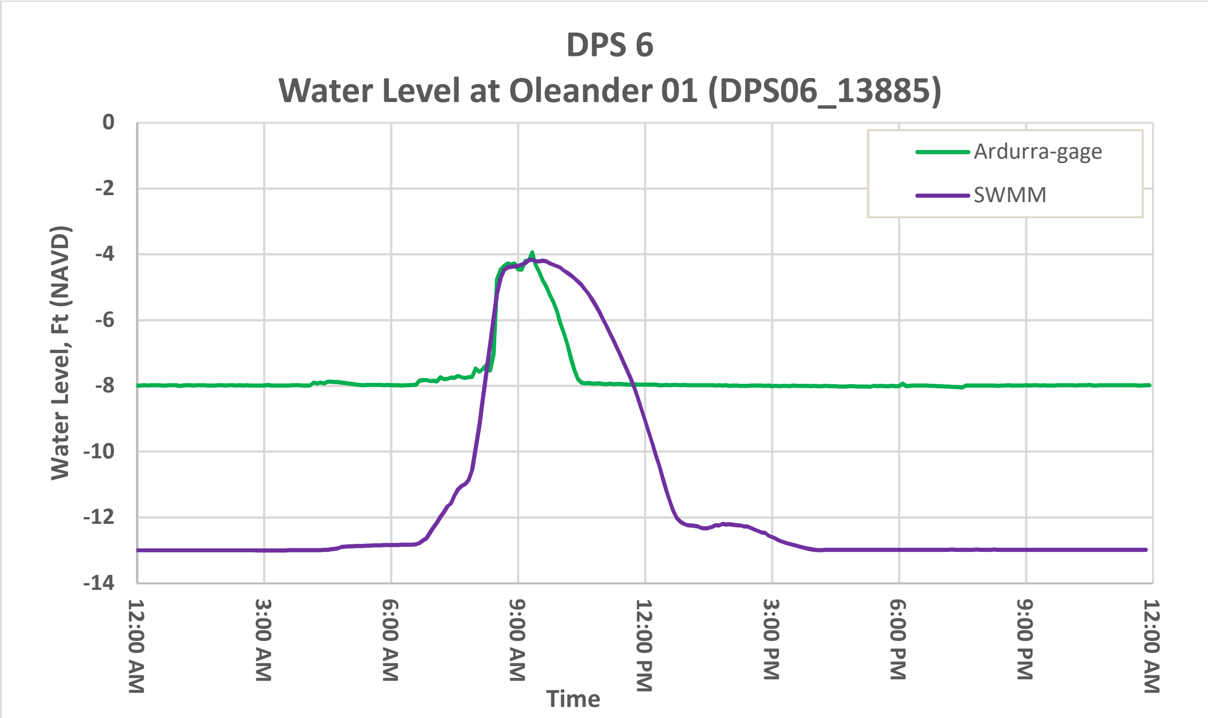


Figure A - 11 DPS 6 Water Level at Oleander 01 (DPS06_13885)

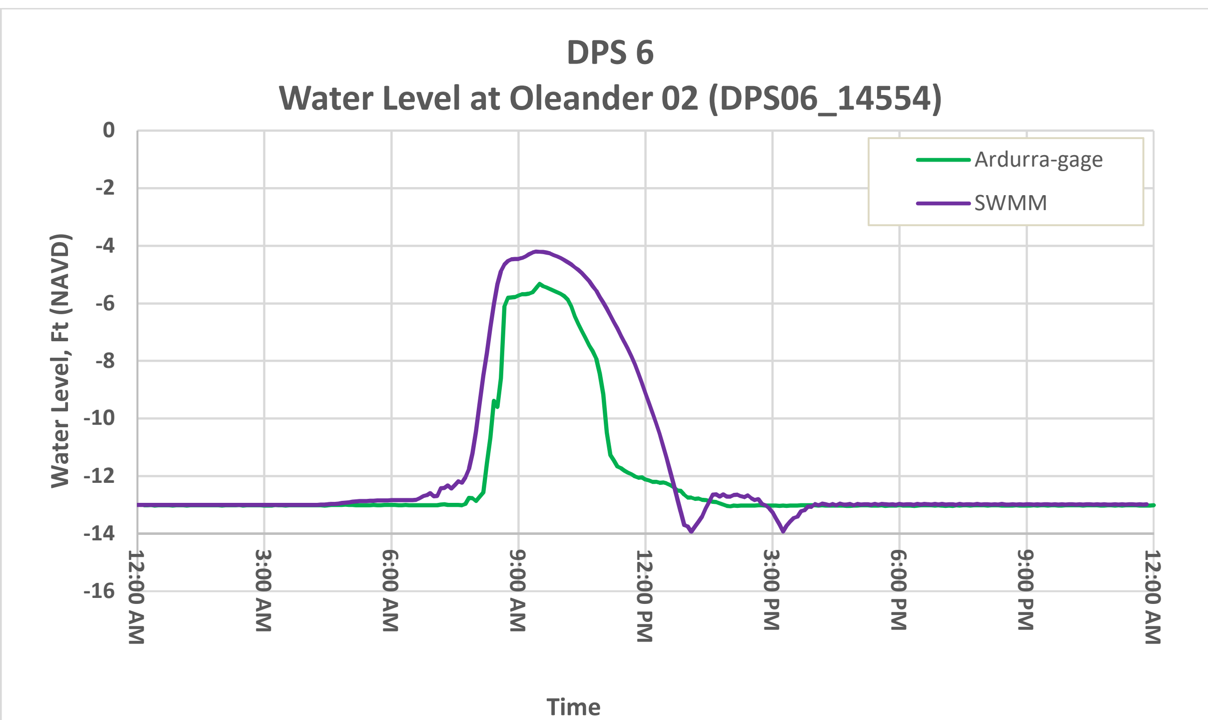


Figure A - 12 DPS 6 Water Level at Oleander 02 (DPS06_14554)

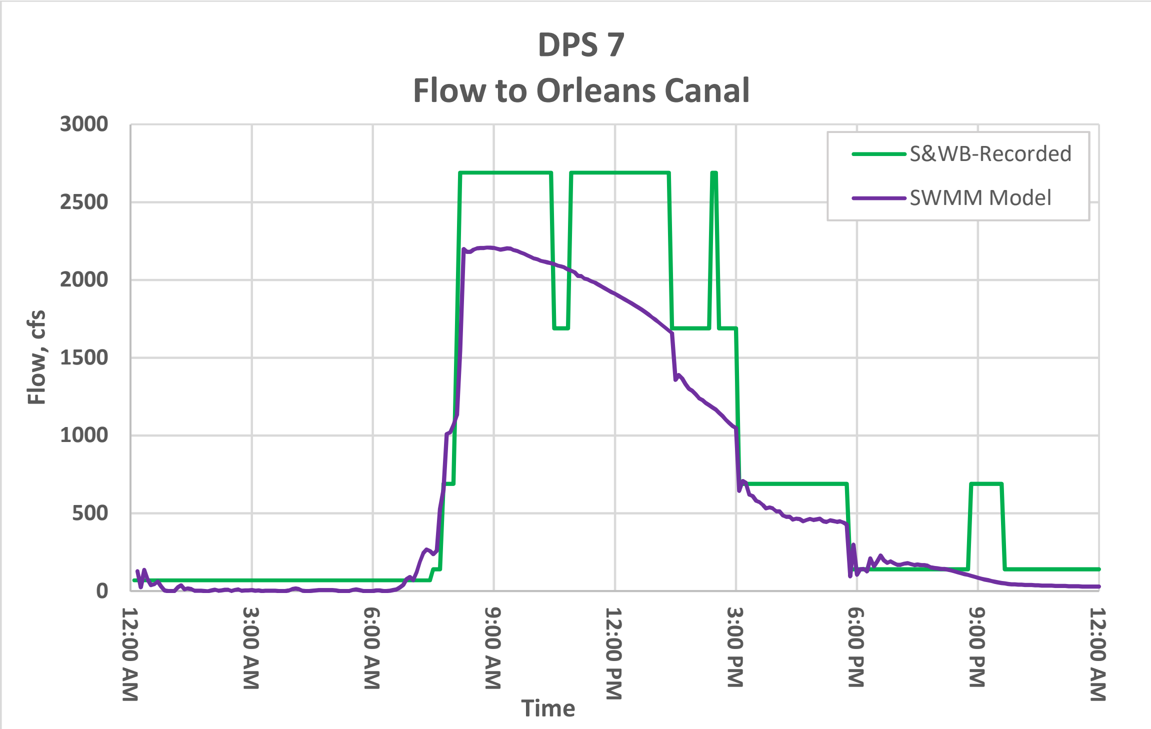


Figure A - 13 DPS 7 Flow to Orleans Canal

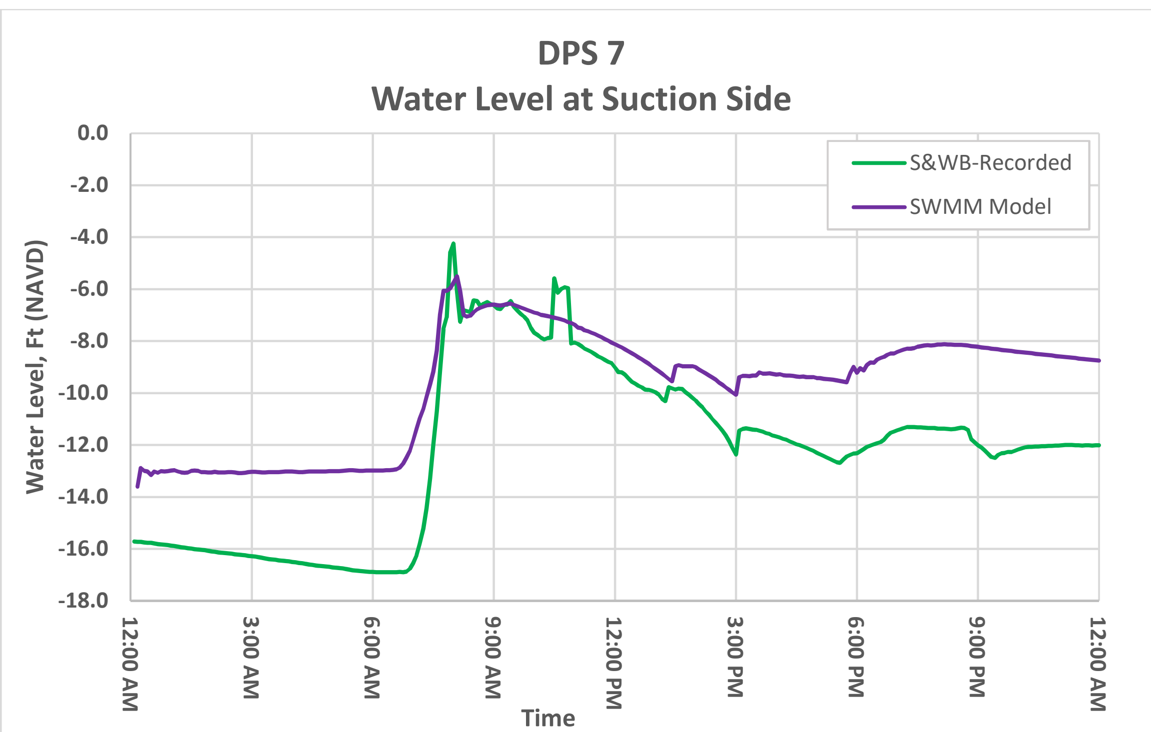


Figure A - 14 DPS 7 Water Level at Suction Side

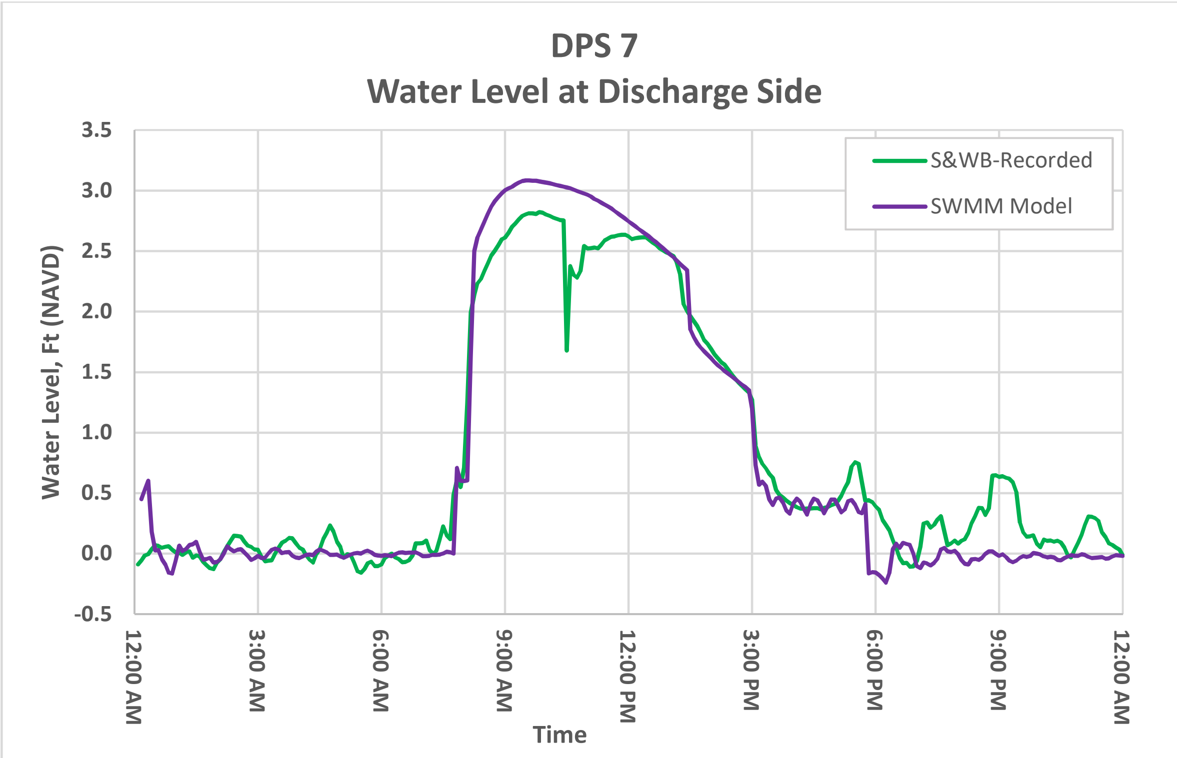


Figure A - 15 DPS 7 Water Level at Discharge Side

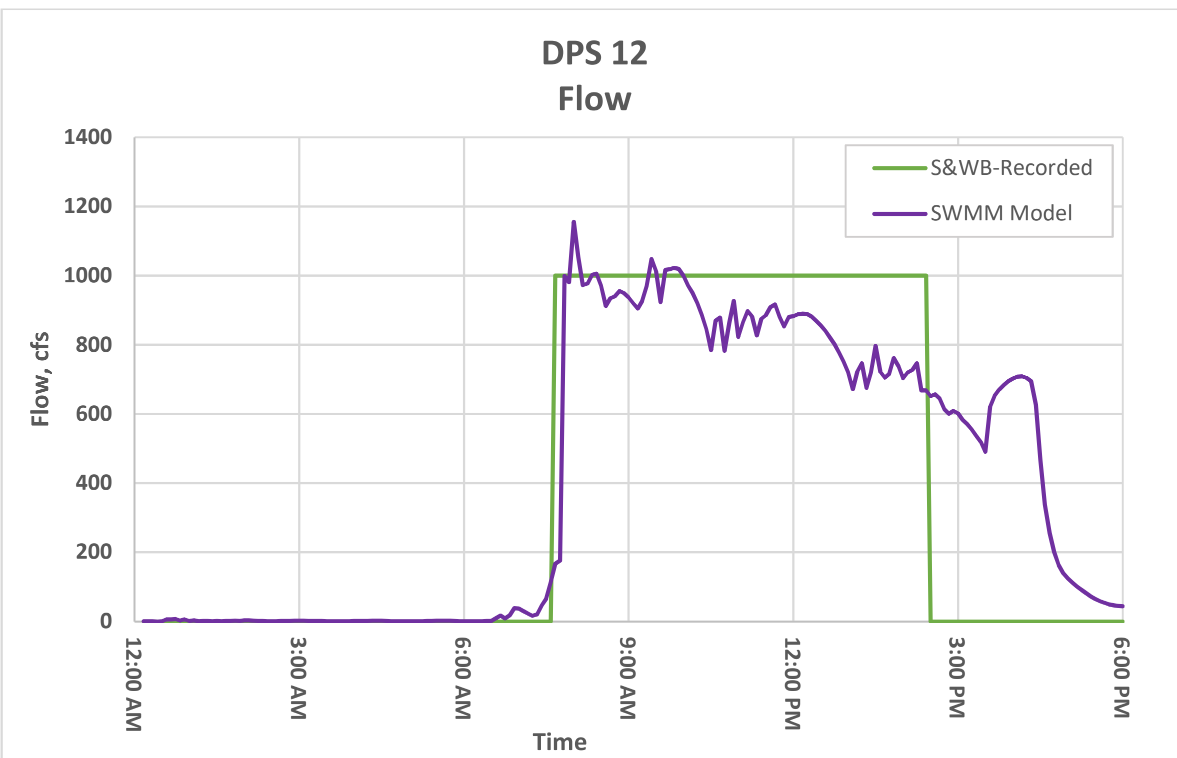


Figure A - 16 DPS 12 Flow

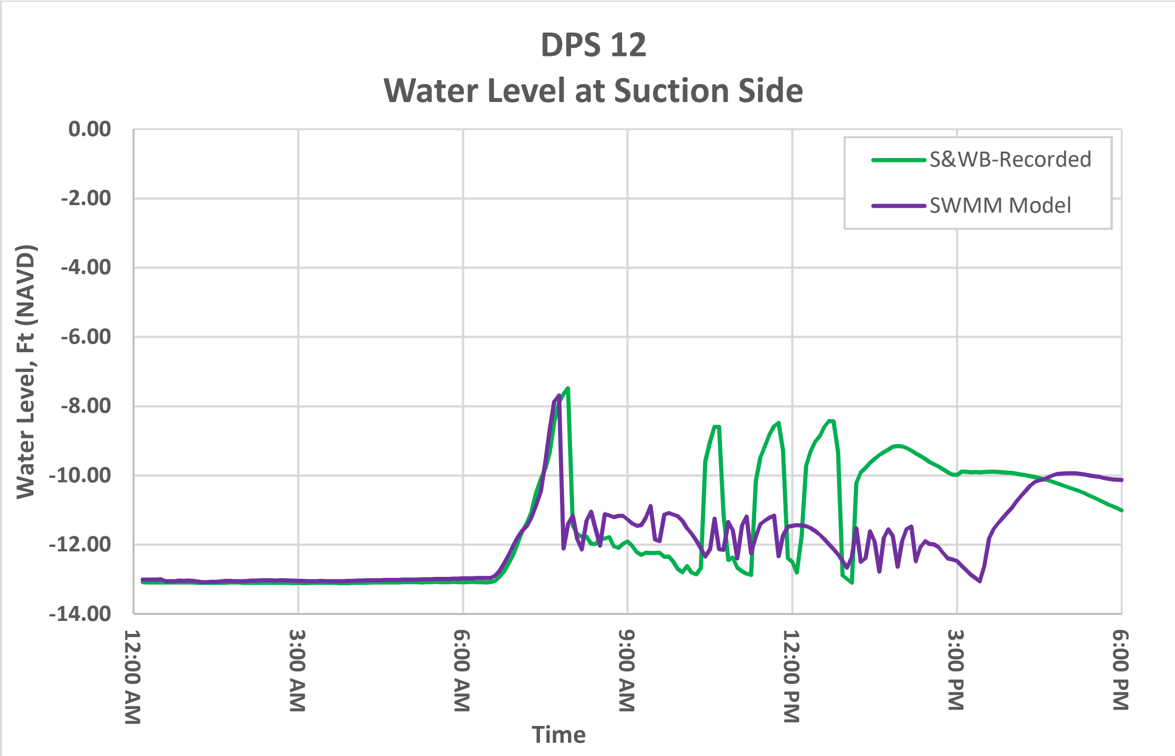


Figure A - 17 DPS 12 Water Level at Suction Side

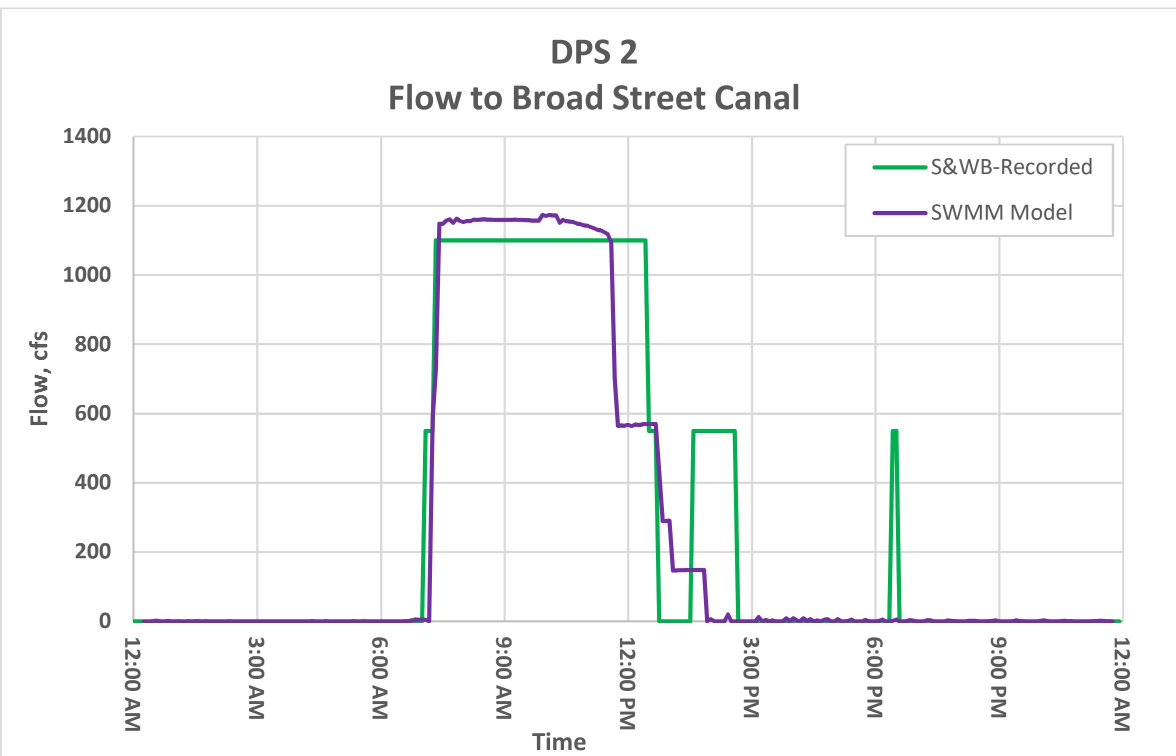


Figure A - 18 DPS 2 Flow to Broad Street Canal

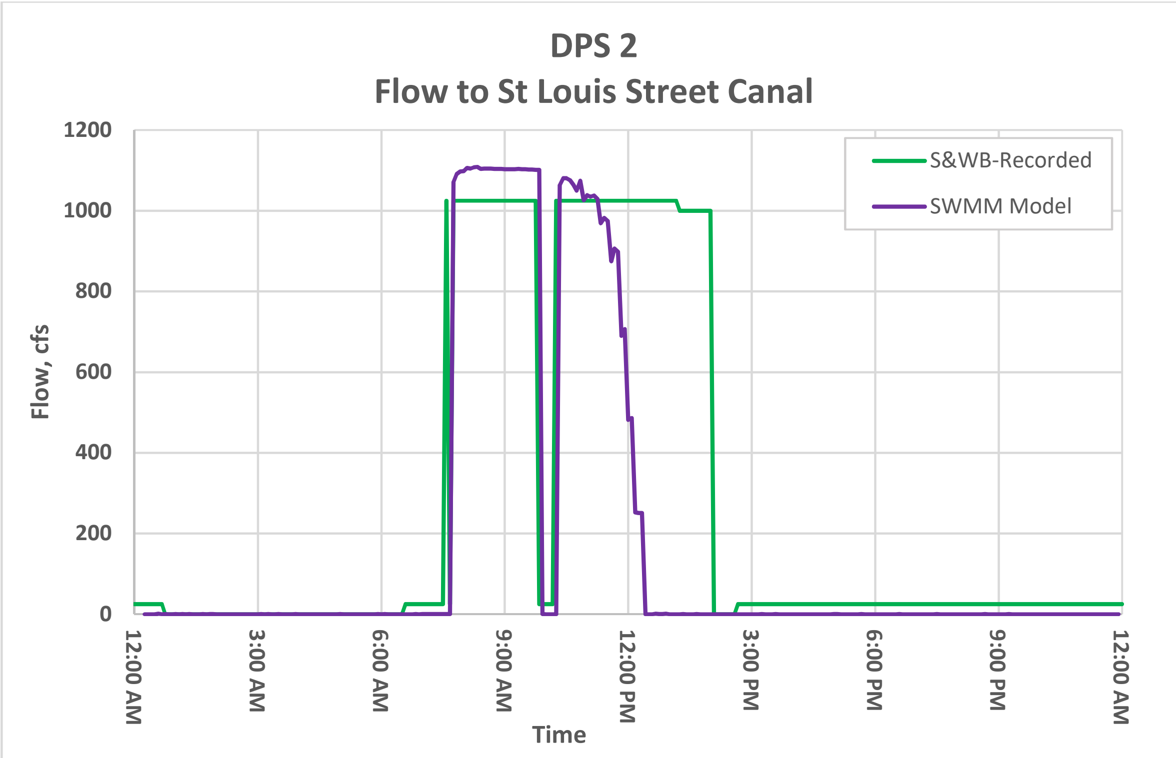


Figure A - 19 DPS 2 Flow to St Louis Street Canal

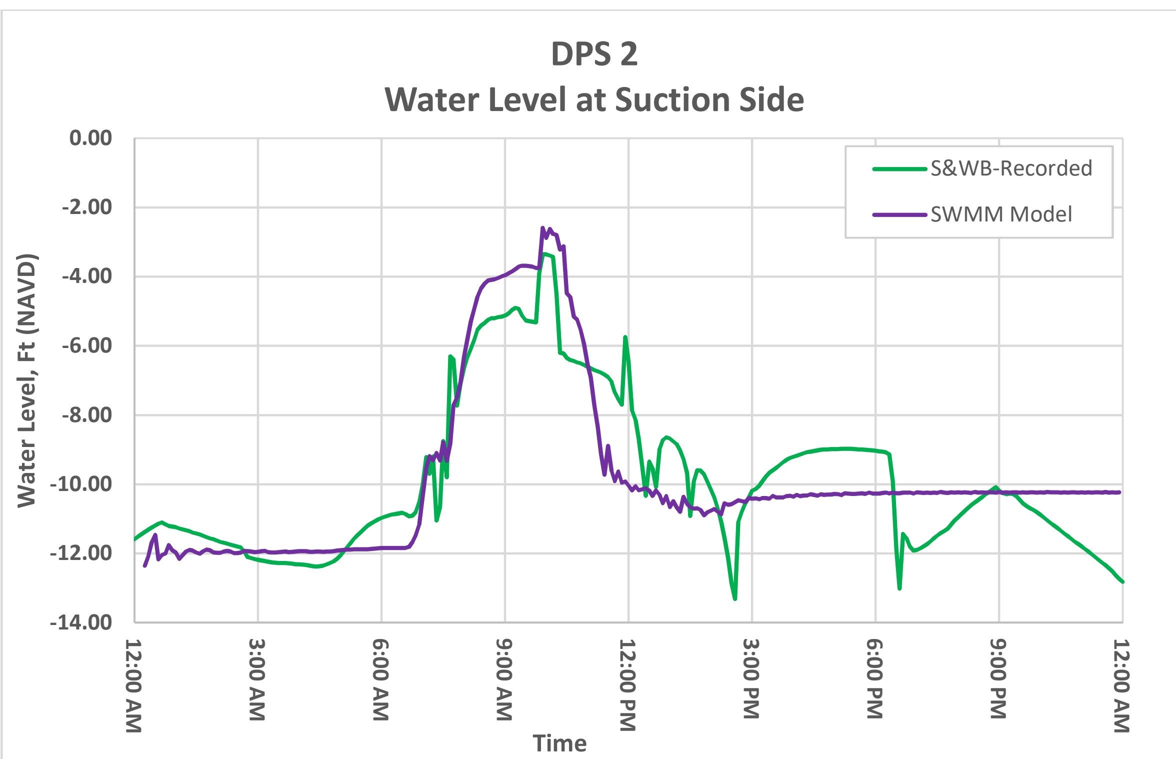


Figure A - 20 DPS 2 Water Level at Suction Side

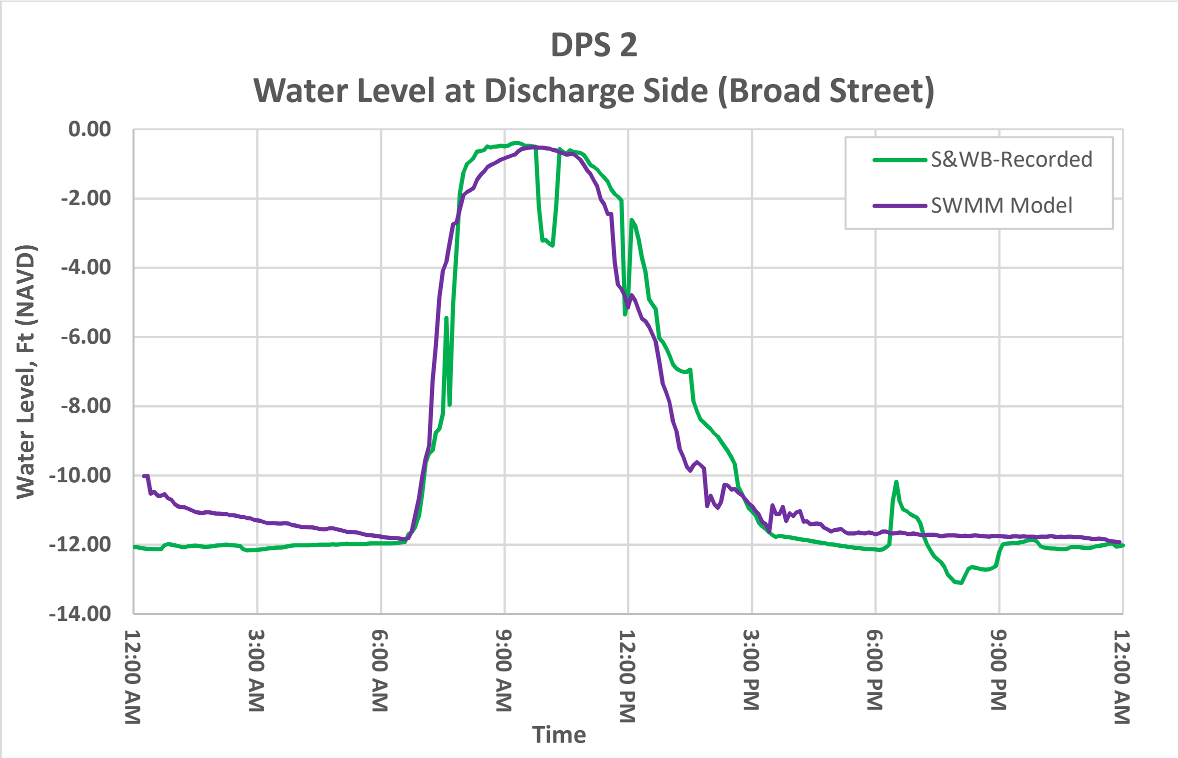


Figure A - 21 DPS 2 Water Level at Discharge Side (Broad Street)

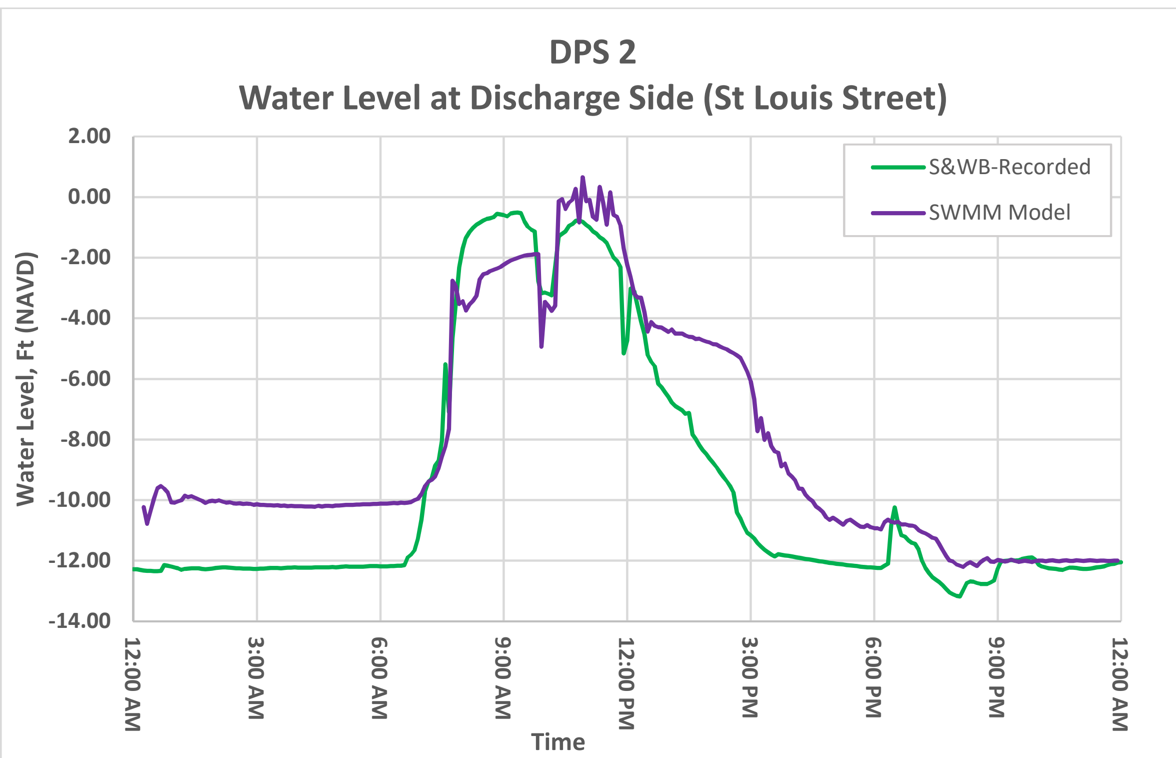


Figure A - 22 DPS 2 Water Level at Discharge Side (St Louis Street)

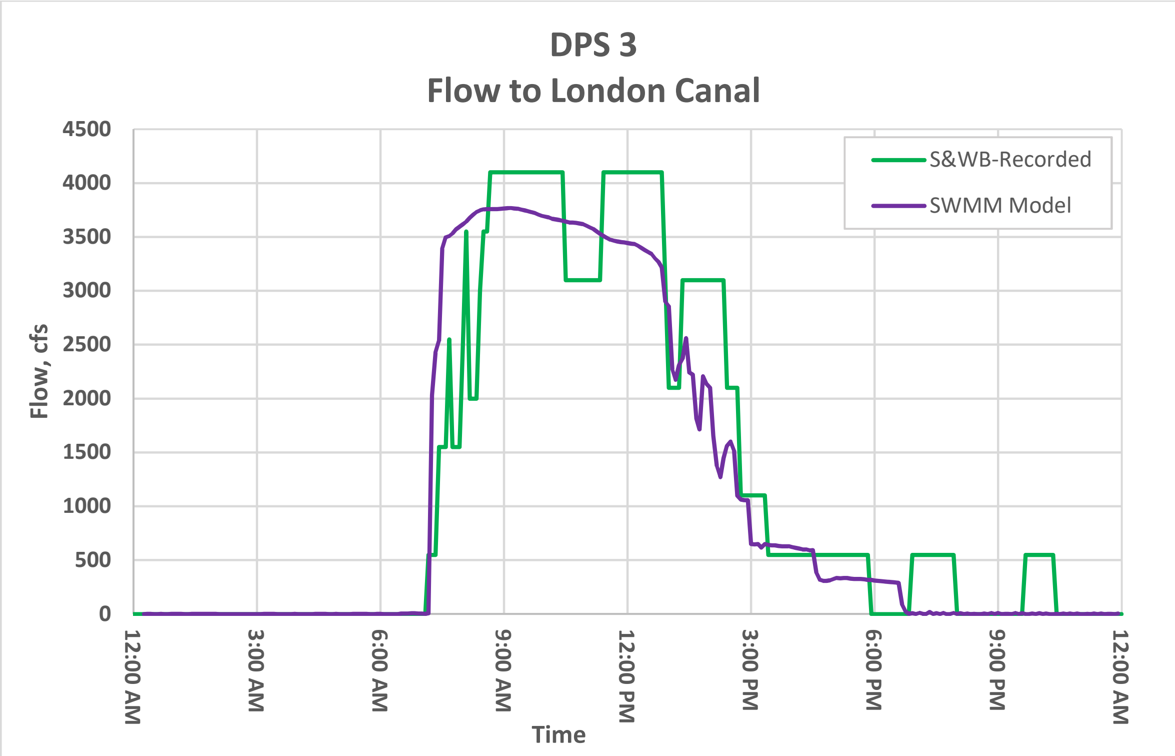


Figure A - 23 DPS 3 Flow to London Canal

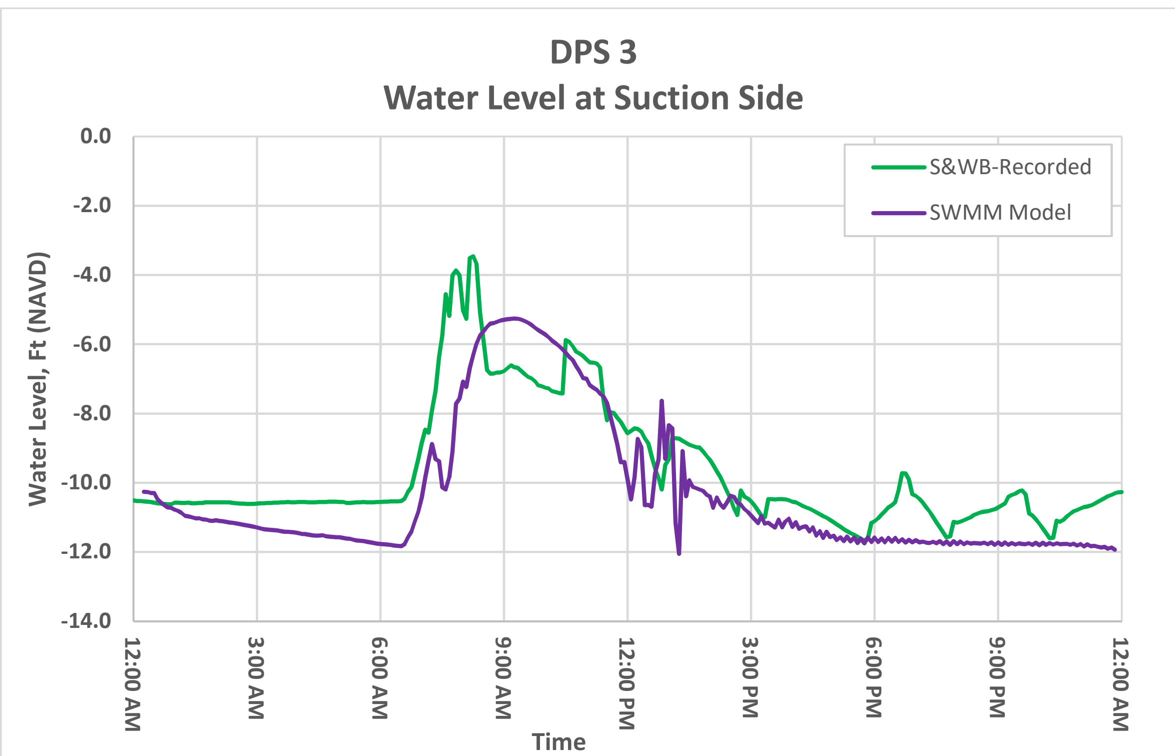


Figure A - 24 DPS 3 Water Level at Suction Side

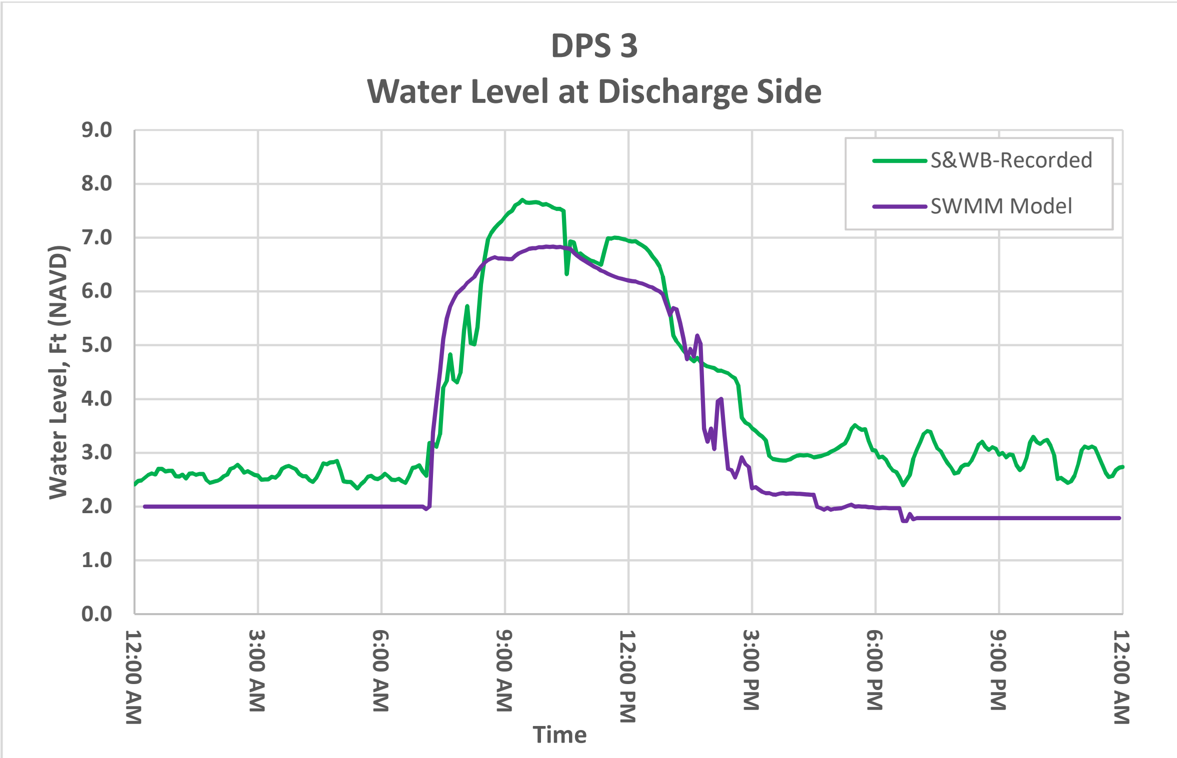


Figure A - 25 DPS 3 Water Level at Discharge Side

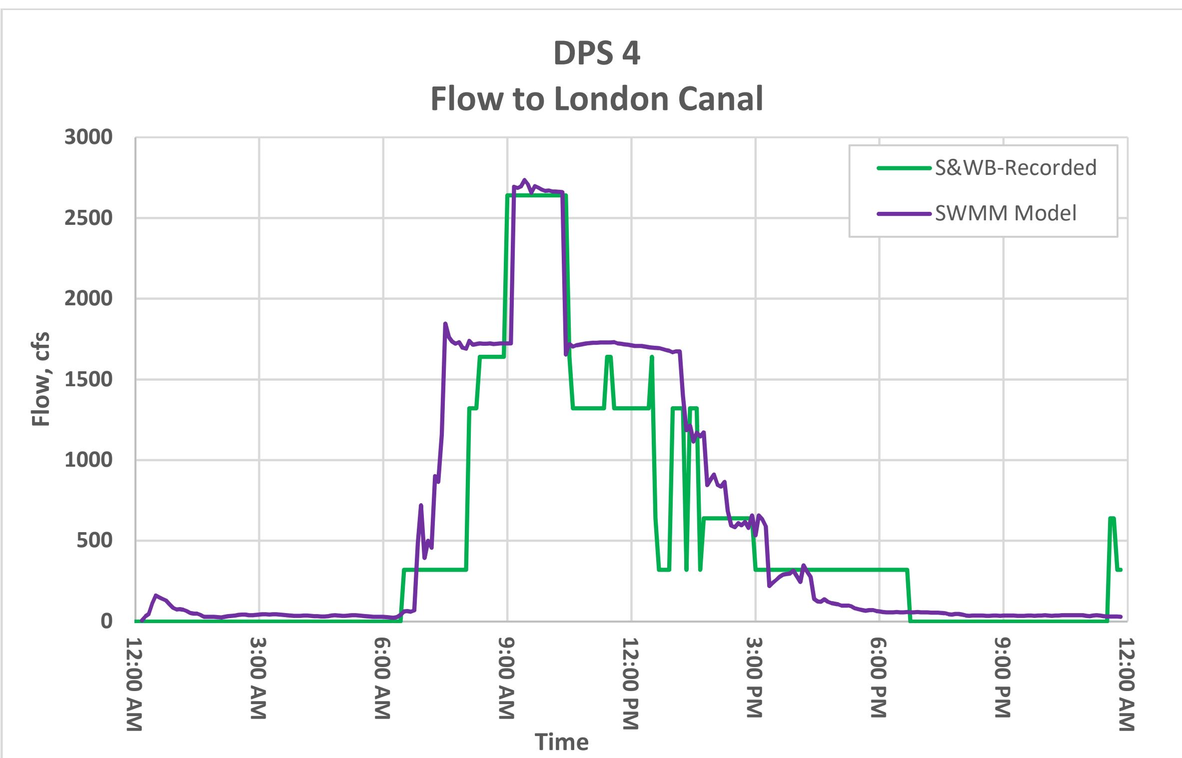


Figure A - 26 DPS 4 Flow to London Canal

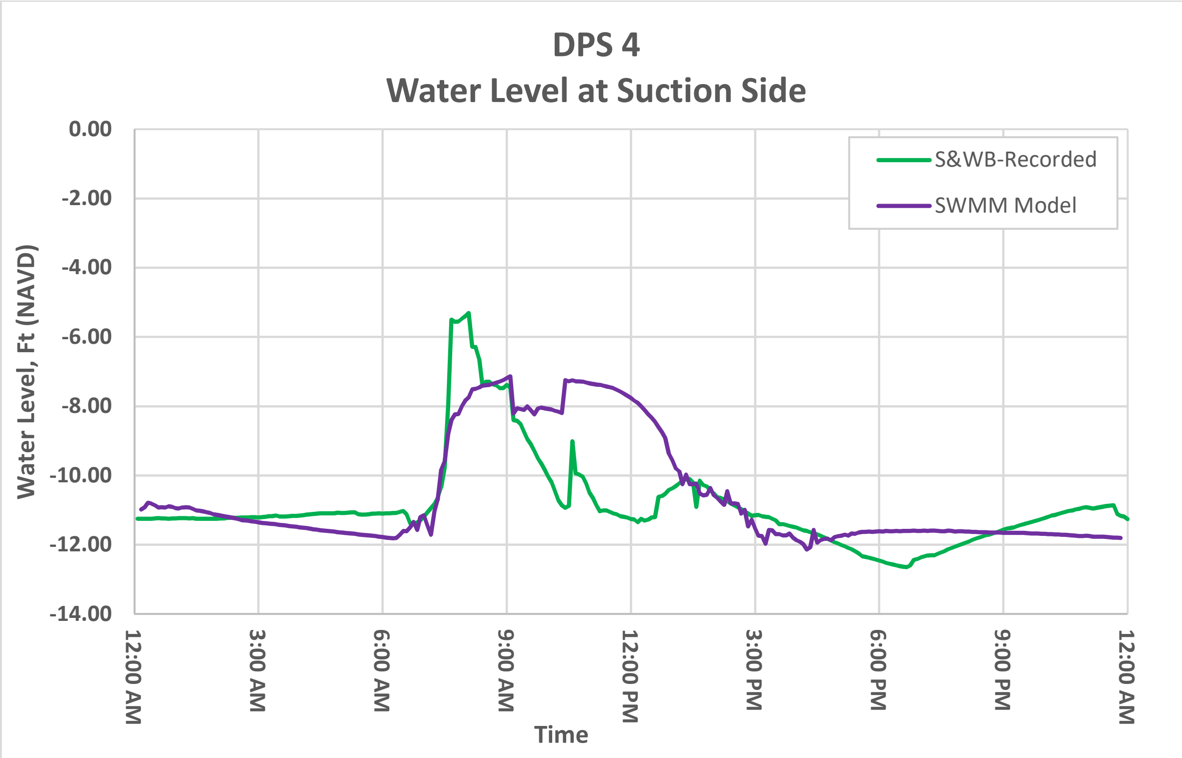


Figure A - 27 DPS 4 Water Level at Suction Side

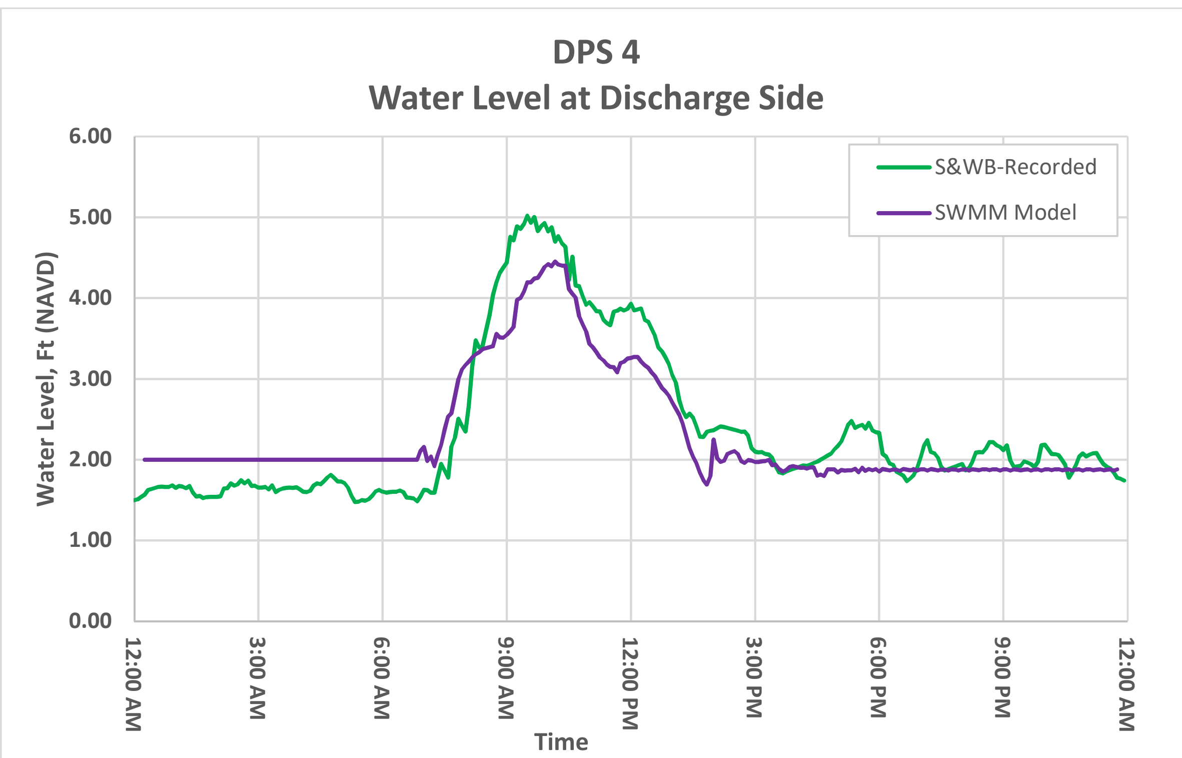


Figure A - 28 DPS 4 Water Level at Discharge Side

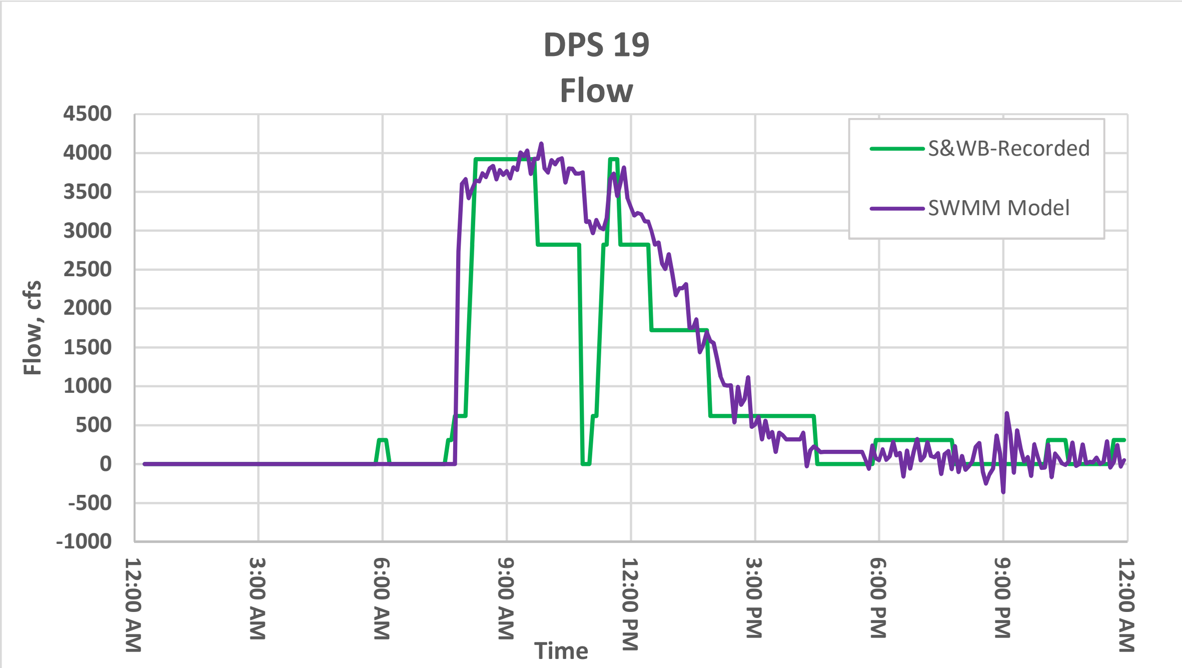


Figure A - 29 DPS 19 Flow

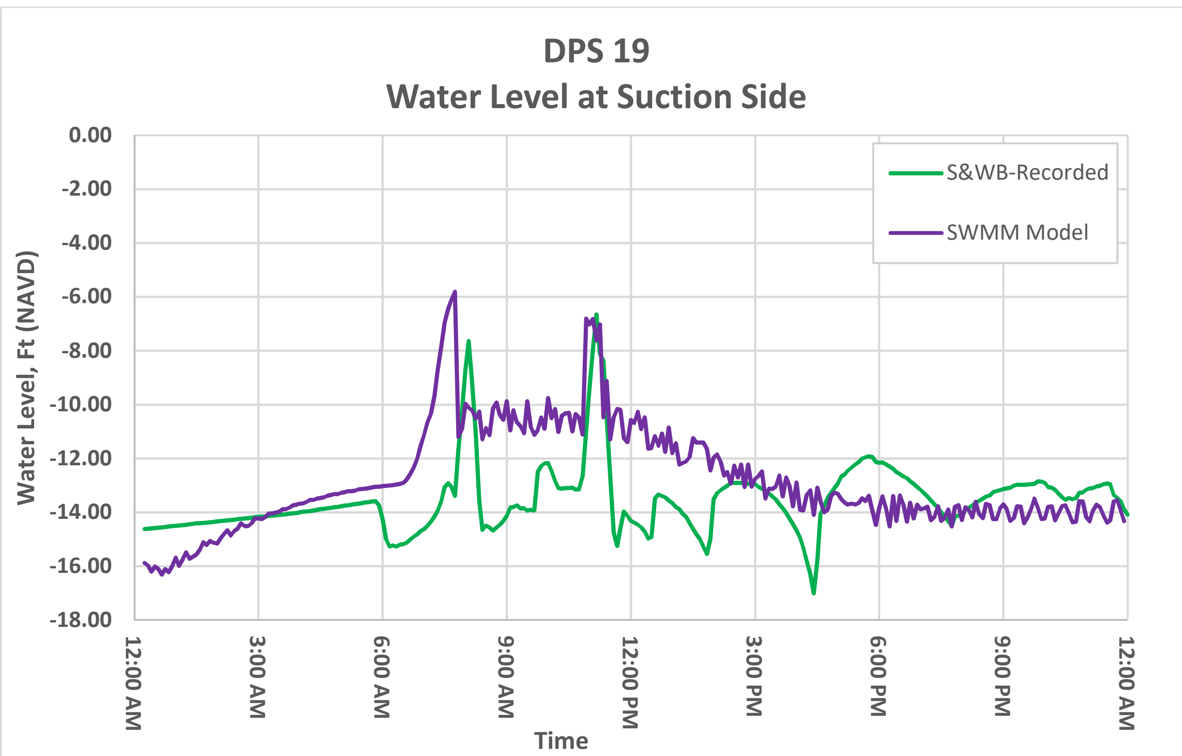


Figure A - 30 DPS 19 Water Level at Suction Side

B. Photos with Street Flooding

Photo 1 Street Flooding on St. Charles Ave.: 1. St. Charles near Broadway

Source :
(https://twitter.com/nolacampanella/status/1148981639256653825/photo/1?ref_src=twsrc%5Etfw%7Ctwcamp%5Etweetembed%7Ctwterm%5E1148981639256653825&ref_url=https%3A%2F%2Fwww.nola.com%2Fnews%2Fhurricane%2Farticle_bdf3482e-a330-11e9-a42d-1f111c5e6452.html

Photo 2 Street Flooding on Belfast St. Near Eagle St.: 2. Eagle-Belfast

Source : https://www.theadvertiser.com/media/cinematic/gallery/1707942001/hurricane-barry-flooding-in-new-orleans-louisiana/

Photo 3 Street flooding near Xavier University (1 Drexel Rd.): 3. Xavier

Source : https://www.nola.com/multimedia/photos/collection_c989d74a-a31a-11e9-bd7c-4b2a2d04ee27.html#17

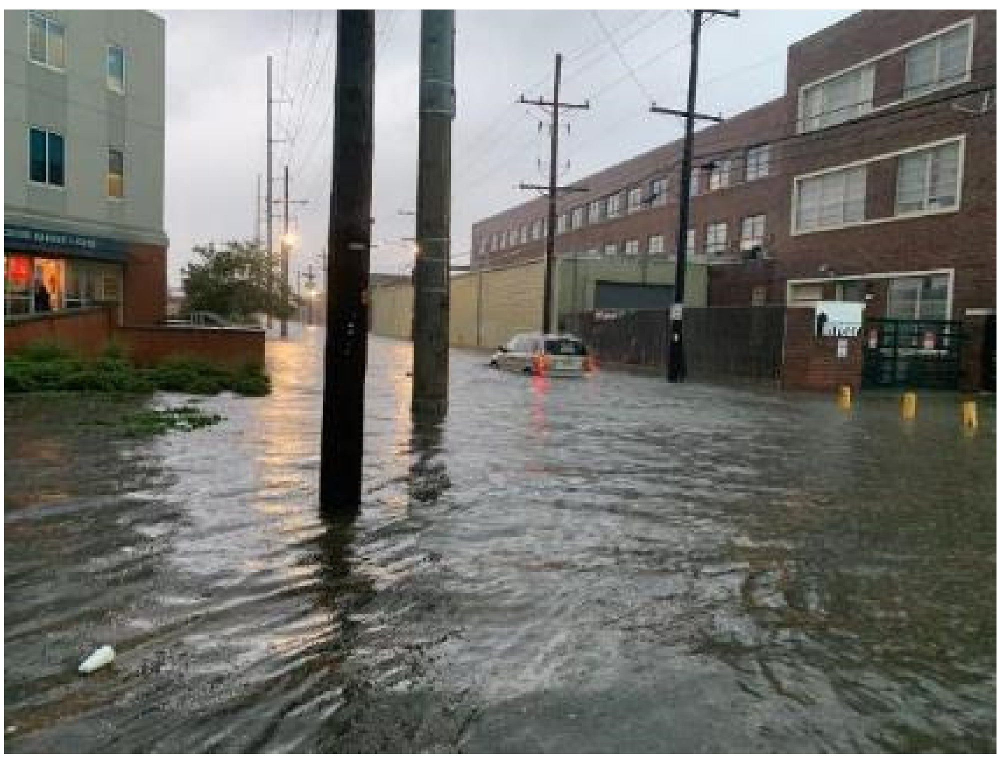


Photo 4 Street flooding in Mid-City (1000 S. Jefferson Parkway: 4. Gracious Bakery + Café

Source : https://www.nola.com/multimedia/photos/collection_c989d74a-a31a-11e9-bd7c-4b2a2d04ee27.html#17

Photo 5 Street flooding on S. Jefferson Davis Pkwy. Near Earhart Blvd.: 5. Earhart-S. Jeff Davis

Source : https://www.nola.com/multimedia/photos/collection_c989d74a-a31a-11e9-bd7c-4b2a2d04ee27.html#15

Photo 6 Street flooding in Broadmoor Neighborhood: 6. Broadmoor

Source : https://www.theadvertiser.com/media/cinematic/gallery/1707942001/hurricane-barry-flooding-in-new-orleans-louisiana/

Photo 7 Flooded bus stop at Tulane and S. Broad: 7. Tulane-S. Broad Bus Stop

Source : https://www.nola.com/multimedia/photos/collection_c989d74a-a31a-11e9-bd7c-4b2a2d04ee27.html#15

Photo 8 Flooding outside business in Treme/LaFitte (1001 N. Broad St.): 8. Crescent City Steaks

Source : https://www.nola.com/multimedia/photos/collection_c989d74a-a31a-11e9-bd7c-4b2a2d04ee27.html#17

Photo 9 Street flooding on S. Galvez St. near Tulane Ave.: 9. S. Galvez-Tulane

Source : https://www.nola.com/multimedia/photos/collection_c989d74a-a31a-11e9-bd7c-4b2a2d04ee27.html#3

Photo 10 Flooding at Poydras St. (2056 Poydras St.): 10. Quality Rebore & Ring Service

Source : https://www.theadvertiser.com/media/cinematic/gallery/1707942001/hurricane-barry-flooding-in-new-orleans-louisiana/

Photo 11 Flooding at Lower Garden District (1115 St. Mary's St.): 11. Tchoup Industries

Source : https://nola.curbed.com/2019/7/10/20688973/heavy-rain-flood-new-orleans-photos-july-10-tropical-storm

Photo 12 Flooded Walgreens in downtown New Orleans (801 Canal St): 12. Walgreens

Source : https://www.nola.com/multimedia/photos/collection_c989d74a-a31a-11e9-bd7c-4b2a2d04ee27.html#17

Photo 13 Partly submerged car in downtown New Orleans (711 Canal St): 13. McDonald's

Source : https://www.nola.com/multimedia/photos/collection_c989d74a-a31a-11e9-bd7c-4b2a2d04ee27.html#1

Photo 14 Manhole overflowing at Canal-Tchoupitoulas intersection: 14. Manhole

Source : https://www.nola.com/multimedia/photos/collection_c989d74a-a31a-11e9-bd7c-4b2a2d04ee27.html#17

Photo 15 Flooding at intersection in Gentilly (Franklin-I 610 Intersection): 15. Submerged Car

Source : https://www.nola.com/multimedia/photos/collection_c989d74a-a31a-11e9-bd7c-4b2a2d04ee27.html#17

C. Modelers Involved

Ardurra supplies a unique standard of excellence in the field of hydraulic modeling. Ardurra boasts a staff that has decades of experience in the field of H&H modeling.

Cecil Soileau has nearly 50 years of modeling experience, with over 30 years of hydraulic and hydrologic experience at the federal level, including leading that hydraulic and hydrologic department before his retirement. After amassing that federal experience, Mr. Soileau began working for BCG/Ardurra in the mid 90s and was instrumental in working with both the federal organization as well as the handling H&H issues of various complexities as the local level. Mr. Soileau has very few peers in the field of H&H. He is supported in this effort by additional leaders in the industry.

Dr. Bhuban Ghimire has a doctorate in the field of Hydraulics and Hydrology and is Cecil's main support for the physical model of the Lower Mississippi River at the CPRA offices in Baton Rouge. He has been working on the SELA model over the last 7 years and has been instrumental in other computer models throughout the world. He is a published author on H&H papers and is recognized internationally as an expert in the field.

Additionally, Mr. Soileau and Dr. Ghimire are supported by Dr. Maryam Roostaee, who recently received her doctorate in Hydraulics and Hydrology from LSU. With the combination of the three experts, Ardurra boasts nearly 80 years of H&H experience and each have extensive experience in a wide variety of modeling software.

The SELA program has continued over more than 20 years and Ardurra/BCG has worked closely with both the Corps of Engineers as well as the local sponsors to evaluate potential drainage projects, to ensure that local designs and submittals met federal guidelines, to assist with construction management and to monitor the construction projects