APPENDIX H

COMBINED OPERATIONAL PLAN

HYDRAULICS & HYDROLOGY

ANNEX 2
MDRSM 8.5-SQUARE-MILE AREA MODELING VALIDATION AND ROBUSTNESS TEST

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H-2 MDRSM 8.5-SQUARE-MILE AREA MODELING VALIDATION AND ROBUSTNESS TEST

H-2.1 MRDSM VALIDATION FOR 8.5 SMA

MDRSM 8.5 Square Mile Area Model Validation for 2017

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03/13/19

The South Florida Water Management District (District) is conducting a study in cooperation with the US Army Corps of Engineers to evaluate flood mitigation alternatives in the 8.5 Square Mile Area of Miami-Dade County. For this purpose, the District has developed and calibrated a hydrologic/hydraulic model (Miami-Dade Regional Simulation Model or MDRSM) as the principal tool for the evaluation of alternatives. Currently the tool is being further validated against observed water level and flow discharge data.

This document describes the results of a validation test for the MDRSM model that compares observed and modeled results for the wet season of 2017. Previous validation checks of the MDRSM have been performed, but these checks were not able to compare model results with observed data during the same time period, with newly constructed 8.5 Square Mile Area (8.5 SMA) and C-111 South Dade features that became operational on an interim basis starting in September 2017 and permanently in August 2018. As this model will be used to evaluate flooding risks in the 8.5 SMA, this evaluation was performed to provide additional validation of model results. The study determined that the model performance for this wet season was consistent with previous studies and confirmed the appropriateness of MDRSM application for the COP assessment of 8.5 SMA flood mitigation performance.

The calibrated MDRSM model (2018) was subject of a previous robustness test in the 8.5 Square Mile Area (8.5 SMA) utilizing the 2018 Water year (May 2017 through April 2018). This model test was described in the "MDRSM 8.5 Square Mile Area Robustness Evaluation" report (SFWMD, 2019). In this test, the observed water levels in the 8.5 SMA for the wet period of August to December of 2017 were compared to the computed stages for the period of August to November of 2005. This period was deemed hydrologically similar to the wet season of 2017 for the purpose of the test, but some hydrologic and operational differences prevented a direct comparison of model data to historical performance.

The validation test described in this report has been conducted to compare the observed stages of May 2017 through April 2018 to corresponding model computed stages in the 8.5 SMA at the locations shown in Figure 1. For this test, the MDRSM model was set up and ran for the water year of 2018 using observed 15-min interval NEXRAD rainfall, daily evapotranspiration and 15-min observed gate openings and pumpage at the water control structures. A brief description of the model setup and results are presented next.

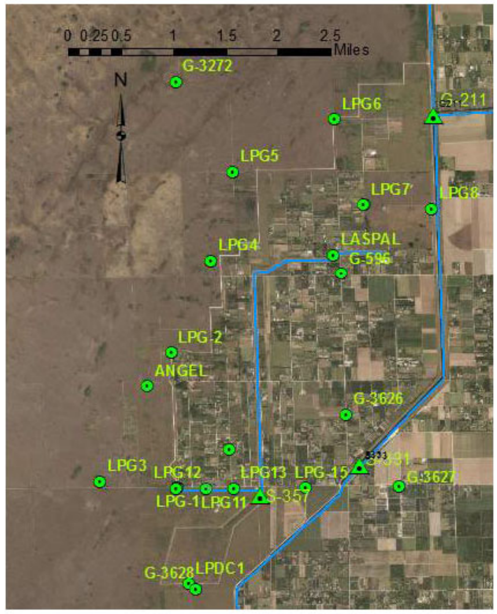

Figure 1. Location of Water Level Gauges in 8.5 Square Mile Area

The MD-RSM model validation for the year 2017 consisted of simulating the water levels and flows using the calibrated version of the model (SFWMD, 2018). The following are the general assumptions used in the model setup.

1. The MDRSM model mesh and canal configuration is the same as that used in the model calibration for the year 2012 and validation of 2008.

2. The simulation period started in January 1st, 2017 to give the model a warm-up period of 4 months. The simulated water year for 2018 ran from May 1st, 2017 to April 31st, 2018.

3. The rainfall data consisted of NEXRAD data with time interval of 15 minutes.

4. The model used daily evapotranspiration (ET) data available for the years 2017 and 2018.

5. The footprint of the impoundments south of the 8.5 Square Mile Area (North Detention Area, South Detention Area, S332DN and S332DS) is the same as in the ECB19 scenario developed in support of the Combined Operating Plan (COP) project.

6. Public water supply wellfield pumpage is the same as the data used for the ECB19 scenario.

7. Boundary conditions for the mesh were based on interpolated water levels from observed daily stages at gauges near the western and northern boundaries for the period of January 1st, 2017 to April 31st, 2018. These gauges include 3A-SW, 3A-2, 3A-12, NP-205, NP-NMP, NP-P35, NP-P36 and NP-P38. Downstream of tidal structures and along the mesh tidal boundary the model uses observed water levels.

8. The model imposes observed 15-minute gate openings at all operable structures including S-333, G-211, S-357N. Operations at pump stations were included in the model run by imposing 15-minute observed pumpage in all the pump stations including S-356, S-3331 and S-357 and all the pump stations south of the 8.5 SMA including pump S-332B, S-332BN, S-332C, S-332D, S-199 and S-200.

Table 1 shows a description of the gauges used in the 8.5 SMA. Figures 2 and 3 show the measured and computed canal stages in and around the 8.5 SMA. Both figures span over the period of May 2017 to March 2018 covering the wet-season period of interest. In mid-July of 2017, pumpage (dashed grey line) on the 8.5 square mile area canal begins to move water from the interior to the C-111 South Dade Northern Detention Area (NDA) impoundment. Pumpage operations at the S-357 pump station are triggered by water levels (pumps turn on when water levels are above elevation 6.0 ft NGVD29, consistent with the operational criteria established for the Increment 2 field test that are used for the ECB19 at the LPG2 gauge located near the western levee of the 8.5 SMA. In this validation test, the S-357 pump was turned on when the headwater stage of the S-357 pump reached an elevation of 6.2 ft NGVD on Jul7 14, 2007 and was turned off at a stage of 5.5 ft NGVD on February 8, 2018.

The observed and computed stages of the 8.5 SMA C-357 canal (upstream of the S-357 pump) shown at the bottom of the graph in light red color are in good agreement with respect to the pumpage at structure S-357. Similarly, at the top of the chart, the computed and measured stages on the downstream side of the pump (inside the 8.5 SMA Detention Cell flowway) are shown in orange color. In between the headwater and tailwater of S-357, the computed stages for gauges G-3272 and Angel follow the same relative order as the observed values, however, the stages at LPG1 are sometimes higher than LPG2. The computed stages at gauge G-3273 did not followed the computed values specially during July-October , 2017 period when the computed stages were significantly lower than the observed values. In general, the bias of the computed stages is consistent with the stage bias of the gauges in the 8.5 SMA used in the calibration (2012) and validation (2008) of about 0.4 ft. In the calibration of the MDRSM, stage data in the 8.5 SMA was limited to five gauges: Angel, G-3626, G-596, G-3272, G-3273 which had stage bias of 0.42 ft, 0.39 ft, 0.39 ft, 0.38 ft and 0.30 ft respectively. There were no stage data at the LPG gauges for the calibration and validation of the model, since these gauges were first installed in approximately July 2011.

Figure 3 shows the observed and computed stages at gauges LASPAL, LPG3, LPG4, LPG5, LPG7 and LPG8. Similar trends in the order of the stages can be seen with stages at gauge LASPAL are at the bottom of the graph and LPG5 and LPG3 at the top and LPG4, LPG7 and LPG8 in between.

Table 1 Canal/Groundwater level Gauges in the vicinity of 8.5 square mile area

Gauge ID	Type	Data time interval	Comments
ANGEL	GW	15-min	ENP
G-3272	GW	1 day	ENP
G-3273	GW	15-min	ENP
LASPAL	Canal	15-min	8.5 square mile area canal
LPG1	GW	15-min	
LPG2	GW	15-min	ENP
LPG3	GW	1 day	ENP
LPG4	GW	1 day	ENP
LPG5	GW	1 day	ENP
LPG7	GW	1 day	
LPG8	GW	1 day	
LPG11	GW	1 day	
LPG12	GW	1 day	
LPG13	GW	1 day	
LPG14	GW	1 day	
LPG15	GW	1 day	
G-3626	GW	1 day	
G-596	GW	1 day	
S357_HW	CANAL	15-min	Canal stage on headwater side of pump S-357
S357_TW	CANAL	15-min	Canal stage on tailwater side of pump S-357
S331_HW	CANAL	15-min	L31N Canal
S331_TW	CANAL	15-min	L31N Canal
S331_Q	CANAL	15-min	15-min observed pumpage flow imposed as internal BC
S357_Q	CANAL	15-min	15-min observed pumpage flow imposed as internal BC

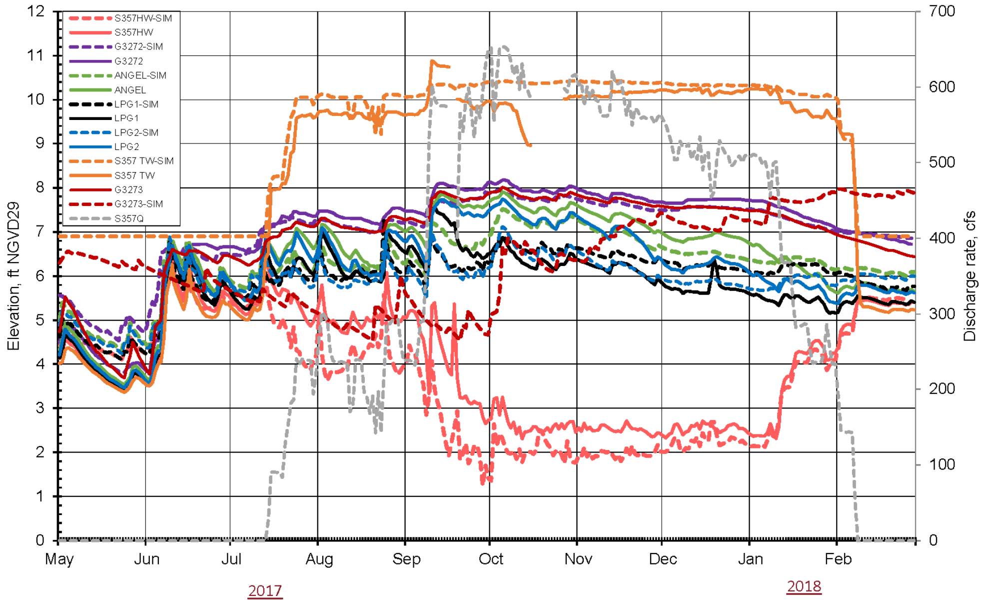

Figure 2. Observed and MDRSM Simulated Stages in 8.5 Square Mile Area for the Period May 2017 to Feb 2018.

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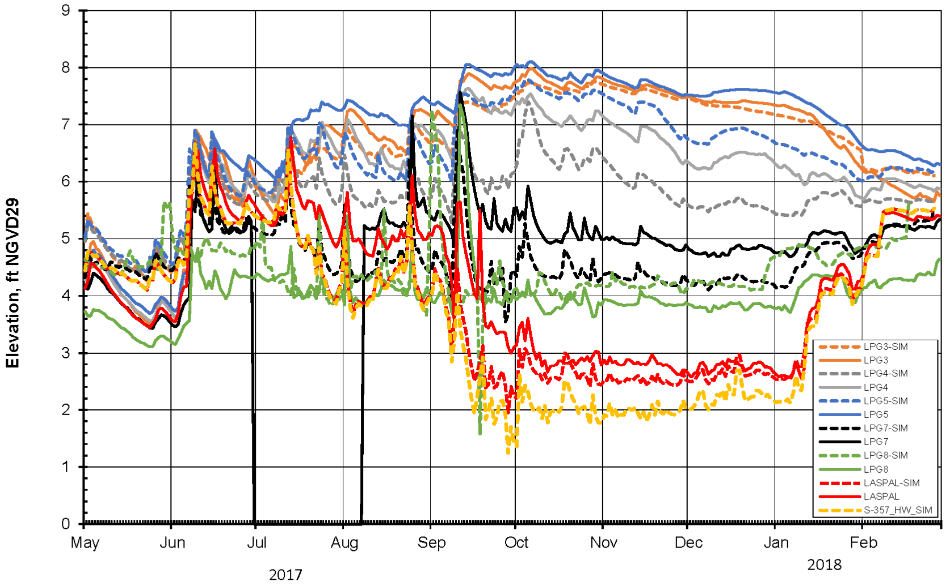

Figure 3. Observed and MDRSM Simulated Stages in 8.5 Square Mile Area for the Period May 2017 to Feb 2018.

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Methods

The calibrated version of the MDRSM was used to compare model performance against observed stage values in the 8.5 square mile area, adjacent to the Everglades National Park for the period of May 2017 to April 2018. In this validation test, the model was set up with observed gate openings at the gated structures and imposed observed pumpage at the pump stations. Observed 15-minute rainfall data were obtained from the NEXRAD database and daily values of ET were used in the model run.

Results and Conclusions

The results of this validation exercise demonstrate that the MDRSM model can reproduce the water levels in the 8.5 SMA for the period of May 2017 to February 2018 with a bias consistent with the results of the calibrated model. During this period, the S-357 pump is heavily used in wet conditions to provide flood mitigation by drawing down the canal levels upstream of the pump S-357 and areas around it. The water level gradient from the western boundary of the 8.5 SMA, adjacent to the ENP to the east is similar to the gradient computed by the model as can be seen at gauges G-3272, LPG2 and , LPG5. For gauges LPG7 and LPG8 the hydraulic head gradient is consistent but much smaller than the observed values. While individual gage comparison gradients (i.e. LPG7-LPG8) may be smaller in the simulations compared to the observed information, this difference does not appear to propagate across multiple gages. These biases remain consistent with the scale of bias observed in model calibration and support our conclusion that the MDRSM provides effective representation of the 8.5 SMA for planning purposes.

REFERENCES

SFWMD, 2019. Hydrology and Hydraulics Bureau, MDRSM 8.5 Square Mile Area Robustness Evaluation. March 7, 2019

SFWMD, 2018. Miami-Dade County Regional Simulation Model (MDRSM) Calibration and Validation. Regional Simulation Model (RSM) Implementation Report. June 25, 2018.

H-2.2 MDRSM ROBUSTNESS TEST FOR 8.5 SMA

MDRSM 8.5 Square Mile Area Initial Robustness Evaluation

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07/25/18

Development and initial implementation of the Miami-Dade County Regional Simulation Model (MDRSM) by the South Florida Water Management District (SFWMD) recently culminated in the release of the MDRSM calibration and validation report (June 2018). This milestone represents a significant advance in the ability to evaluate the southern portion of the South Florida watershed using a tool with high spatial resolution and sub-daily timesteps. The intended application of the MDRSM is in support of restoration project planning (including the Comprehensive Everglades Restoration Plan or CERP) and other efforts including the United States Army Corp of Engineer's (USACE) development of the Combined Operating Plan (COP) update to the South Florida System Operating Manual. As part of these intended applications, there is a need to evaluate flood protection in a portion of the model domain encompassed within and surrounding the 8.5 Square Mile Area (8.5 SMA) in Miami-Dade County. Since this area has been the subject of ongoing construction improvement in recent years, an additional "robustness evaluation" has been pursued and described in this document to further demonstrate capability of the MDRSM to effectively simulate the response of 8.5 SMA interior stages using more recent observed data beyond the period considered during formal calibration and validation efforts.

Since the additional robustness analysis was desired prior to the evaluation of COP alternatives (scheduled for the fall of 2018) and the effort represents a scope expansion with limited modeling staff resources available, the scope of the robustness effort attempted to leverage products under development for model application, such as the "current condition" (ECB19) modeling baseline. The strategy pursued compared field observation from the 2018 ending water year (May-Apr) to a model simulation representing the 2006 ending water year ("wet year" simulation for COP). Although the model simulation uses 2006 climate data, the infrastructure represented in the simulation is the "current" infrastructure that is generally consistent with the features in place during the observed 2017/2018 operating period. The following preliminary list of COP performance measure are planned to be used to assess 8.5 SMA flood mitigation (excerpted from DRAFT COP "COMBINED OPERATIONS PLAN FLOOD RISK MANAGEMENT EVALUATION METHODOLOGY AND PERFORMANCE MEASURES" dated 05/08/18):

- *Maintain Peak Stages within 8.5 SMA*: Areas within the levee will not have an increase in flooding impacts as specified by the 1983 Baseline condition.
- *Maintain Hydroperiods within 8.5 SMA*: Indicator locations within the levee will not have an increase in hydroperiod as specified by the 1983 Baseline condition.
- *Consecutive Days of Inundation within 8.5 SMA*: Areas within the L-357 protective levee will not have an increase in consecutive days of inundation as specified by the 1983 Baseline condition.

Consistent with the listed performance measures, the recession rates and stages from the MDRSM model within the interior of the 8.5 SMA should reasonably correlate to empirical data given the same external influencing factors. To evaluate these trends, stages were compared between observed and simulated data at three locations (LPG1, LPG2 & LPG5) along the marsh/developed perimeter of the 8.5 SMA and at one interior location (LPG7) as shown in Figure 1. At the time of this evaluation, the operational assumptions built into the MDRSM simulation were not fully implemented to represent a condition similar to the 2017/2018 observed period and as a result, the interior C357 canal is higher in the model simulation than in the observed period. Some characteristics of this bias caused by operating assumptions are shown in Table 1.

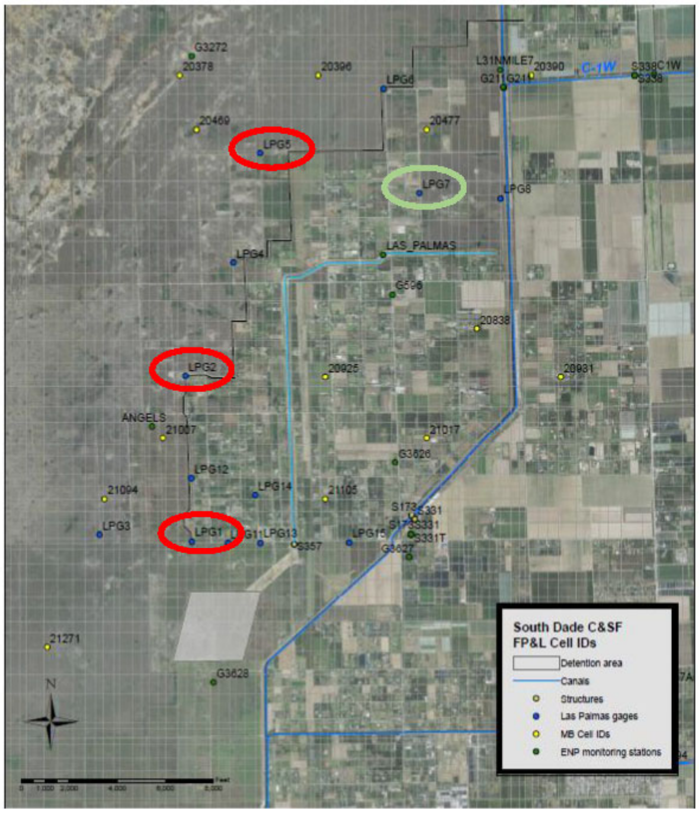


Figure 1. Gage Reference Map (Note: Mesh Displayed from Former ModBranch Model, not MDRSM)

Table 1. Comparison of Stages in the vicinity of C357 in 8.5 SMA

Data Source	Range of Stages (ft, NGVD)	Mean of Stages (ft, NGVD)
Observed 2017/2018 data	~ 3.2 – 7.0	~ 4.5
"Current" MDRSM simulated stages for 2006 "wet year"	~ 4.5 – 7.6	~ 6.3

Figures 2-5 show comparison of the historical observation and the MDRSM for analogous periods (not the same climate inputs) representing two generalized conditions: 1) Near Steady-State with little or no rainfall influence and 2) Unsteady conditions responding to significant rainfall stress (as shown, an approximately 9” event in the historical period and an approximately 11” event in the simulation period). Observations of these plots demonstrate several positive comparisons (and some limitations of the available data) including:

- Generally, regional gradient and responses look reasonable for comparative recent historical and ECB19 MDRSM simulation (e.g. order of gages and proportional offsets)
- The MDRSM reproduces the condition of little stage change during steady conditions.
- The magnitude of the increases in stage following significant rainfall events is captured by the MDRSM and the proportionally different response between interior and perimeter gages is also captured.
- The recession timing to recover to pre-storm levels observed in the MDRSM is comparable to the historical data, on the order of 2-3 weeks.
- The 8.5 SMA canal is currently not being drawn down enough in the available MDRSM simulation relative to the observed 2017/2018 data (resulting from assumed operating ranges represented in the model not being consistent with the deviation / lower operations in the historical data period). This outcome results in a reduced range of response in the simulated data compared to historical.

While many of these trends are encouraging and lend confidence to the MDRSM beyond the calibration efforts, it is acknowledged that this robustness evaluation is limited by the current state of the operations represented in the MDRSM simulation. As such, it is recommended that further evaluation continue as operational logic & refinements are further implemented in the MDRSM. If performance trends in the future do not fully reflect the additional spread between gages shown in the historical data, it is possible that local parameter modifications (e.g. canal seepage parameters in the 8.5 SMA canal system) may be pursued. At this time, given the performance of this evaluation and the calibration work, regional changes to model parameters are not expected. It is recommended that an updated and more comprehensive version of this document be prepared near completion of the ECB19 baseline implementation to further memorialize this robustness effort using the most mature version of the MDRSM as it will be applied in project support.

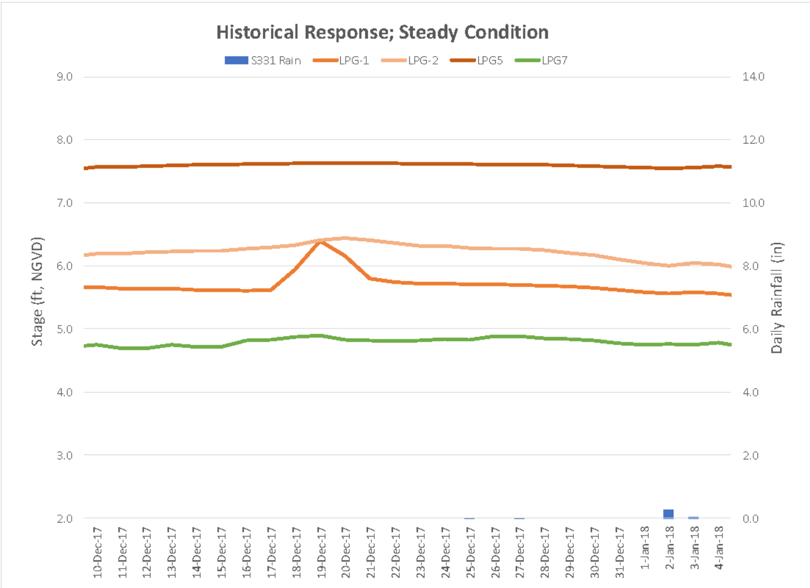
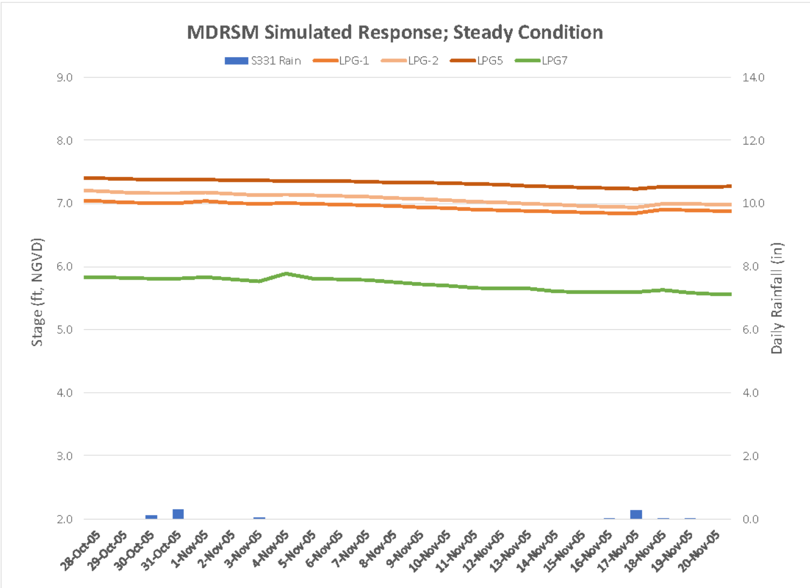


Figure 2



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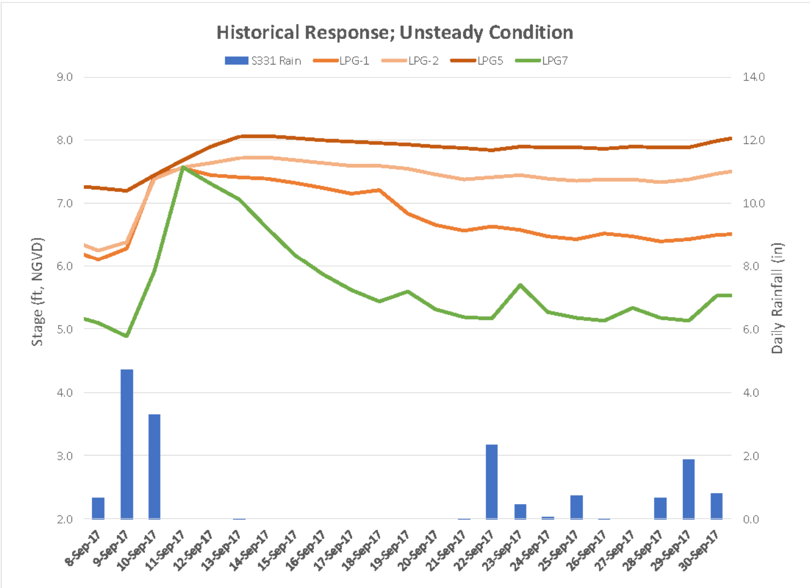

Figure 4

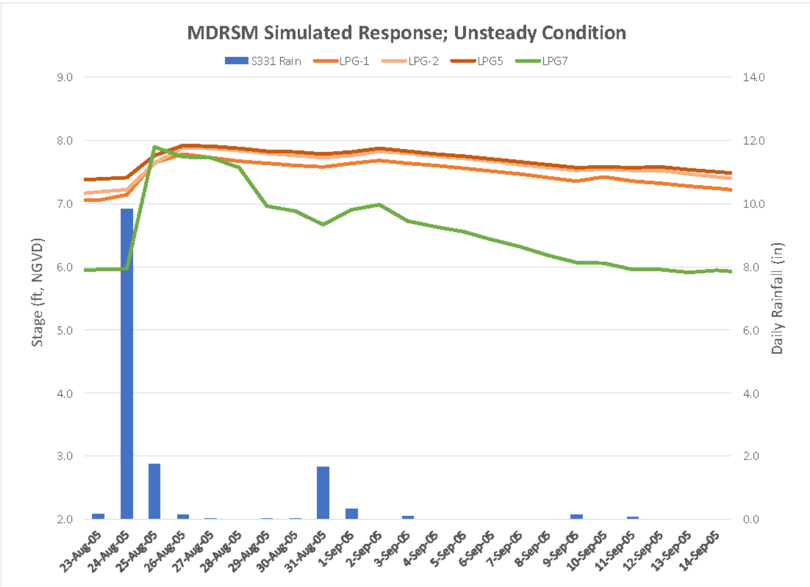

Figure 5