TECHNICAL MEMORANDUM

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TO:	Michael V. Reedy, P.E.
FROM	Jeremy D. Dixon, P.E., CFM
SUBJECT:	Lake Conroe Dam Gate Operations Modification Analysis
PROJECT:	SPH18133
DATE:	April 10, 2018
CC:	

STATE OF TEXAS
JEREMY D. DIXON
121614
LICENSED
PROFESSIONAL ENGINEER

04/10/18

FREESE AND NICHOLS, INC.
TEXAS REGISTERED
ENGINEERING FIRM
F-2144

1.00 BACKGROUND AND PURPOSE

The San Jacinto River Authority (SJRA) received a letter from Lyle Larson, Chair of the Texas House of Representatives Committee on Natural Resources, dated December 18, 2017 regarding actions that may be undertaken to prevent future flooding, similar to that which occurred as a result of Hurricane Harvey. In particular, Representative Larson requested a response to the following question:

> *"If the SJRA were to drop the elevation of Lake Conroe by one to three feet, what would the impact be on permits that are already issued for water in the basin based on historic use during hurricane season (August and September) over the last two decades? What would be the flood control capacity gained by lowering the lake level annually during hurricane season (August and September) by one, two, or three feet?"*

The purpose of this memorandum is to document the potential impact on lake levels and downstream maximum water surface elevation of a two-foot and a three-foot reduction in the normal pool level of Lake Conroe. Two hypothetical storms, the 1-percent annual exceedance probability (100-year) storm event and the 0.2-percent annual exceedance probability (500-year) storm event, are used as test cases to demonstrate the impacts of the proposed changes.

Freese and Nichols, Inc. (FNI) updated and amended the existing gate operations policy for the San Jacinto River Authority (SJRA) in April 2017 based on historical operations data. This memorandum uses the spreadsheet tools from the April 2017 gate operations policy.

2.00 METHODOLOGY

To answer the question of the amount of flood control capacity gained by lowering the normal pool elevation of the reservoir to elevation by one, two, or three feet, a relatively simple calculation can provide the answer. Table 1 shows this calculation, based on the bathymetric survey by Texas Water Development Board in 2010[1]. The Runoff Storage column indicates the amount of basin-averaged runoff that can be stored within the volume in flood pool.

Table 1: Lake Conroe Conceptual Flood Pool Volume Calculation

	Normal Pool Elevation, feet-MSL	Normal Pool Volume, ac-ft	Flood Pool Storage, ac-ft	Runoff Storage, inches
Lowered 3 feet	198.00	355,653	55,369	2.30
Lowered 2 feet	199.00	373,635	37,387	1.55
Lowered 1 foot	200.00	392,078	18,944	0.79
Current	201.00	411,022	0	0.00

The operators of Lake Conroe Dam use a spreadsheet tool that records time-series data of lake level and gate opening, computes an estimated inflow over the time step, and recommends a minimum, target, and maximum gate opening for each time step. FNI has developed a version of the spreadsheet tool to compute the resulting lake level and discharge based on a known inflow hydrograph.

FNI used the HEC-HMS version 4.2.1 PMF hydrologic model developed for the Emergency Action Plan (EAP) to apply the 100-year (24-hour) and 500-year (24-hour) storm events to the Lake Conroe basin. These storm events were modeled as nested intensity Frequency Storms, with the peak centered at 50% of the duration of the storm. The resulting hydrographs from the HEC-HMS model

[1] TWDB, 2010. "Volumetric and Sedimentation Survey of Lake Conroe". http://www.twdb.texas.gov/hydro_survey/conroe/2010-08/

were input into the spreadsheet tool to compute the lake level and discharge for each hypothetical storm event. Table 2 shows the precipitation depths used to determine the inflow hydrographs.

Table 2: Precipitation Depths

Duration	100-year Precipitation Depth, inches	500-year Precipitation Depth, inches
15 Minutes	2.3	2.8
1 Hour	4.4	5.8
2 Hours	6.2	8.5
3 Hours	6.75	9.4
6 Hours	9	13
12 Hours	11	16
1 Day	11.5	17.5

The hypothetical storm inflow hydrographs for the 100-year and 500-year events are shown in **Figure 1**.

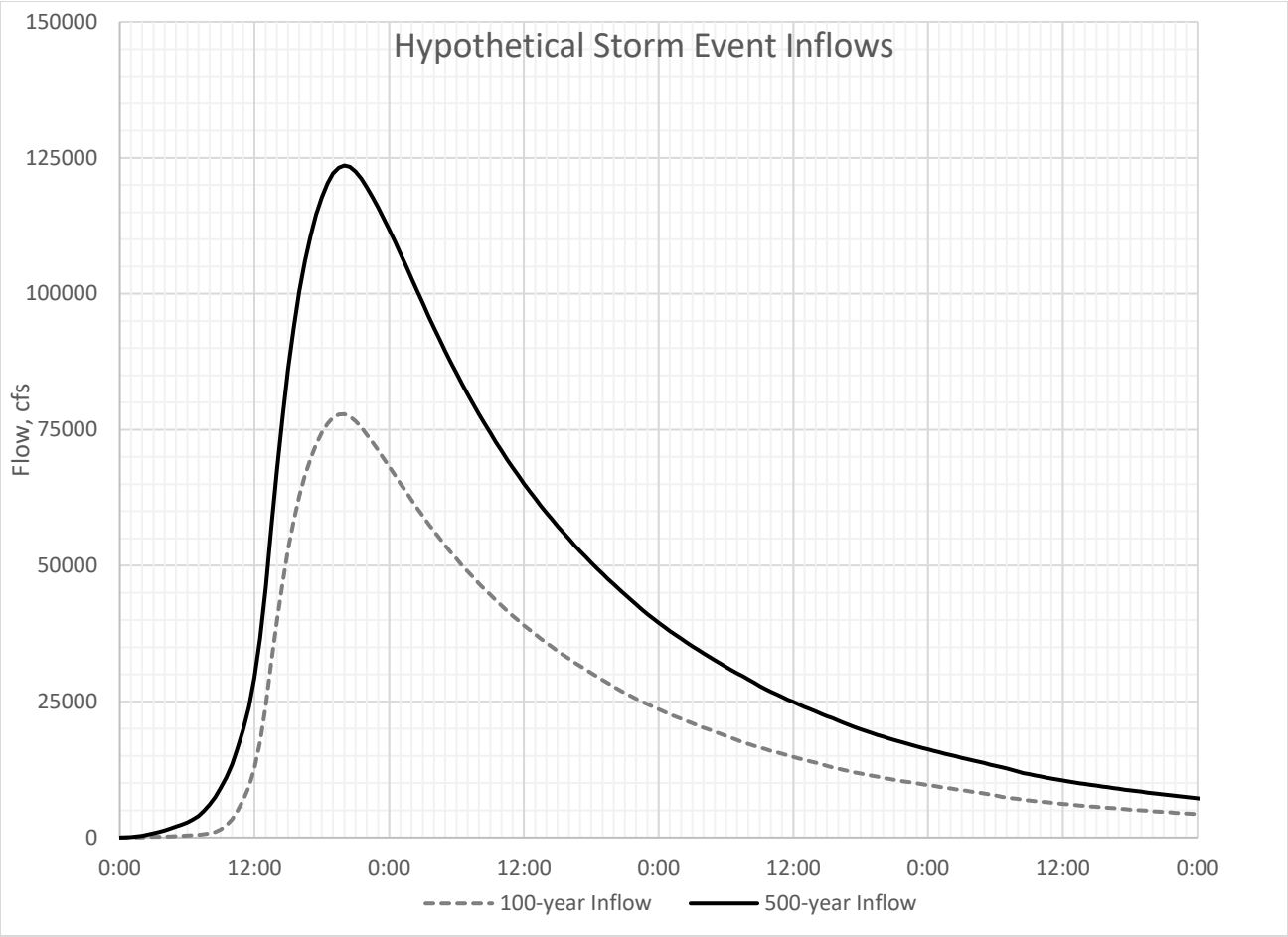

Figure 1: Hypothetical Storm Event Inflows

The impact of lowering the normal pool is determined by using these same hypothetical storm event inflows at different starting lake levels, with gate operations run at the target release rate, as determined by the gate operations spreadsheet.

The three scenarios to be evaluated include:

- Base condition, which is representative of the current gate operations plan
- 199 ft-msl normal pool (lowered 2 feet)
- 198 ft-msl normal pool (lowered 3 feet)

Comparisons will be made with the Base condition, as it represents the current gate operations plan. The impacts to those downstream of Lake Conroe Dam will be evaluated using the EAP HEC-RAS model truncated at IH-45.

3.00 100-YEAR EVENT COMPARISONS

FNI used the spreadsheet tool to evaluate the impact of lowering the normal pool elevation by 2 feet (199 ft-msl starting elevation) and 3 feet (198 ft-msl starting elevation). The same 100-year inflow hydrograph was used as input for all scenarios, with the starting lake level being the only difference. The recommended target release was used for each gate operation in all three scenarios. The resulting lake level and discharge is shown tabularly in Table 3 and graphically in Figure 2.

Lowering the normal pool by two or three feet allows the full rising limb of the inflow hydrograph to be stored prior to releasing any water. This alters the timing of the event and causes the releases to begin only on the descending limb of the inflow hydrograph, for which the spreadsheet tool recommends different gate openings than the ascending limb. Because the lake level did not exceed the flowage easement, and in order to make direct comparisons, no overrides of the gate openings were incorporated.

Table 3: 100-year, 24-hour Event Results

	Base	199 ft-msl Normal Pool	198 ft-msl Normal Pool
Peak Lake Level, ft-msl	205.14	204.64	204.26
Time of Peak Lake Level, hours	49.00	56.50	56.50
Peak Outflow, cfs	22,664	16,837	16,733

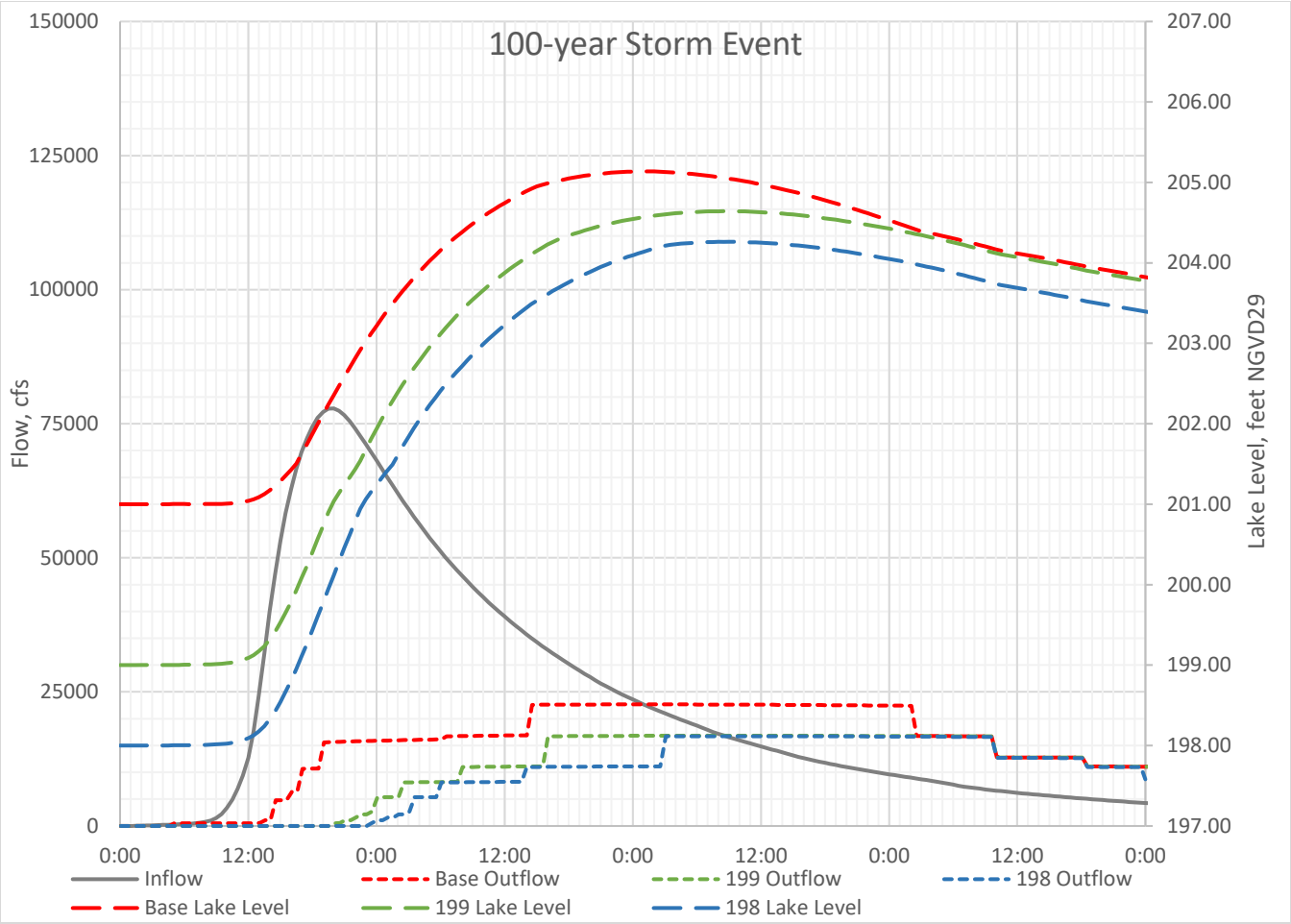

Figure 2: 100-year Event Inflow, Outflow, and Lake Level

4.00 500-YEAR EVENT COMPARISONS

FNI used the spreadsheet tool to evaluate the impact of lowering the normal pool elevation by 2 feet (199 ft-msl starting elevation) and 3 feet (198 ft-msl starting elevation). The same 500-year inflow hydrograph was used as input for all scenarios, with the starting lake level being the only difference. The recommended target release was used for each gate operation in all three scenarios. The resulting lake level and discharge is shown tabularly in Table 4 and graphically in Figure 3.

Lowering the normal pool by two or three feet allows the full rising limb of the inflow hydrograph to be stored prior to releasing any water. This alters the timing of the event and causes the releases to begin only on the descending limb of the inflow hydrograph, for which the spreadsheet tool recommends different gate openings than the ascending limb. It is for this reason that there were several manual overrides of the discharges, which are represented in Figure 3 as dots labeled "Override". These overrides were selected to be consistent between the two alternative runs, so that the results would be comparable, and also consistent with historic gate operations.

Table 4: 500-year, 24-hour Event Results

	Base	199 ft-msl Normal Pool	198 ft-msl Normal Pool
Peak Lake Level, ft-msl	205.73	205.72	205.67
Time of Peak Lake Level, hours	40.00	45.50	47.50
Peak Outflow, cfs	54,532	43,349	39,918

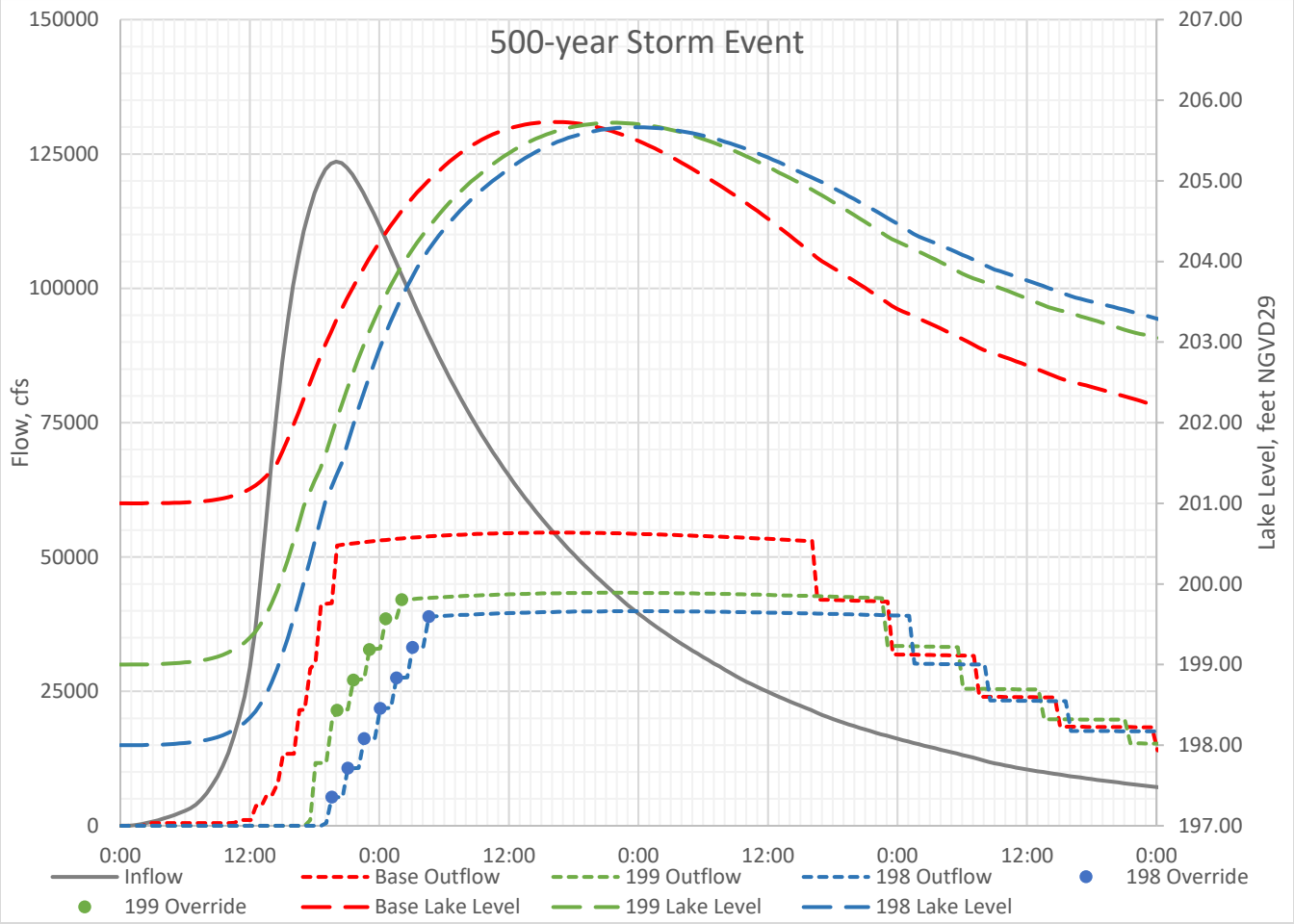

Figure 3: 500-year Event Inflow, Outflow, and Lake Level

5.00 DOWNSTREAM IMPACTS

Water surface elevations downstream of Lake Conroe Dam are computed based on the same HEC-RAS v 5.0.3 model as used in the EAP. This model is calibrated for the PMF storm event, but the hydraulic parameters seem to be sufficient for analyzing peak discharges from the Lake Conroe Dam in this situation.

The hydraulic model was truncated upstream of the IH-45 bridge, with a downstream boundary condition of a rating curve based on the unsteady flow 72-hour PMF run results at that cross section. The steady state flows applied to the hydraulic model include both the peak discharge from Lake Conroe, as well as the coincident flow from Lake Creek at the same time of the peak. No attenuation or lag was assumed between Lake Conroe Dam and the Lake Creek confluence. A summary of the simulated discharges is shown in Table 5.

Table 5: Hydraulic Model Flows

	Base	199 ft-msl Normal Pool	198 ft-msl Normal Pool
100-year Lake Conroe Discharge, cfs	22,664	16,837	16,733
100-year Lake Creek Confluence, cfs	77,768	70,965	66,374
500-year Lake Conroe Discharge, cfs	54,532	43,349	39,918
500-year Lake Creek Confluence, cfs	142,577	131,208	127,708

The computed floodplain within and downstream of Lake Conroe are plotted in Exhibit 1 for the 100-year storm event and Exhibit 2 for the 500-year storm event.

The computed water surface elevations downstream of Lake Conroe Dam are plotted on a profile, including the Base condition (201 NP), the 199 ft-msl Normal Pool (199 NP), and the 198 ft-msl Normal Pool (198 NP) for the 100-year (100yr) and 500-year (500yr) storm events in Exhibit 3. These values are also shown in Table 6, and the difference relative to the Base condition is shown in Table 7.

Table 6: Computed Downstream Water Surface Elevation

	Base	199 ft-msl Normal Pool	198 ft-msl Normal Pool
100-year Water Surface Elevation at Cross Section, ft-msl			
261977 DS Lake Conroe	153.94	152.47	152.44
245816 US SH 105	149.57	148.10	148.07
209465 Lake Creek	136.88	136.36	136.01
182231 IH-45	124.44	123.70	123.19
500-year Water Surface Elevation at Cross Section, ft-msl			
261977 DS Lake Conroe	159.31	157.74	157.20
245816 US SH 105	154.33	153.00	152.55
209465 Lake Creek	141.02	140.37	140.17
182231 IH-45	129.69	128.89	128.63

Table 7: Computed Downstream Water Surface Elevation Difference

	199 ft-msl Normal Pool	198 ft-msl Normal Pool
100-year Water Surface Elevation Difference, ft		
261977 DS Lake Conroe	-1.47	-1.50
245816 US SH 105	-1.47	-1.50
209465 Lake Creek	-0.52	-0.87
182231 IH-45	-0.74	-1.25
500-year Water Surface Elevation Difference, ft		
261977 DS Lake Conroe	-1.57	-2.11
245816 US SH 105	-1.33	-1.78
209465 Lake Creek	-0.65	-0.85
182231 IH-45	-0.80	-1.06

6.00 DISCUSSION AND CONCLUSIONS

This analysis shows the reduction in normal pool elevation does provide some benefit to areas upstream of Lake Conroe for flood events, and there is also a limited benefit for those downstream as the peak outflow is slightly reduced relative to the base condition. The average change in downstream water surface elevation for a normal pool elevation of 199 ft-msl is a reduction of approximately 1.0 feet for both the 100-year and 500-year storm events. The average change in downstream water surface elevation for a normal pool elevation of 198 ft-msl is a reduction of approximately 1.25 and 1.50 feet for the 100-year and the 500-year storm events, respectively. These reductions are relative to flows that are on average 8 feet above the channel banks in the 100-year event, and more than 12 feet above the channel banks in the 500-year event.

As mentioned above, the approximate extents of flooding for the compared scenarios are shown in Exhibit 1 and Exhibit 2, and Water Surface Elevation profiles of the West Fork San Jacinto River between Lake Conroe Dam and Interstate Highway 45 are shown in Exhibit 3. The benefits to those downstream, though the water surfaces are reduced by a foot or more in places, are generally not enough to be considered wholesale improvements to the flood hazard and show minimal differences in spatial extent.

For storm events larger than a 500-year event, it is anticipated that the addition of the flood pool will likely yield no additional benefit to the upstream and could potentially increase the flood hazard downstream of the dam if the peak release is delayed such that it occurs at the same time as other tributaries to the West Fork San Jacinto River. For lake levels above elevation 205.00 ft-msl, the gate operations policy is generally dictated by the requirements of the PMF storm, and the peak releases begin to converge to the same discharge rate.

The addition of a flood pool below the current normal pool elevation of 201 ft-msl will likely require a change to the gate operations policy, especially as lake levels exceed elevation 201 ft-msl. With the high rate of rise shown in the 100-year and 500-year scenarios, the amount of time prior to when the gates would be overtopped is reduced by approximately 13 hours. An update to the gate operations policy would be needed to ensure appropriate management and technical staff are present whenever the lake level was sufficiently high into the flood pool, but not yet above the 201 ft-msl level for releases, because the lake level will be rising rapidly as the level exceeds 201 ft-msl and rapid gate operations will be required.

The amount of data currently available to operators in real-time is not conducive to the fine-tuning of gate operations in this way. Gate Operators must have flexibility to operate the gates in accordance with their mission to ensure safe, dependable reservoir operations, so that when dam safety issues arise, the lake level can be controlled safely without additional deleterious effects.

FNI recommends that the analyzed modifications to the gate operations policy for Lake Conroe Dam not be undertaken without:

- A thorough study of the impact of the revised policy on lake levels and flows for multiple storm events, up to and including the PMF.
- A detailed design storm review to make sure that the dam can safely pass the appropriate design storm with the revised policy.
- A significant initial and ongoing investment to develop additional streamflow gauging stations upstream of Lake Conroe Dam to more accurately quantify inflow into the lake.

EXHIBIT 1
LAKE CONROE GATE OPERATIONS
100-YEAR EVENT MAPPING

LEGEND

- Base (201 ft-msl Normal Pool)
- 199 ft-msl Normal Pool
- 198 ft-msl Normal Pool

Note: Flood Mapping assumes no lag or attenuation of flows from Lake Conroe to the confluence with Lake Creek.

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Montgomery County

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EXHIBIT 2
LAKE CONROE GATE OPERATIONS
500-YEAR EVENT MAPPING

LEGEND

- Base (201 ft-msl Normal Pool)
- 199 ft-msl Normal Pool
- 198 ft-msl Normal Pool

Note: Flood Mapping assumes no lag or attenuation of flows from Lake Conroe to the confluence with Lake Creek.

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Exhibit 3
HEC-RAS Profiles