

MEMORANDUM

TO: Steven A. Kirk, PE

FROM: Bob Horner, PE, Meghan Moody, PE & Blake Duke, EIT

DATE: December 8, 2021

SUBJECT: Sea Level Rise Effects on Proposed Church Creek and Long Branch Drainage Improvements

As part of an ongoing effort to evaluate the benefits of various drainage improvements in the Church Creek Drainage Basin as well as the Long Branch Drainage Basin, Weston & Sampson, on behalf of the City of Charleston, simulated the effects of sea level rise using the previously developed and calibrated ICPR4 model. The simulations were analyzed to determine the effects of future sea level rise on the overall hydraulics of the basins as well as the previously proposed and evaluated drainage improvements. The proposed improvement scenarios evaluated were based on a combination of Weston & Sampson's work for the City to include: *The Church Creek Drainage Basin Study 2018*, the *Church Creek Drainage Improvements Storage Analysis 2020*, and the *Evaluation of Impacts of the Lake Dotterer Diversion 2021*.

Background

The City of Charleston has prioritized stormwater management and flood mitigation with a release of their updated *Sea Level Rise Strategy* in February of 2019 focused on the future of sea level rise, recurring king tides, increased storm surge, and population density within the City. The City also updated its *Stormwater Design Manual* in 2020 to include design provisions to promote resiliency against sea level rise with implementations of minimum tailwater conditions and roadway elevations.

The 2020 Stormwater Design Manual defines Sea Level Rise as:

“an increase in sea level that is primarily related to climate change: added water from melting ice sheets and glaciers and the expansion of seawater as it warms. Global sea level has been increasing over the past century, and the rate has increased in recent decades. In 2014, global sea level was 2.6 inches above the 1993 average—the highest annual average in the satellite record (1993-present). Sea level continues to rise at a rate of about one-eighth of an inch per year.”

Tidal Conditions

To represent sea level rise benchmarks, the existing boundary conditions for the Church Creek Basin and Long Branch Basin models were set for the existing tidal conditions (MHHW) with two and a half foot increments added to each peak and valley of the synthetic tide (MHHW+2.5', MHHW+5.0') at Nodes A010 and LB010, as shown in Figures 1 and 2. These synthetic tides, as discussed in the *Mid-Basin Storage Report* and the *Lake Dotterer Report* were based on observations of the NOAA Ashley River Tide gage at the I-526 bridge (USGS gage No. 86650999), and a field deployed gage at the confluence of Long Branch and Stono River in January 2020.

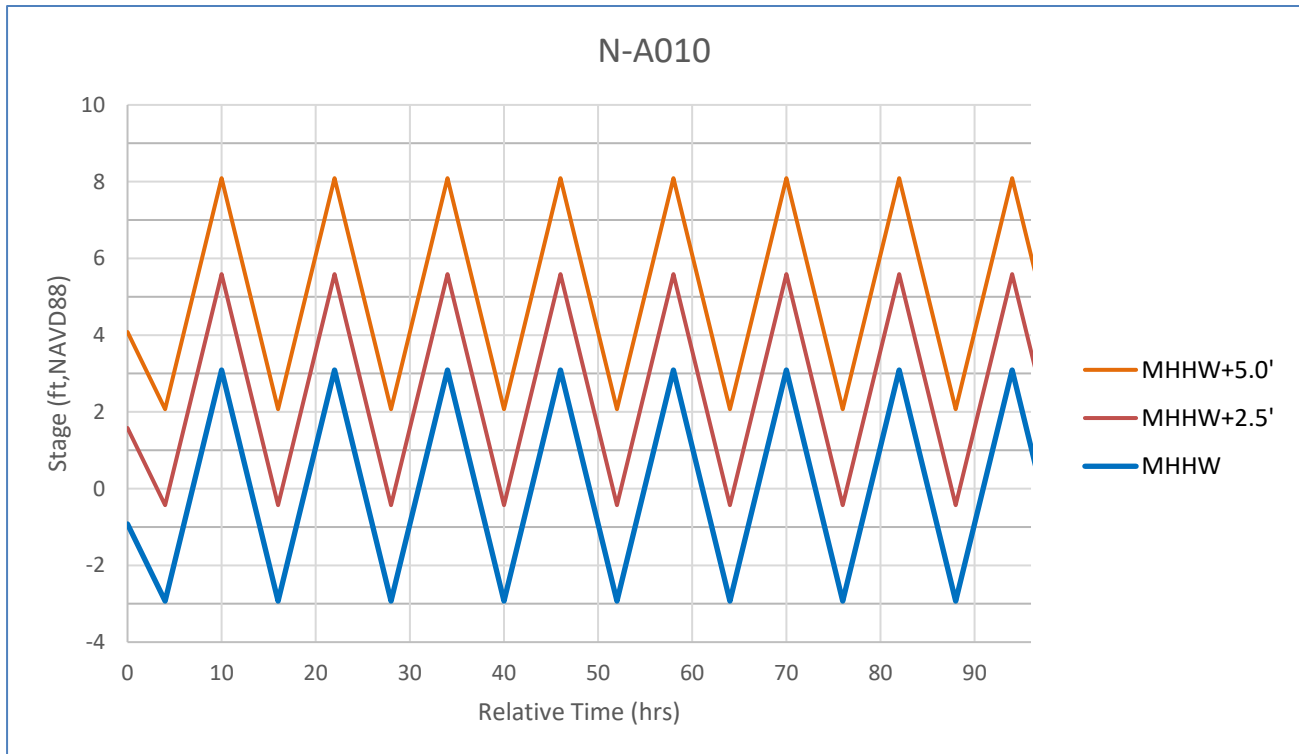


Figure 1 - Ashley River tidal conditions set at Node A010 for Church Creek boundary input.

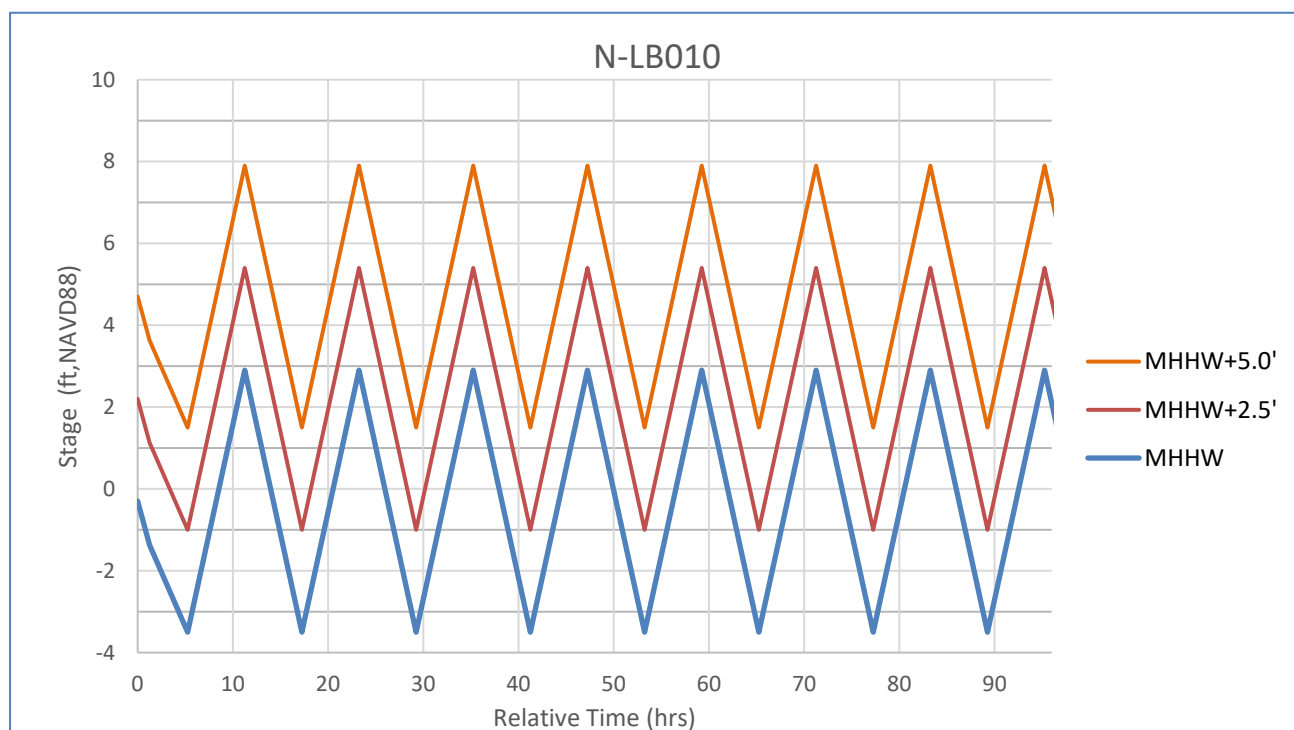


Figure 2 - Stono River tidal conditions set at Node LB010 for Long Branch boundary input.

Scenarios Evaluated

Of the proposed storage scenarios discussed in the previously completed study reports, the effects of sea level rise were evaluated for the model scenarios and combinations shown in Table 1, based on the tidal conditions, and simulated storm events listed in Tables 2 and 3 below.

Table 1 Modeled Scenarios

Scenario	Combination
Mid Basin Storage	
West Ashley Circle	
Mid Basin Storage	West Ashley Circle
Lake Dotterer Diversion	Without Downstream Improvements, Without Church Creek Connection
Lake Dotterer Diversion	With Downstream Improvements, Without Church Creek Connection
Lake Dotterer Diversion	Without Downstream Improvements, With Church Creek Connection
Lake Dotterer Diversion	With Downstream Improvements, With Church Creek Connection

Table 2 Tidal Conditions

Tidal Conditions
MHHW
MHHW + 2.5' SLR
MHHW + 5.0' SLR

Table 3 Simulated Storm Events

24-hr Storm	Rainfall (inches)
10%	6.4
4%	7.8
1%	10.0

Results

As the hydrographs in Attachment 1 show, the initial staging of the model scenarios was set at the present-day low tide condition. However, prior to the peak and bulk of the SCS rainfall curve in the simulated storm, the tidally influenced areas of the model reflect the increased initial staging due to the elevated tide. The peak of the simulated future tidal condition occurs at the peak of the rain event. The following subsections summarize our observations of the model results for the various scenarios.

Existing Conditions with Sea Level Rise

- The dry-weather high-tide level for the existing condition in Church Creek at Node B-020 will increase from approximately 1.7' to approximately 4.5' elevation NAVD 88 with 2.5' of sea level rise.
- Based upon model results for the future sea level rise of 2.5' without any drainage improvements, the 1% storm will result in a baseline flood elevation of approximately 7.5' NAVD 88 in the mid-basin area. This future-looking flood delineation is 0.2' higher than present day water surface elevations during the same storm event near node B-020.
- There is an increase in the water surface elevation in Long Branch in the existing condition with 2.5' of sea level rise. An overall increase between approximately 0.75' to 1.0' in peak staging varying along Long Branch is predicted during the 1% storm event with 2.5' sea level rise.

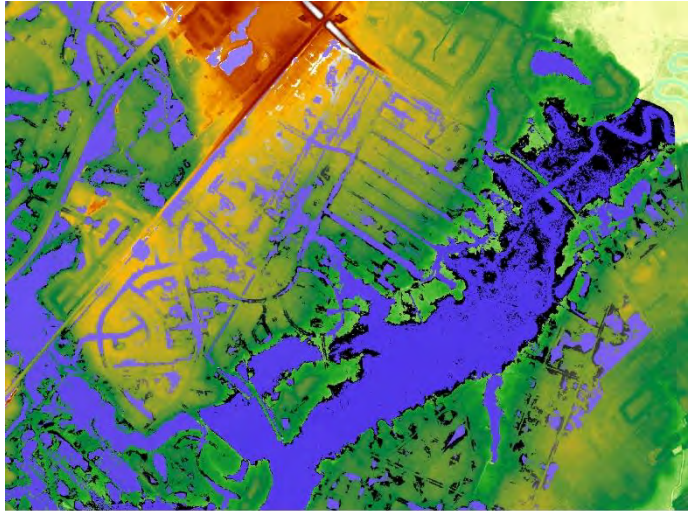


Figure 3 Church Creek flood extents for existing conditions scenario during the 1% storm. Black color indicates flood extents with future sea level rise of 2.5' and blue shows extents for present day tide condition.

Mid Basin Storage Options with Sea Level Rise

- The decrease expected in peak staging elevations from additional storage at the mid-basin is nearly the same as the difference for present day tidal conditions when the future improvements and future existing condition are compared. However, the overall staging increase due to heightened tidal conditions negates the predicted staging improvement for present day tidal conditions.

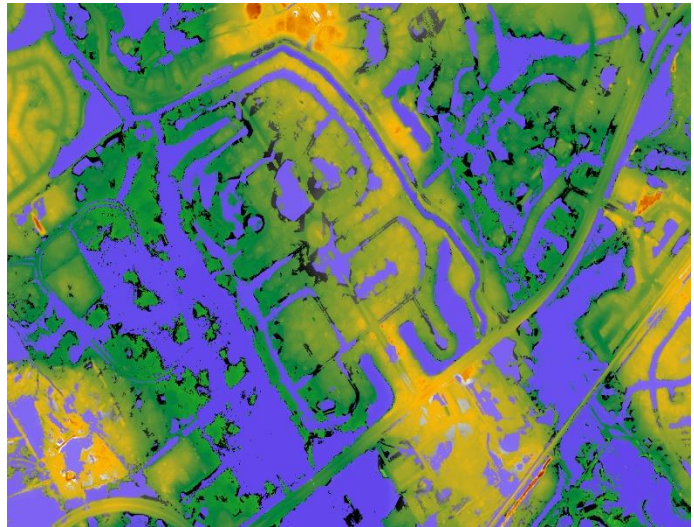


Figure 4 Church Creek mid-basin flood extents with mid-basin storage improvements during the 1% storm. Black color indicates flood extents with future sea level rise of 2.5' and blue shows extents for present day tide condition.

Lake Dotterer Diversion with Sea Level Rise

- Implementation of Lake Dotterer Diversion provides protection and preservation of capacity for the Lake Dotterer sub-basin in all scenarios.
- A Church Creek connection to Lake Dotterer by weir at 4' elevation predicts adverse impacts to Lake Dotterer storage in scenarios with sea level rise conditions.
- In the scenario where the connection between Church Creek and Lake Dotterer is severed by a levee at 8' elevation NAVD88 and the Glen McConnell Parkway culverts are implemented for flow diversion, but downstream improvements in Long Branch are not implemented, the water surface elevation within Lake Dotterer peaks lower than the future sea level rise scenario where Church Creek is connected to Lake Dotterer with the 4' weir and the Lake Dotterer diversion with Long Branch downstream improvements is included.
- In each of the Lake Dotterer Diversion scenarios, water surface elevations in Lake Dotterer are decreased below flood stage more quickly when downstream improvements are included in Long Branch.
- Due to the increased tidal baseline from sea level rise, staging in Long Branch is increased overall. This increased staging at the Glenn McConnel Parkway limits the ability for Lake Dotterer to relieve itself into Long Branch via its proposed outfall; therefore, the static water surface elevation in Lake Dotterer is increased.

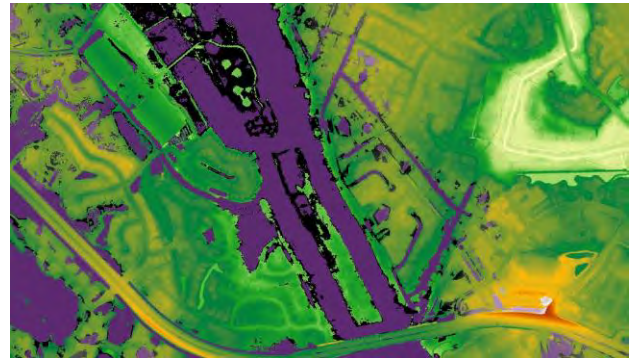


Figure 5 Lake Dotterer flood extents during the 1% storm with Lake Dotterer diversion and Long Branch downstream improvements, but without the Church Creek connection. Black color indicates flood extents with future sea level rise of 2.5' and purple shows extents for present day tide condition.

Conclusions

- Tide and surge gates will be a necessity in the future to help preserve hydraulic capacity within both Church Creek and Long Branch. Another option to mitigate flooding impacts would be elevation based strategic retreat.
- The results of the mid-basin storage scenarios demonstrate the benefits of increased storage in the basin to help reduce the volume of flow entering the main hydraulic conveyance channels. Overall peak staging increases with sea level rise, but there is still a benefit to adding storage to the basin.
- Tide gates in Church Creek have a larger benefit in sea level rise conditions than in the existing condition. It is estimated that tide gates may provide a foot of decreased peak staging with sea level rise of 2.5' due to the preserved capacity in the basin from closing a gate at low or outgoing tide.
- The effects of Church Creek on Lake Dotterer during sea level rise scenarios demonstrate the necessity of a flexible solution at their connection to allow water to either flow into Lake Dotterer or not during higher intensity storm events. This would allow for the capacity in Lake Dotterer to be preserved for its sub basin in larger storms, and not be inundated by Church Creek. However, the connection would allow flexibility during smaller storms to provide relief for Church Creek and direct flow between basins.
- Roadway flooding is increased under sea level rise scenarios. Existing low-lying areas currently affected during extreme storm events will continue to be affected under sea level rise conditions with increased extents.
- In the Lake Dotterer Diversion scenarios with downstream improvements, 2.5' of sea level rise raises the water surface elevations in Long Branch at high tide above flood elevations between LB240 and LB100. The implementation of tide gates at the West Ashley Greenway (LB100) would prevent the tide above a set elevation from entering Long Branch, and thus prevent flooding from occurring during future dry weather, high tide. The resulting decrease in staging from tide gates would also reduce flood staging upstream in Long Branch during storm events by preserving the capacity in Long Branch.

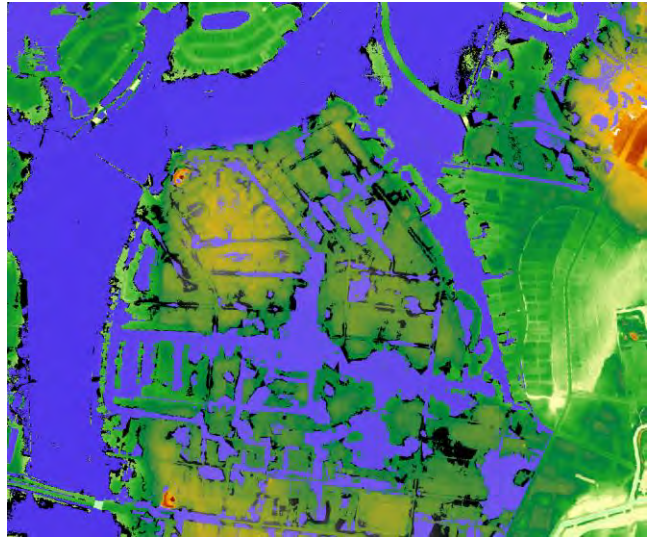
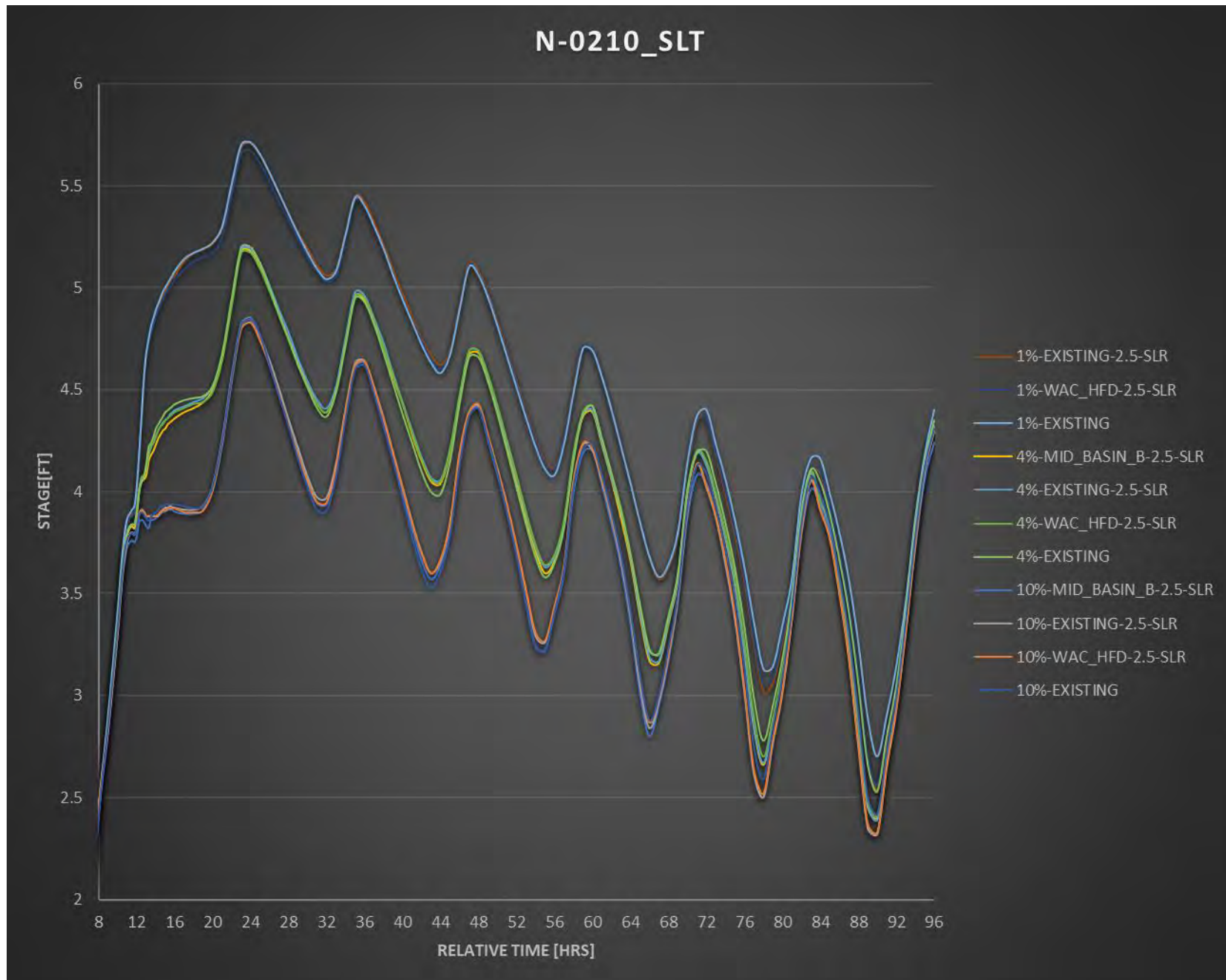
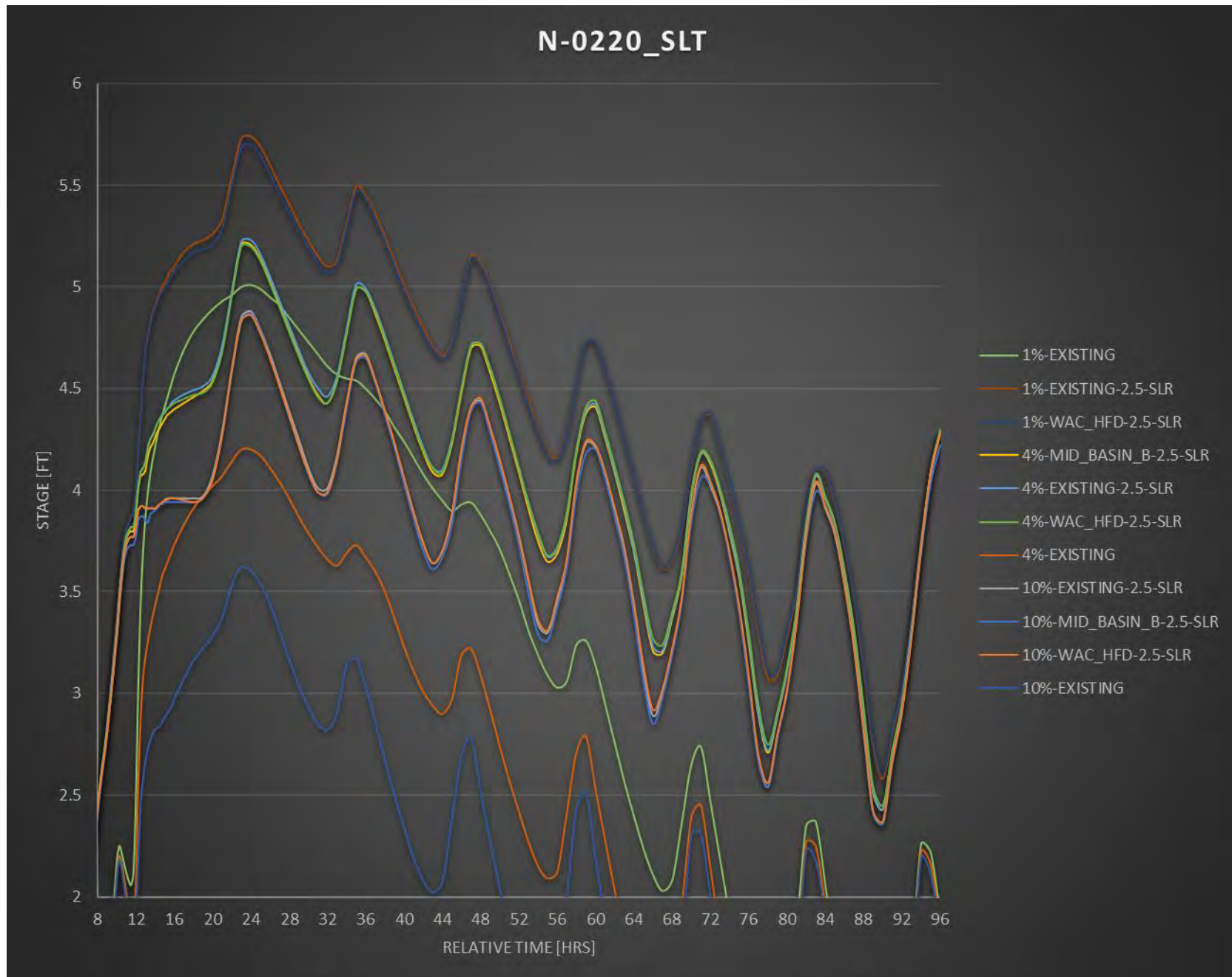


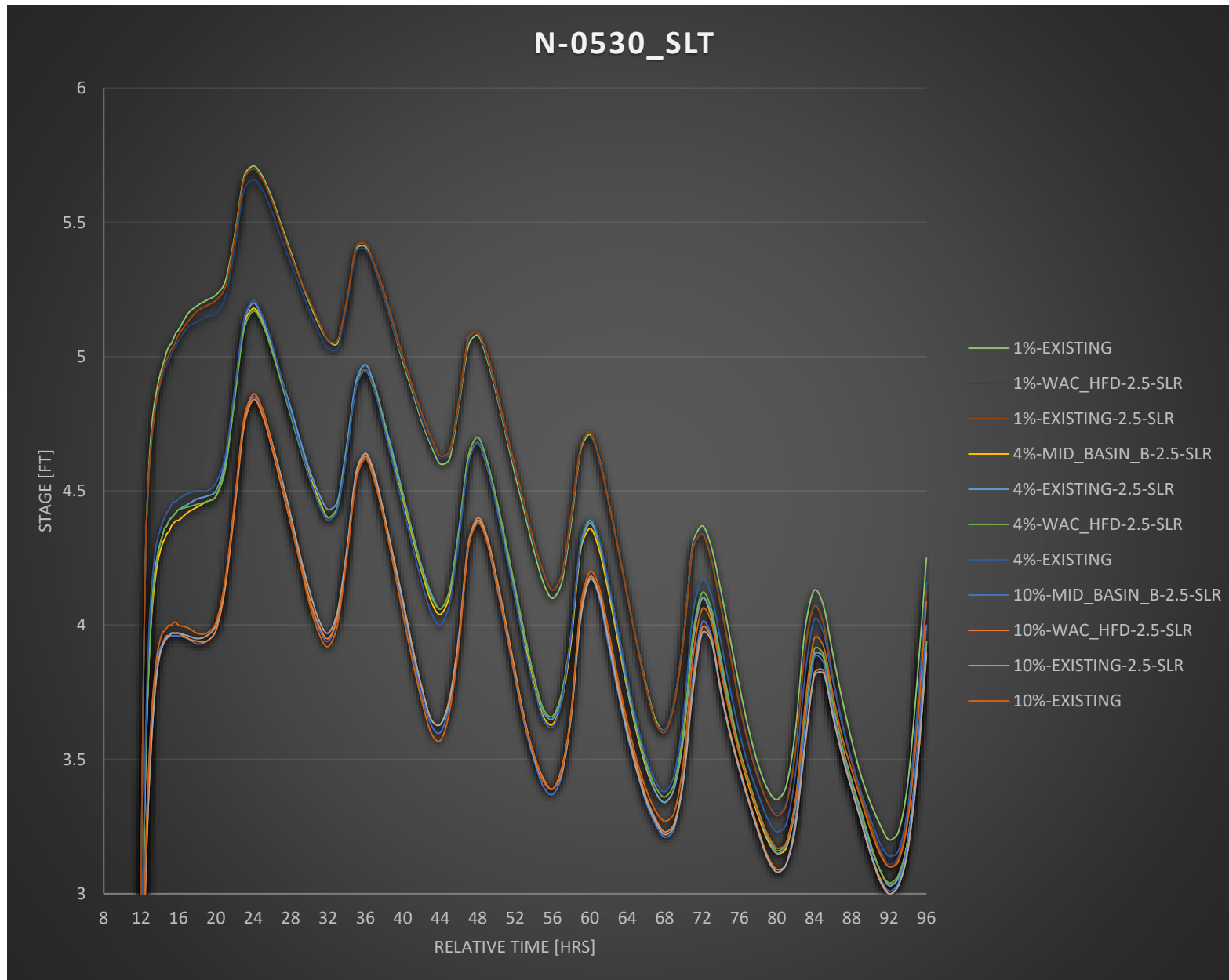
Figure 6 Long Branch flood extents during the existing condition scenario with 1% storm. Black color indicates flood extents with future sea level rise of 2.5' and blue shows extents for present day tide.

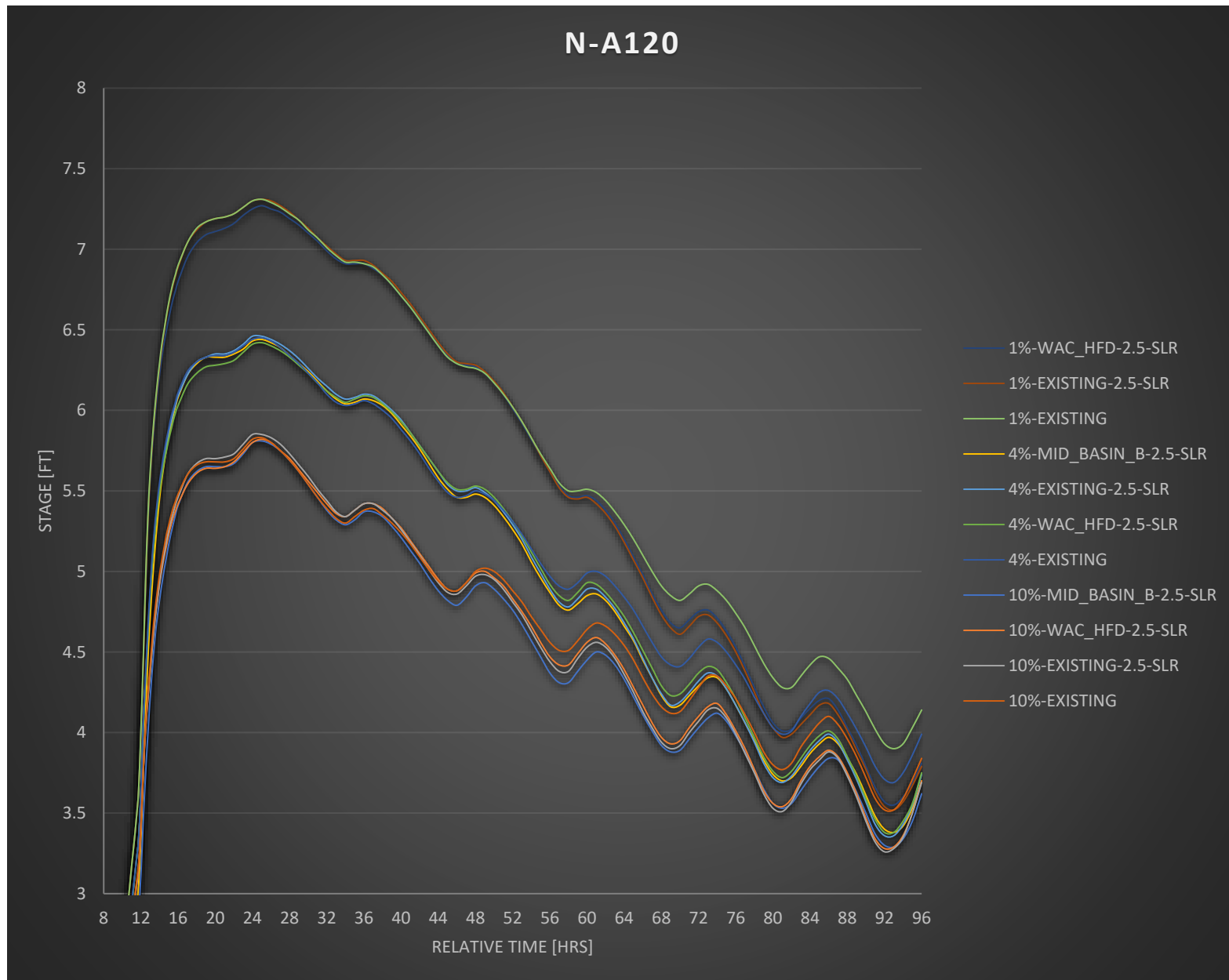
ATTACHMENT 1

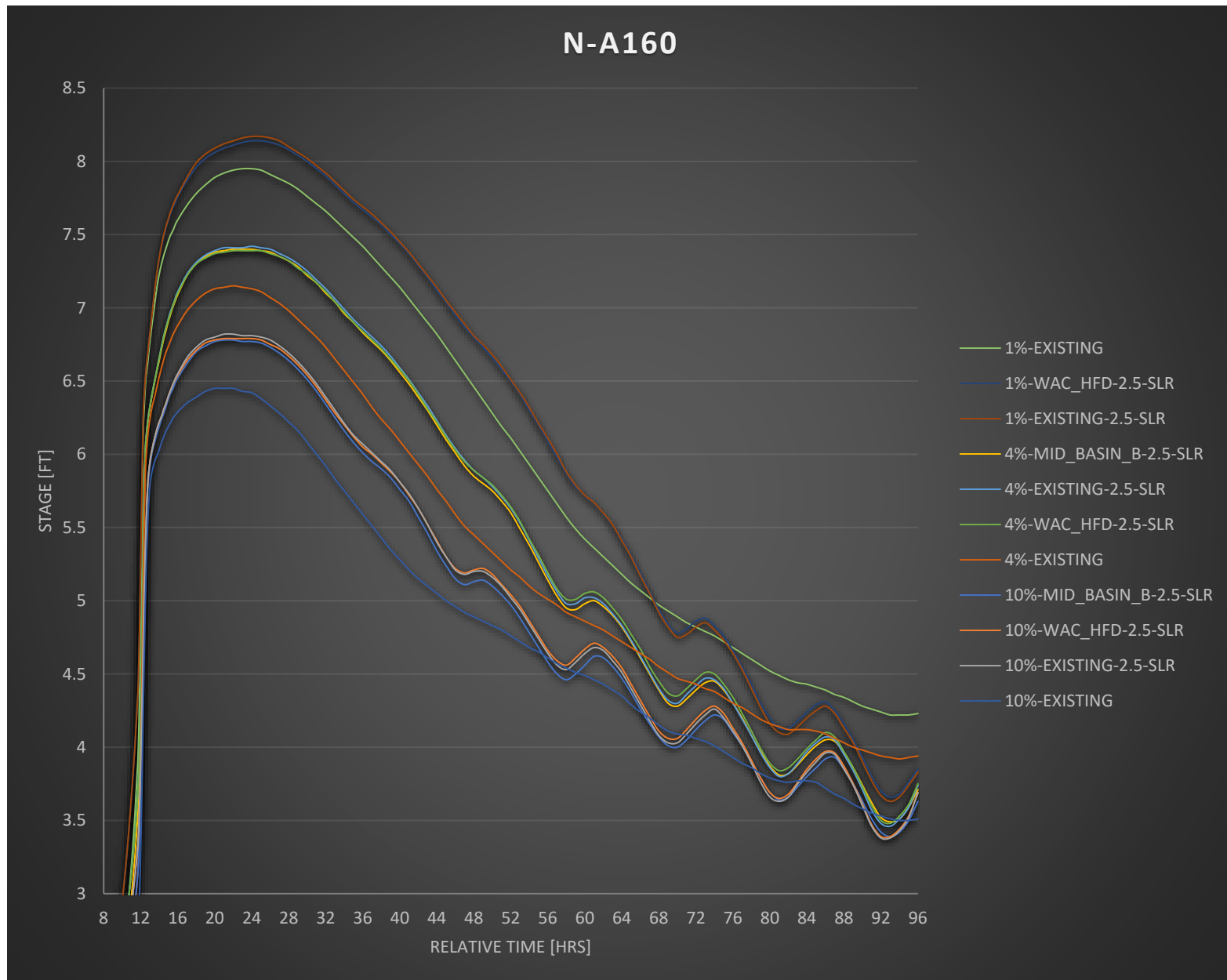
Attachment 1A. Effects of 2.5' Sea Level Rise on Mid Basin Improvements

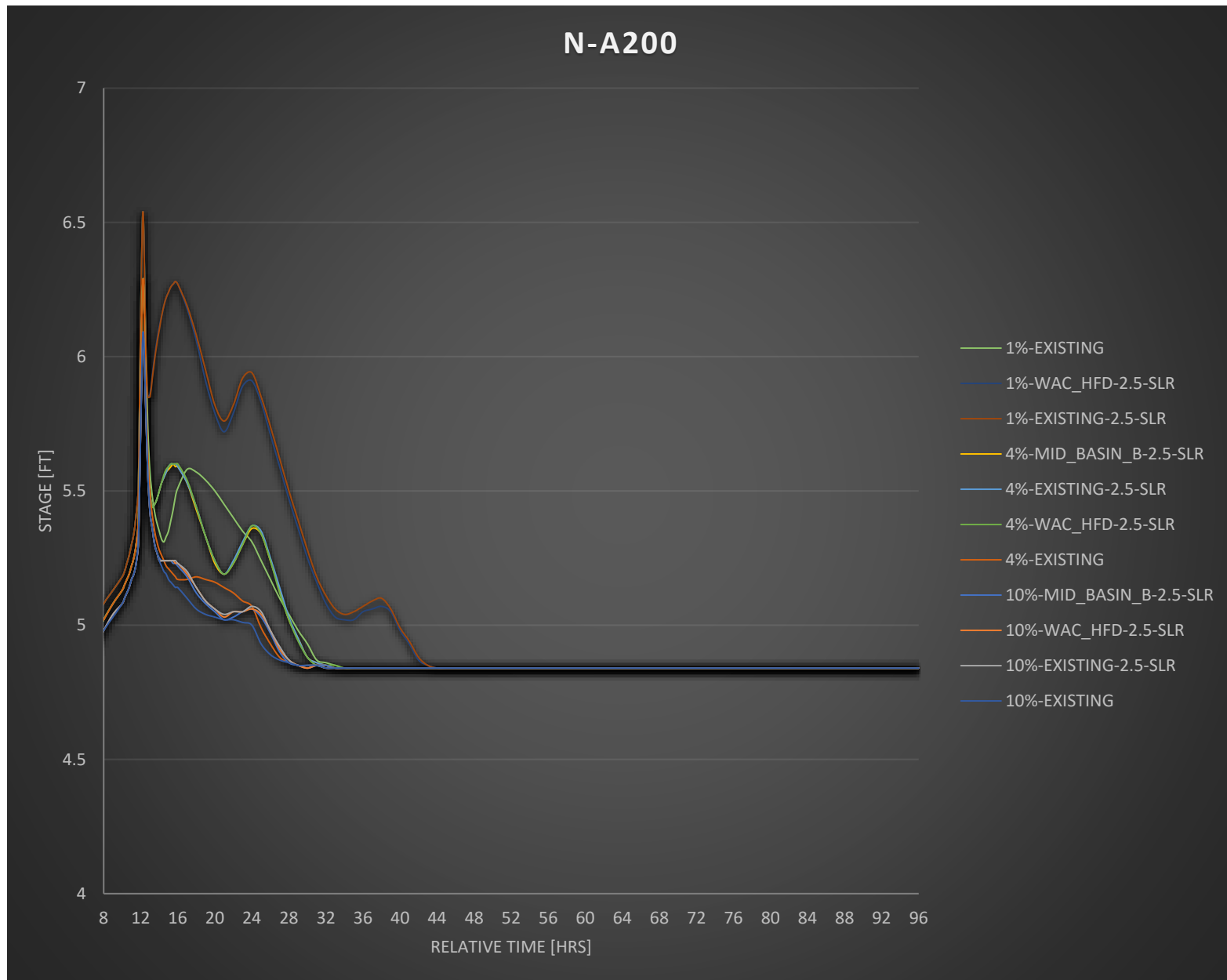


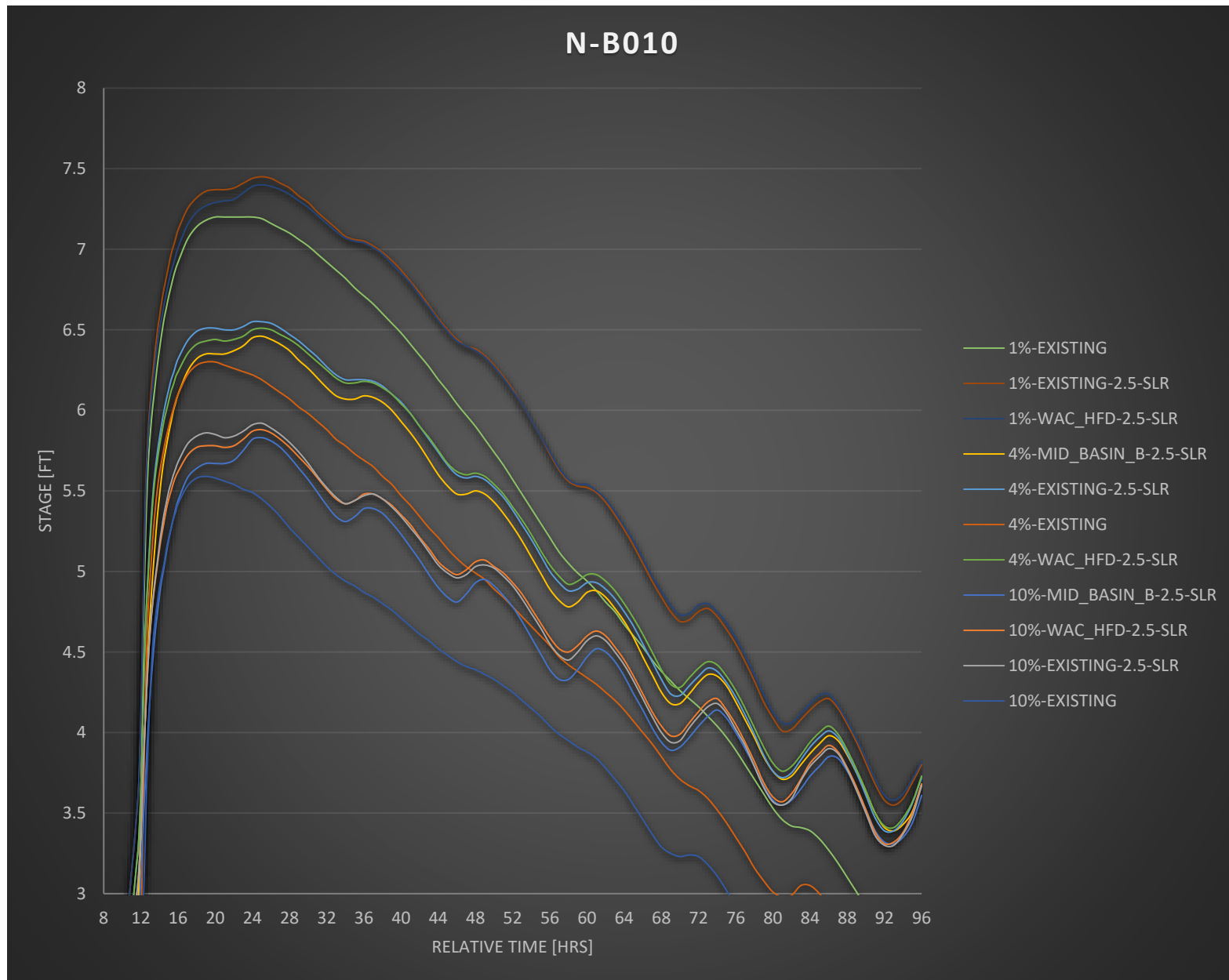


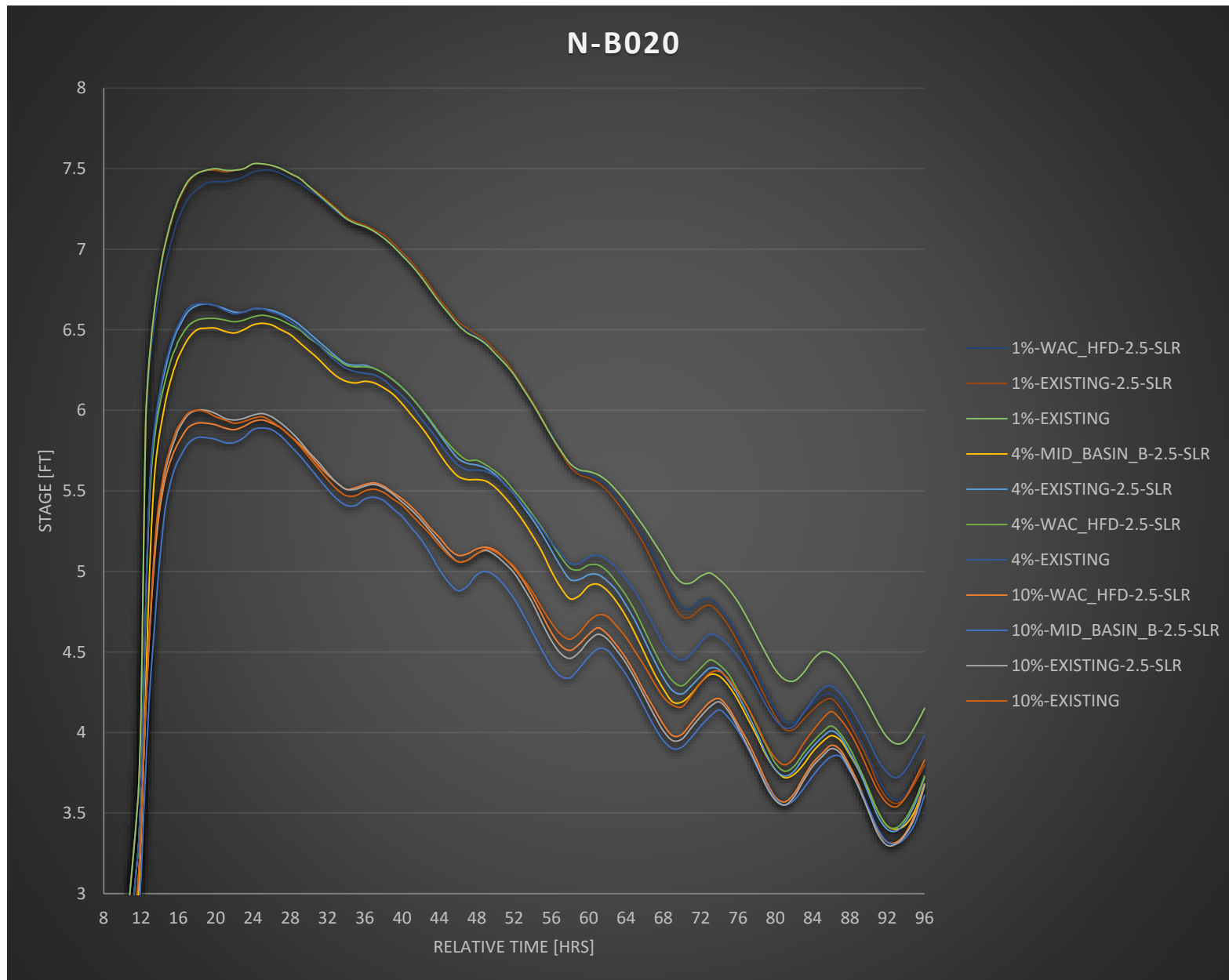


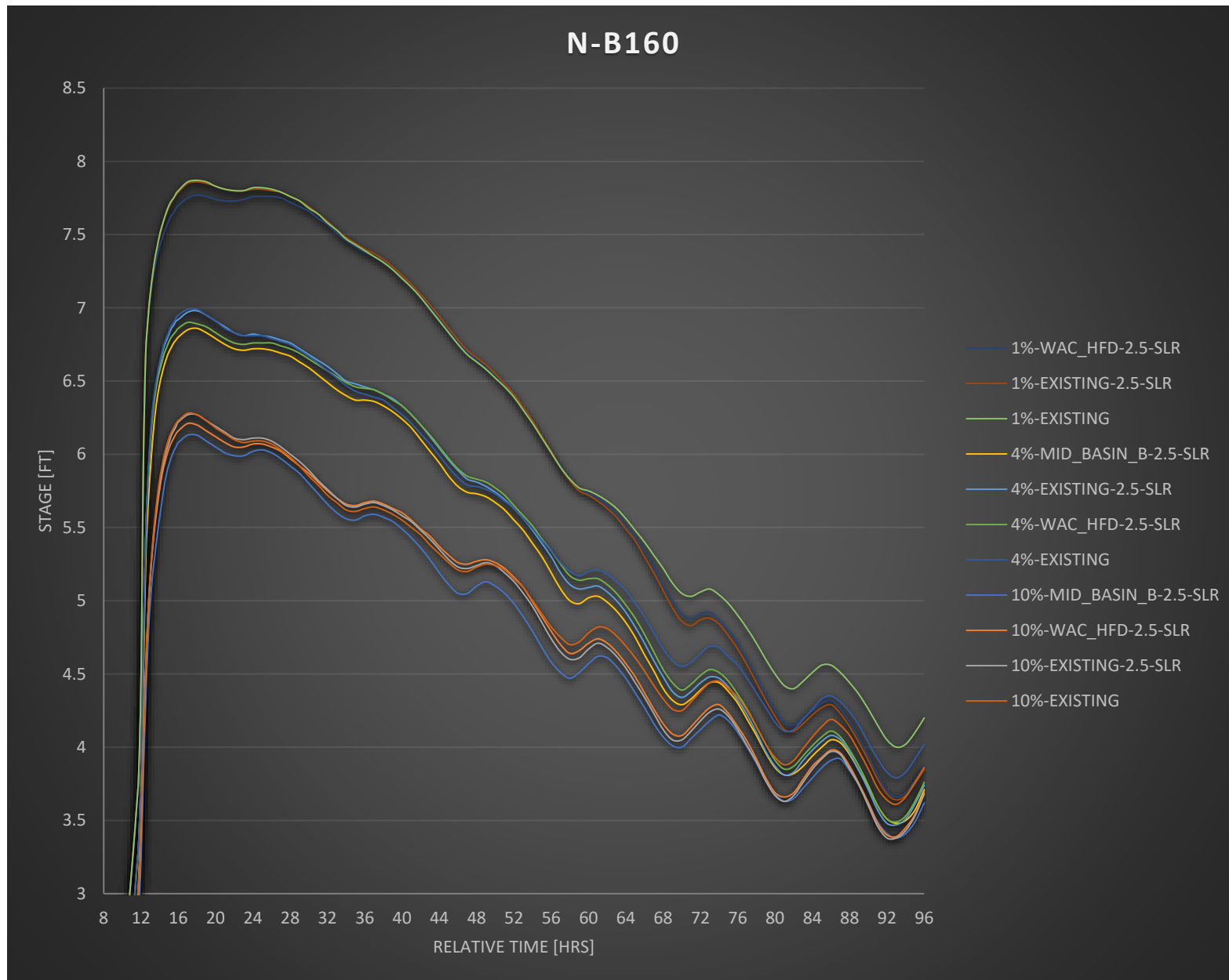


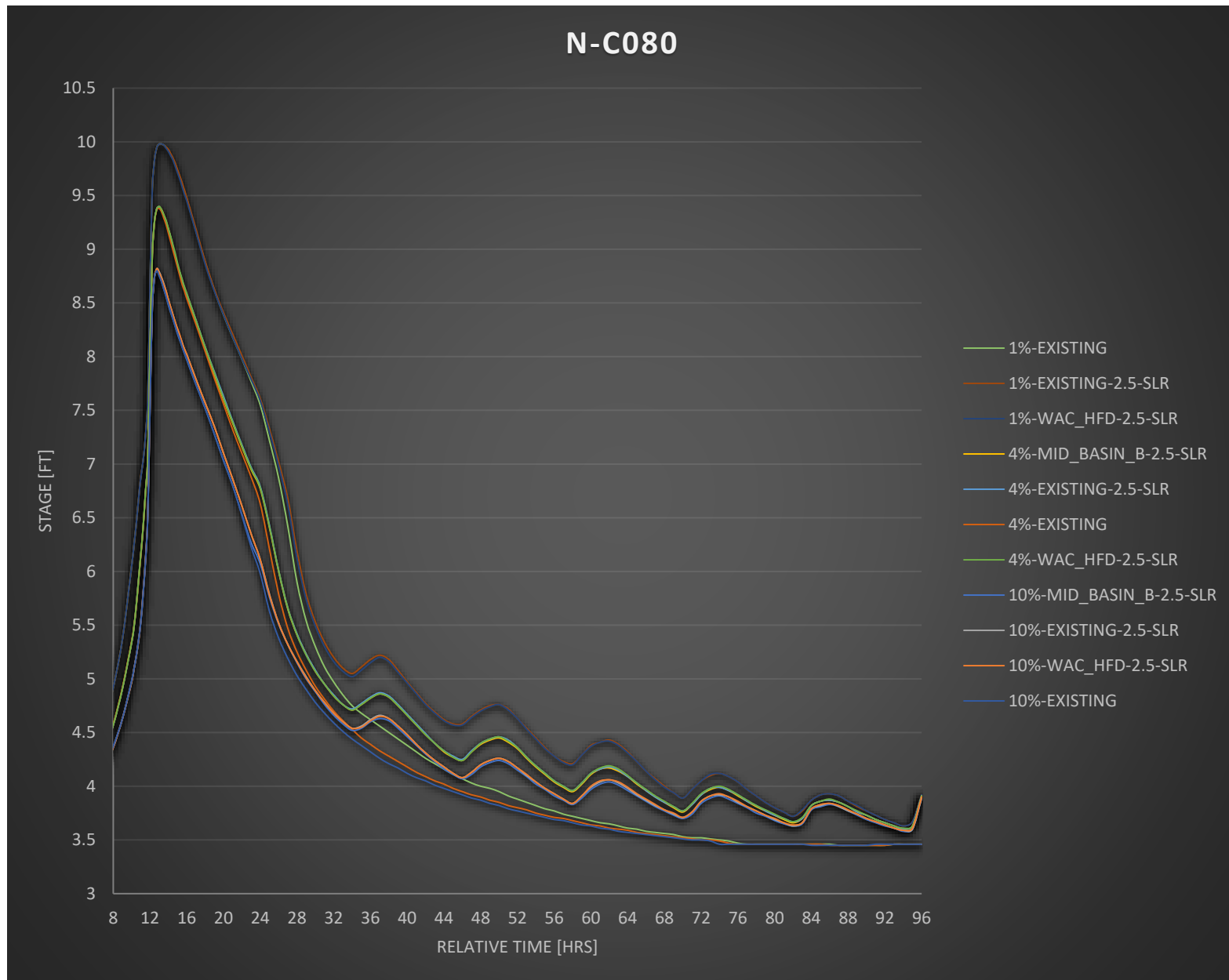


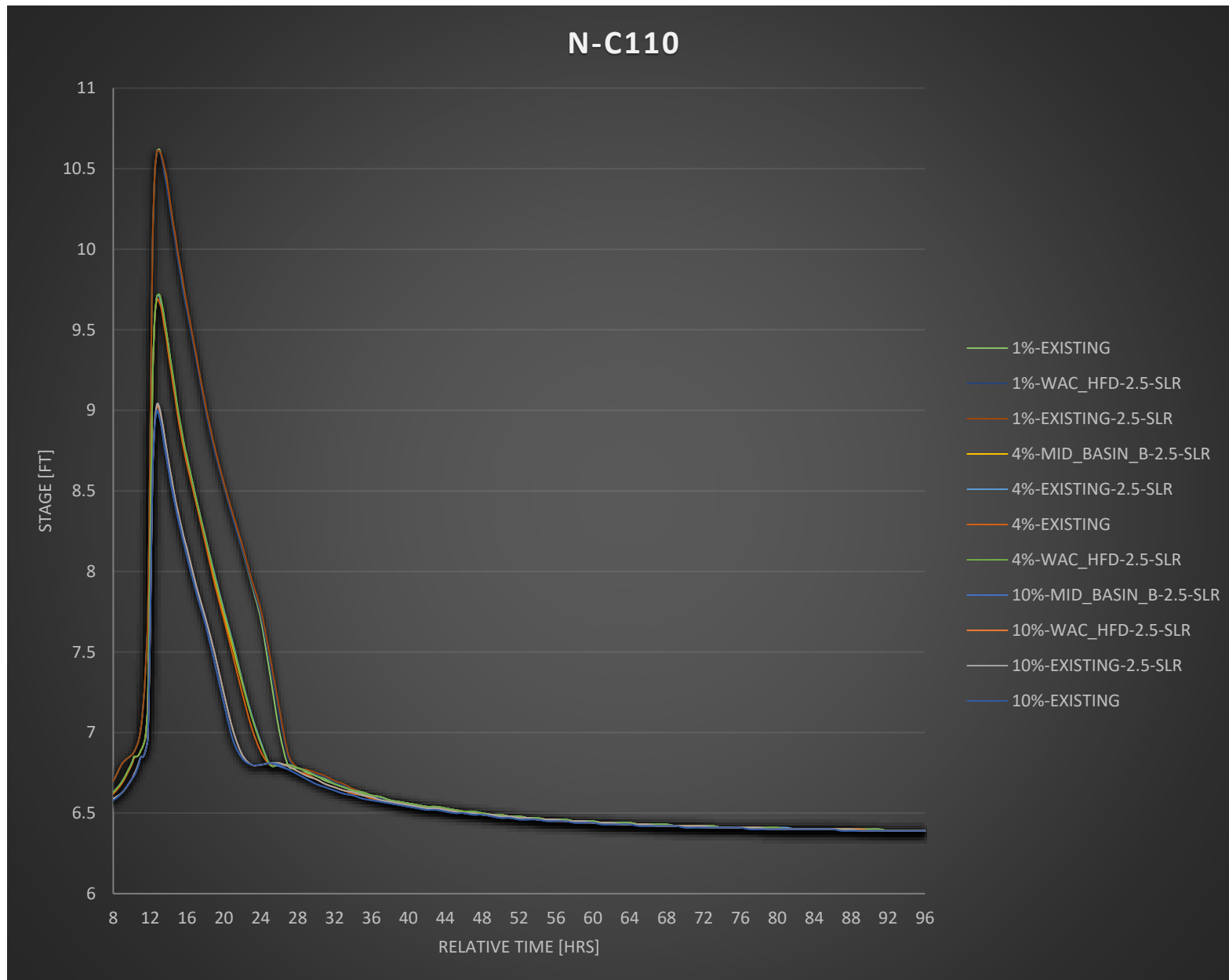


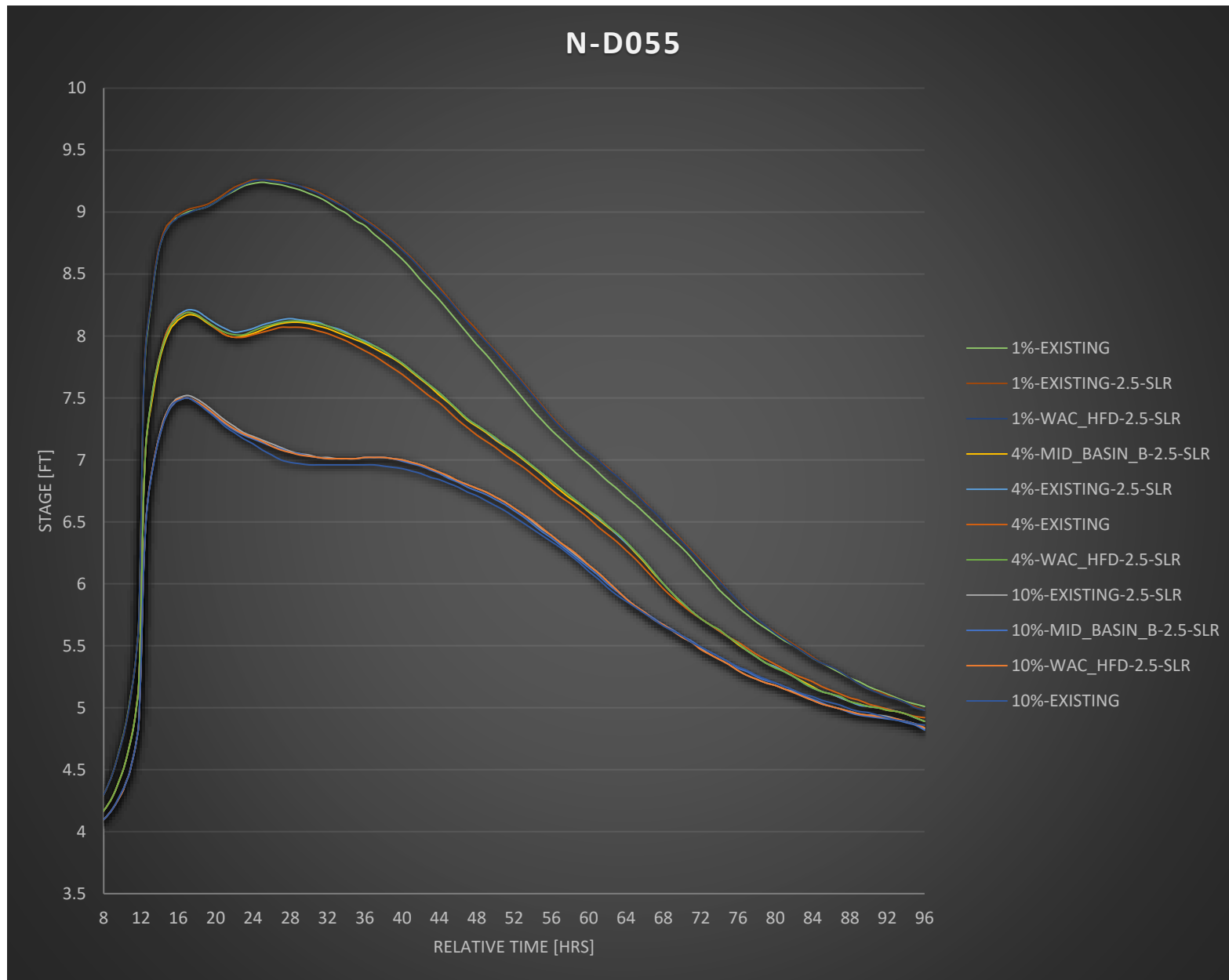


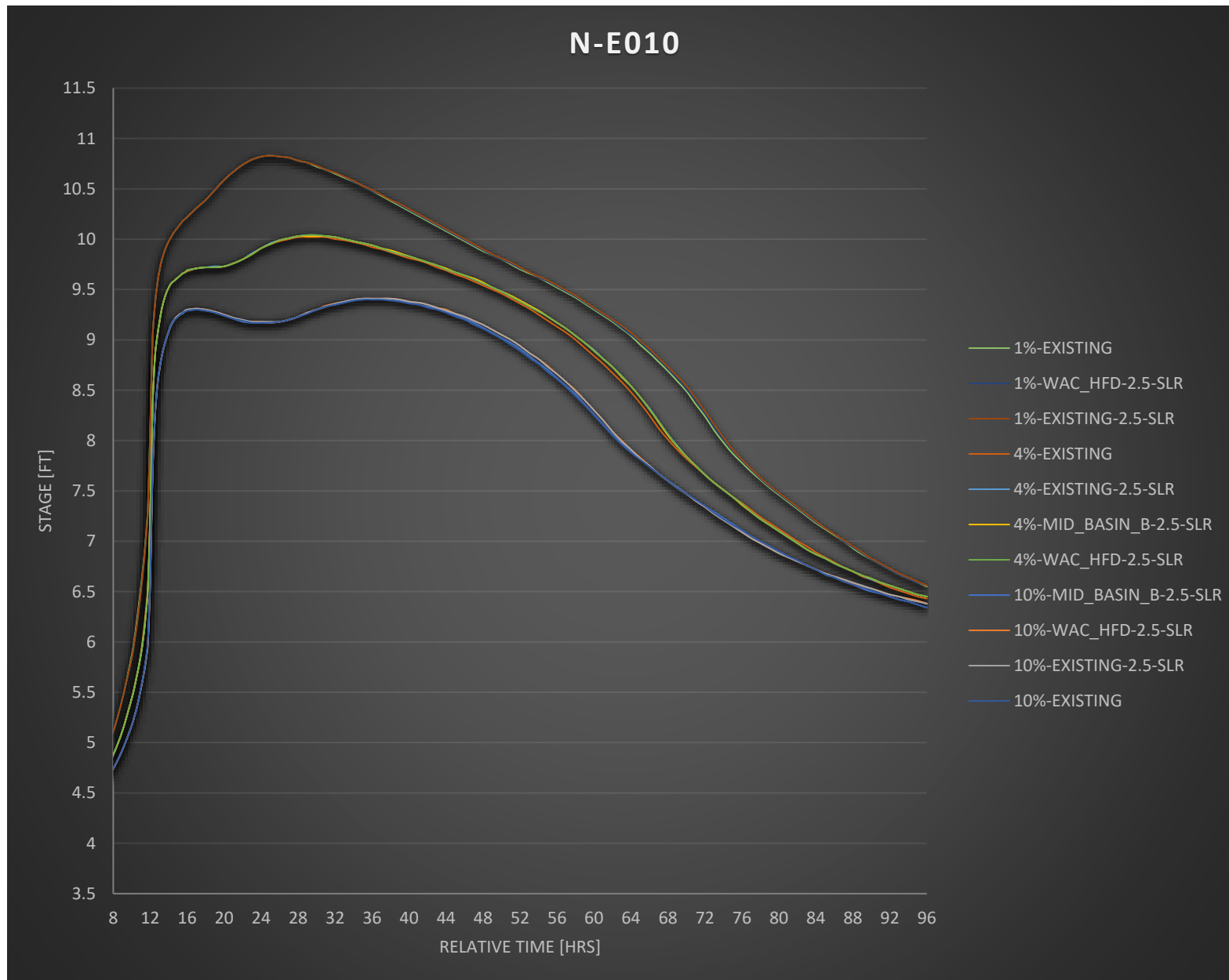


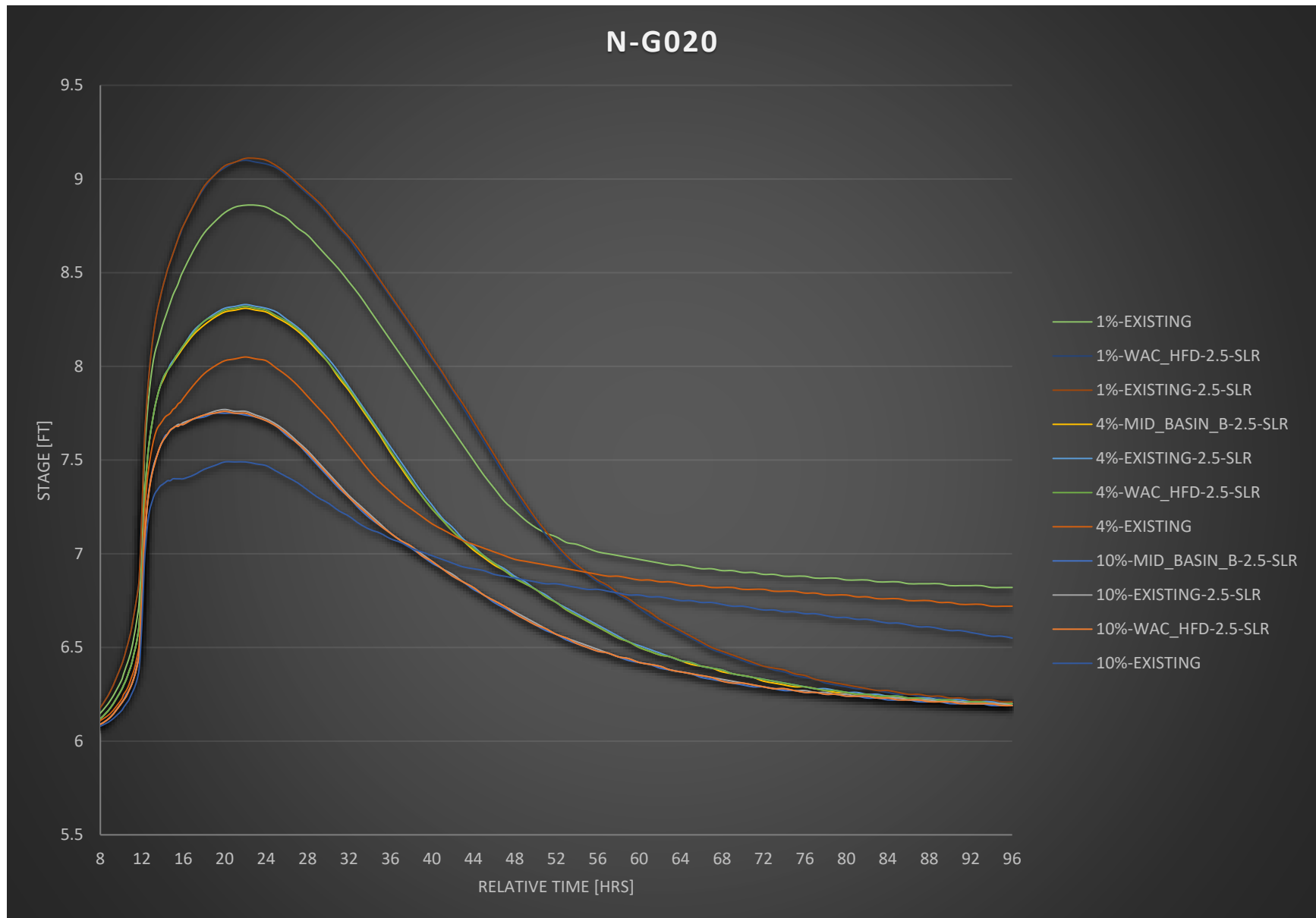




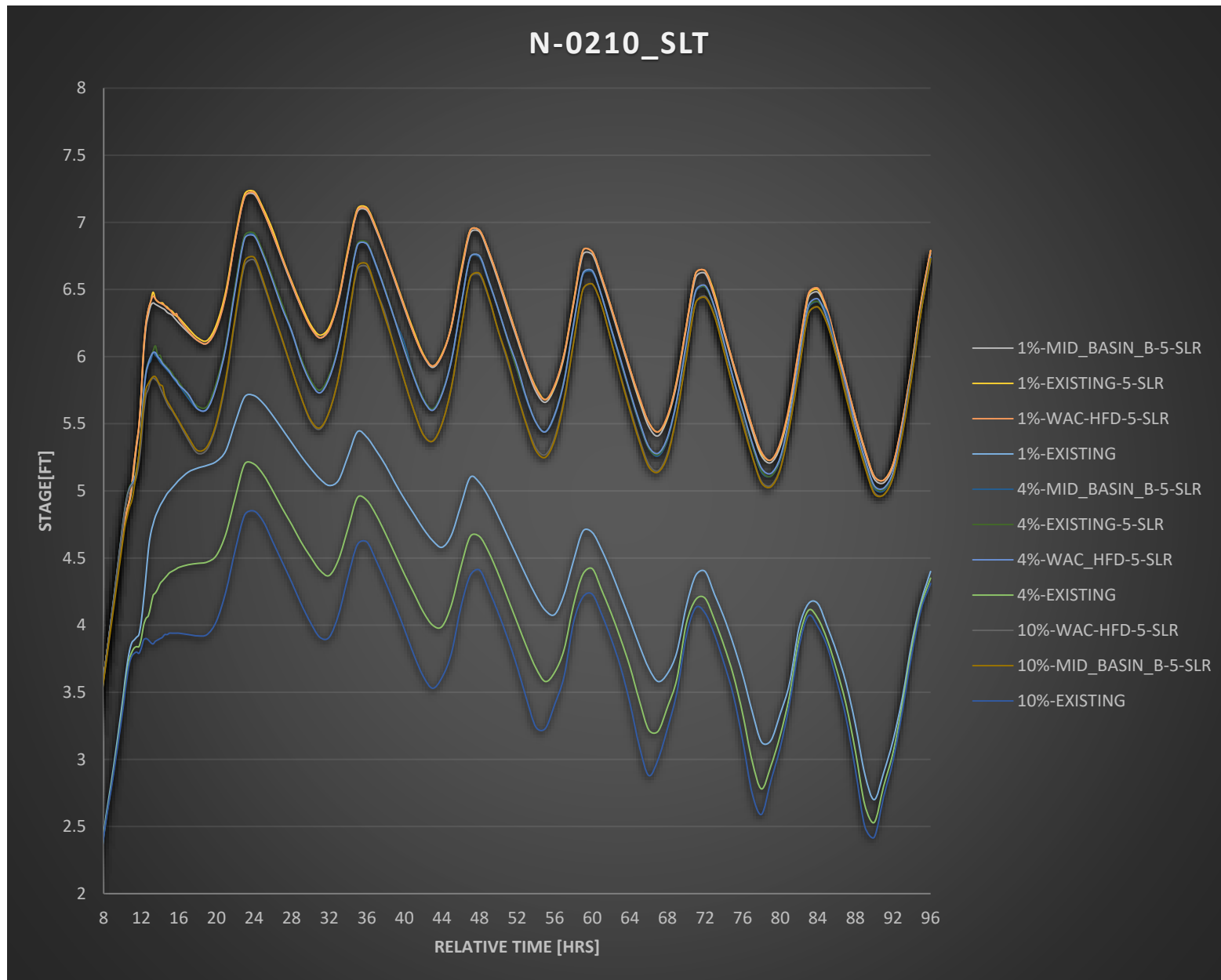


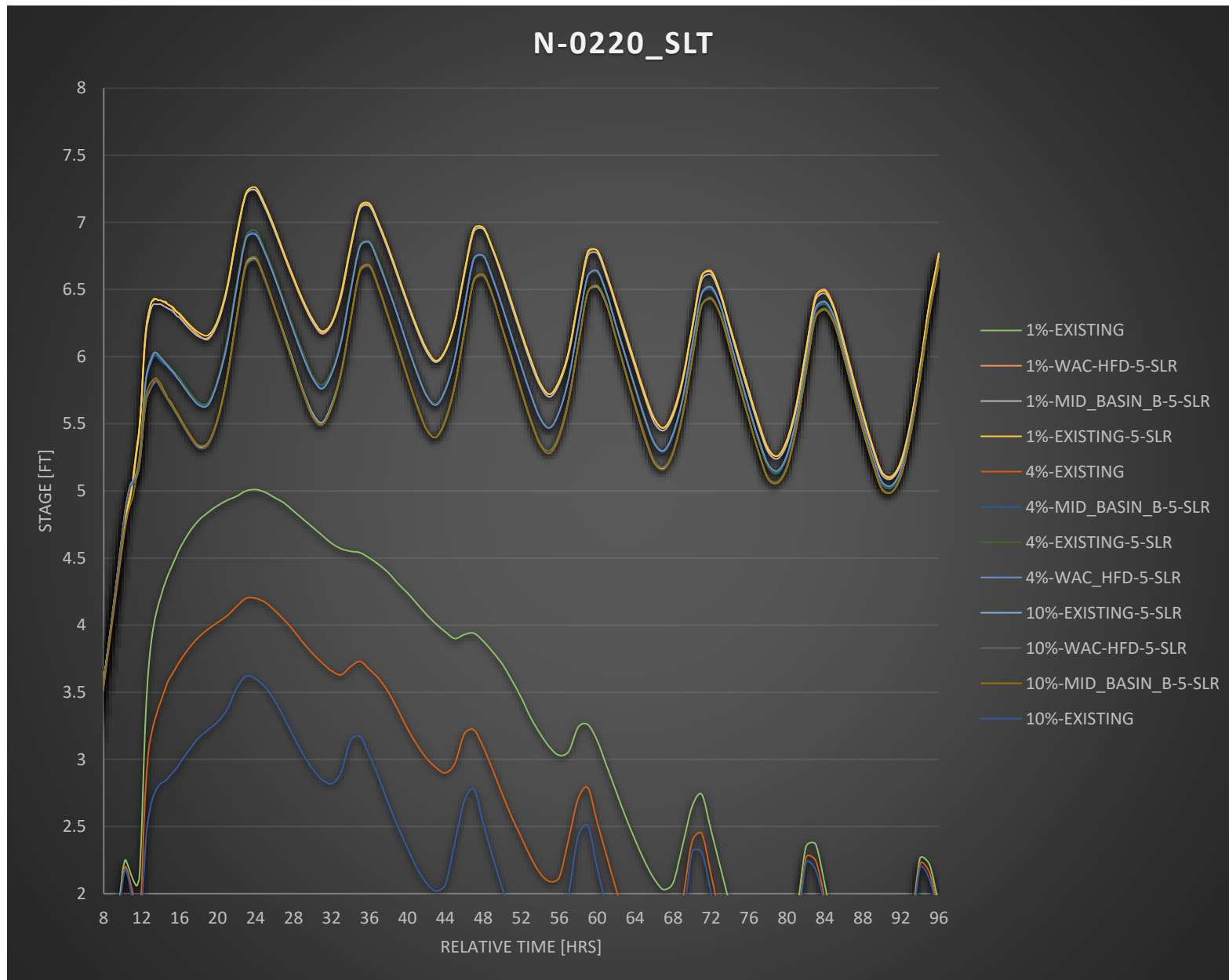


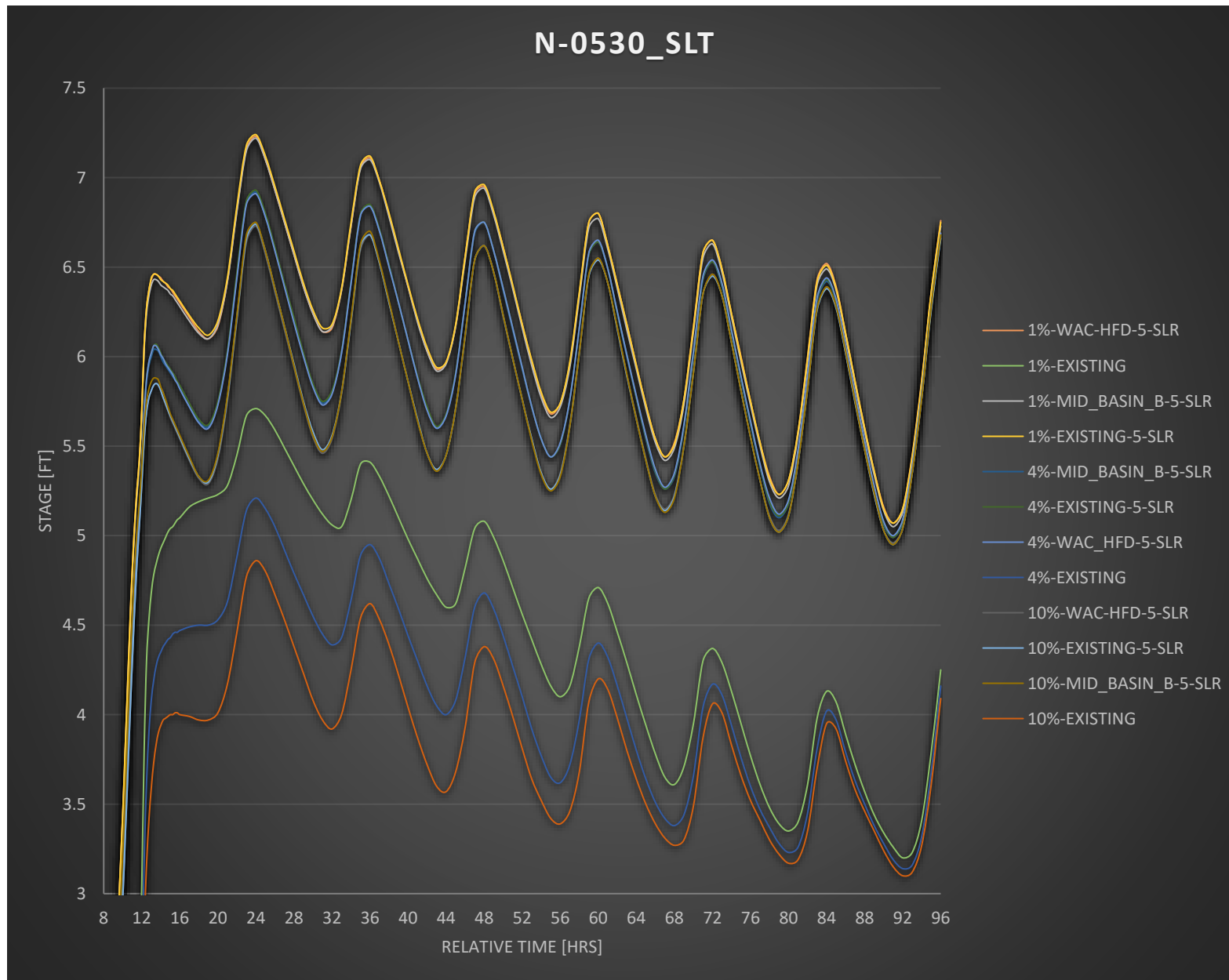


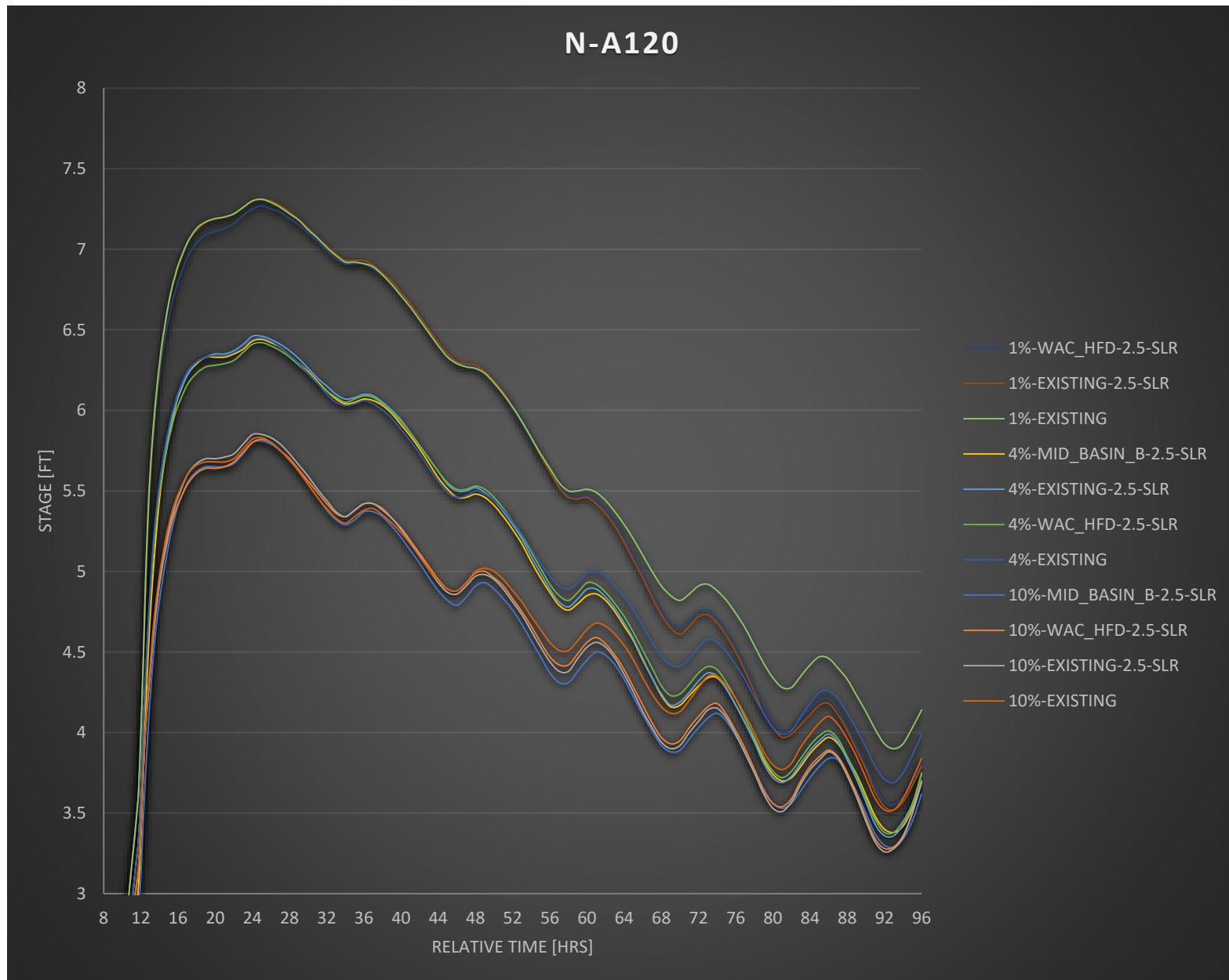


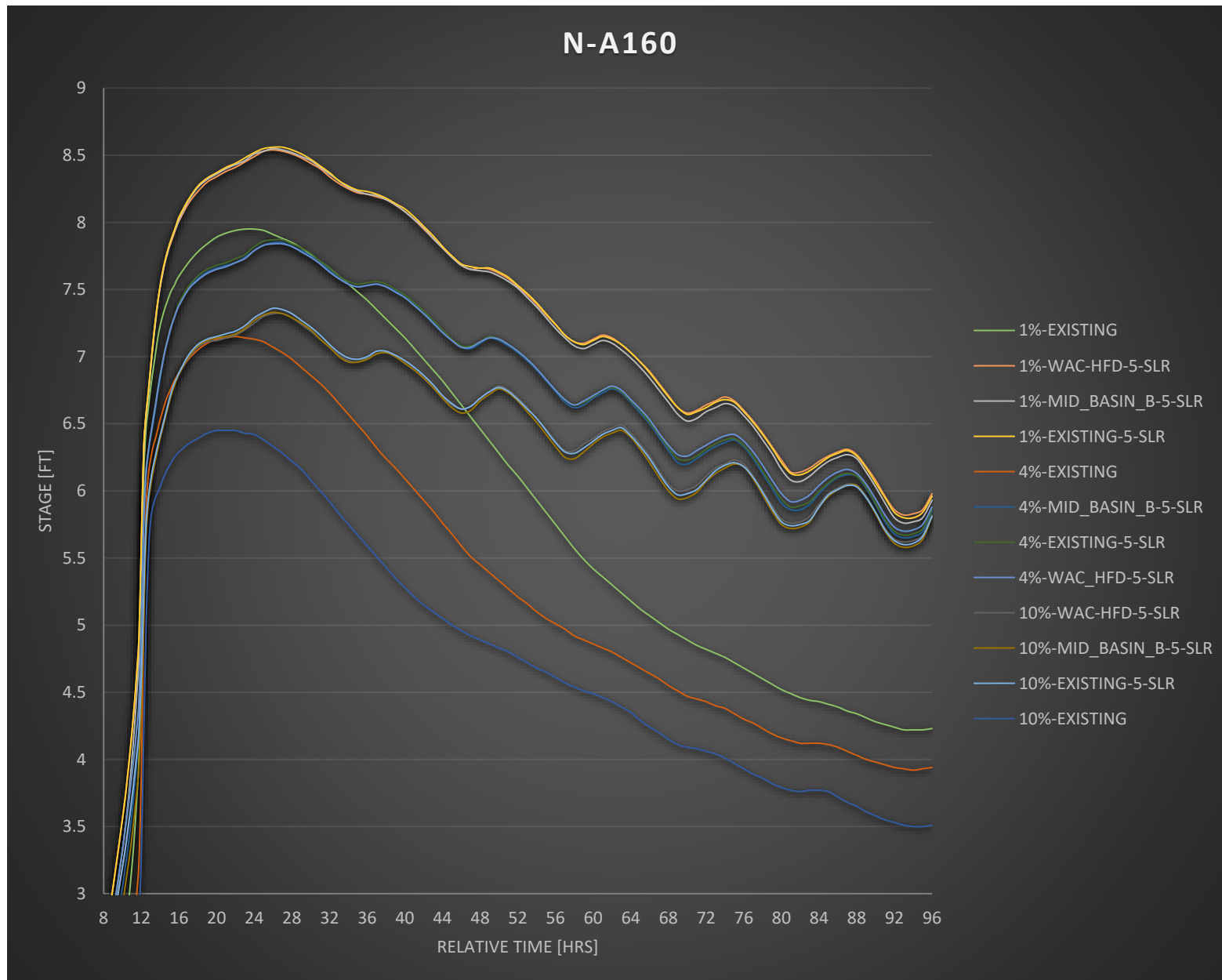
Attachment 1B. Effects of 5.0' Sea Level Rise on Mid Basin Improvements

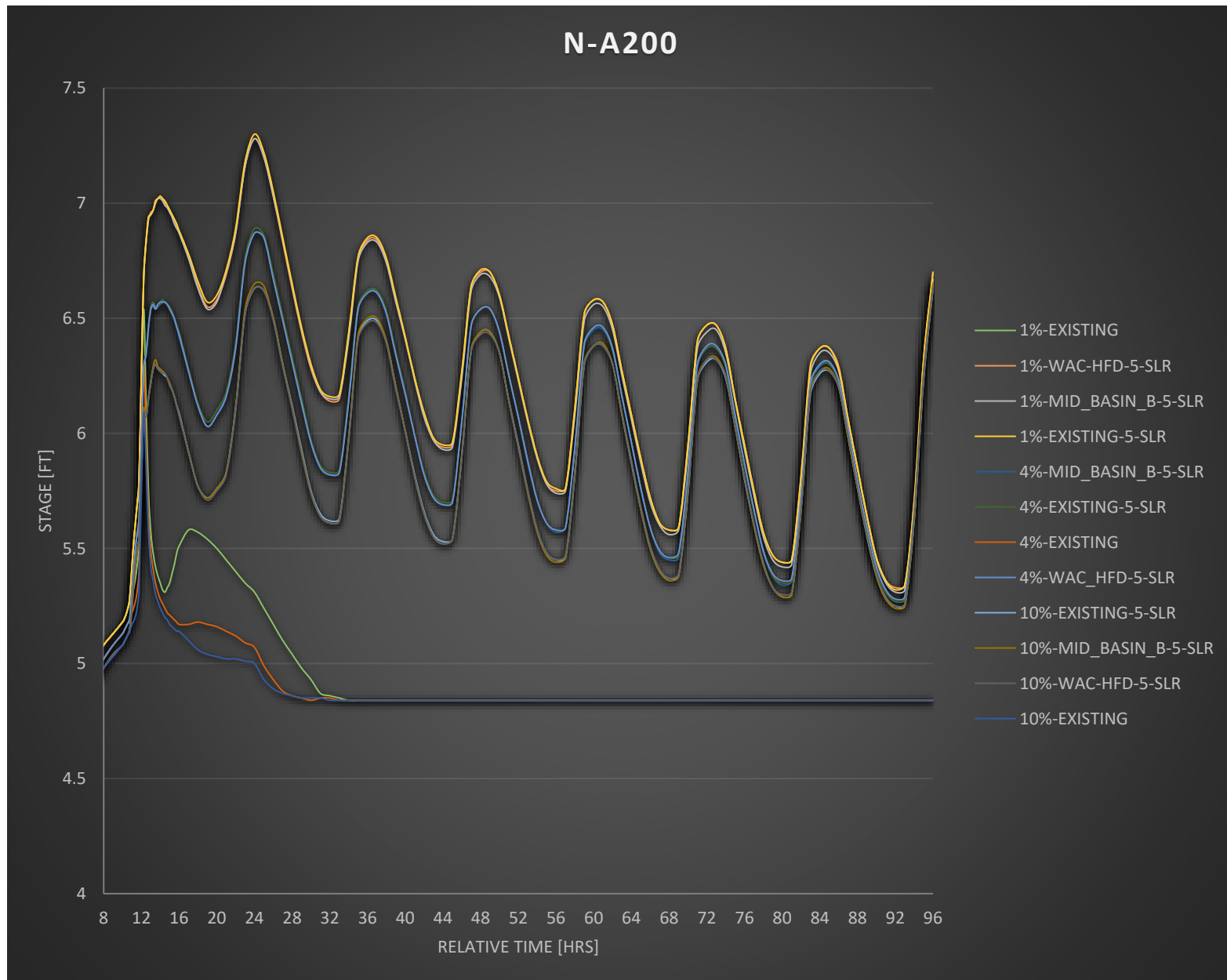


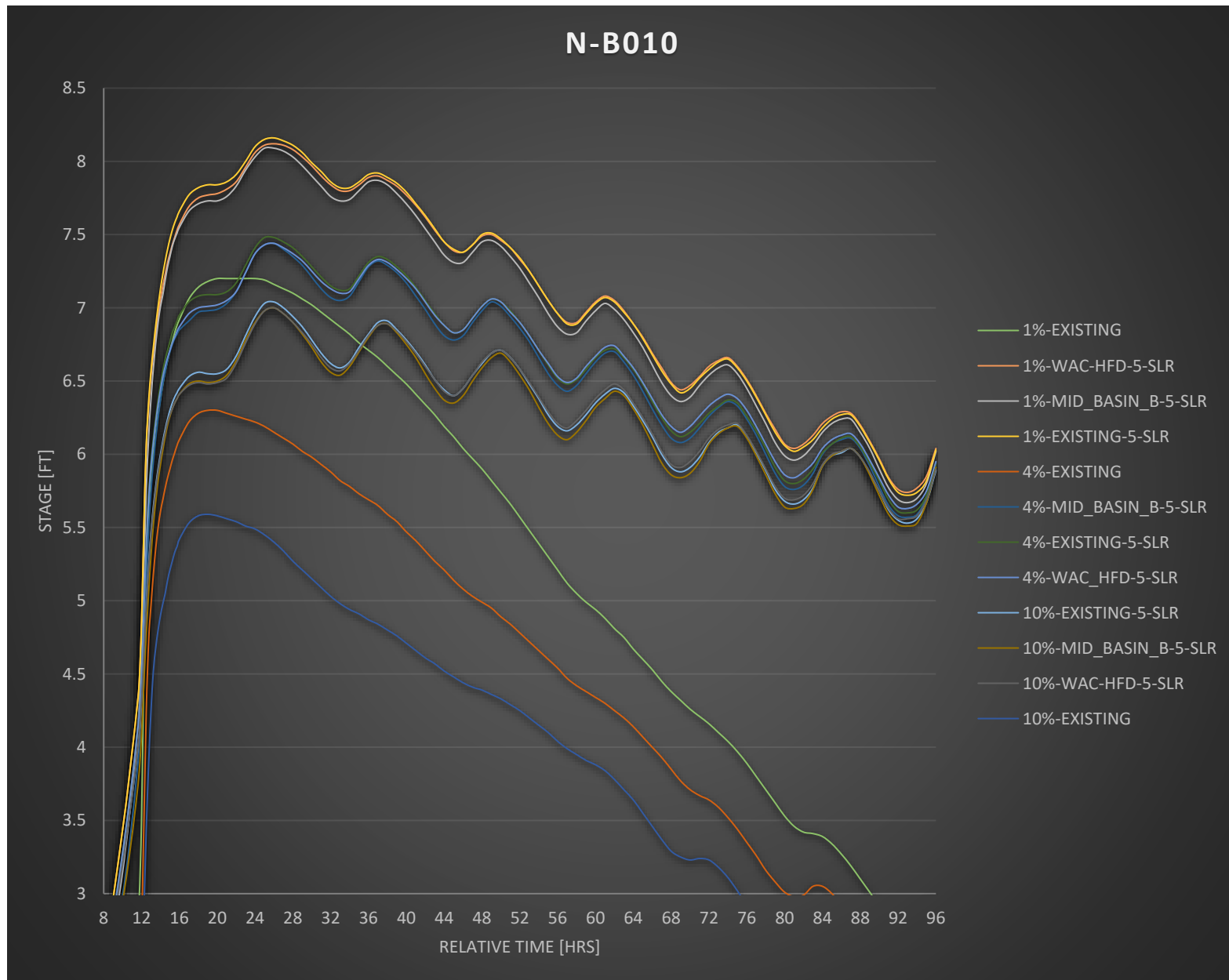


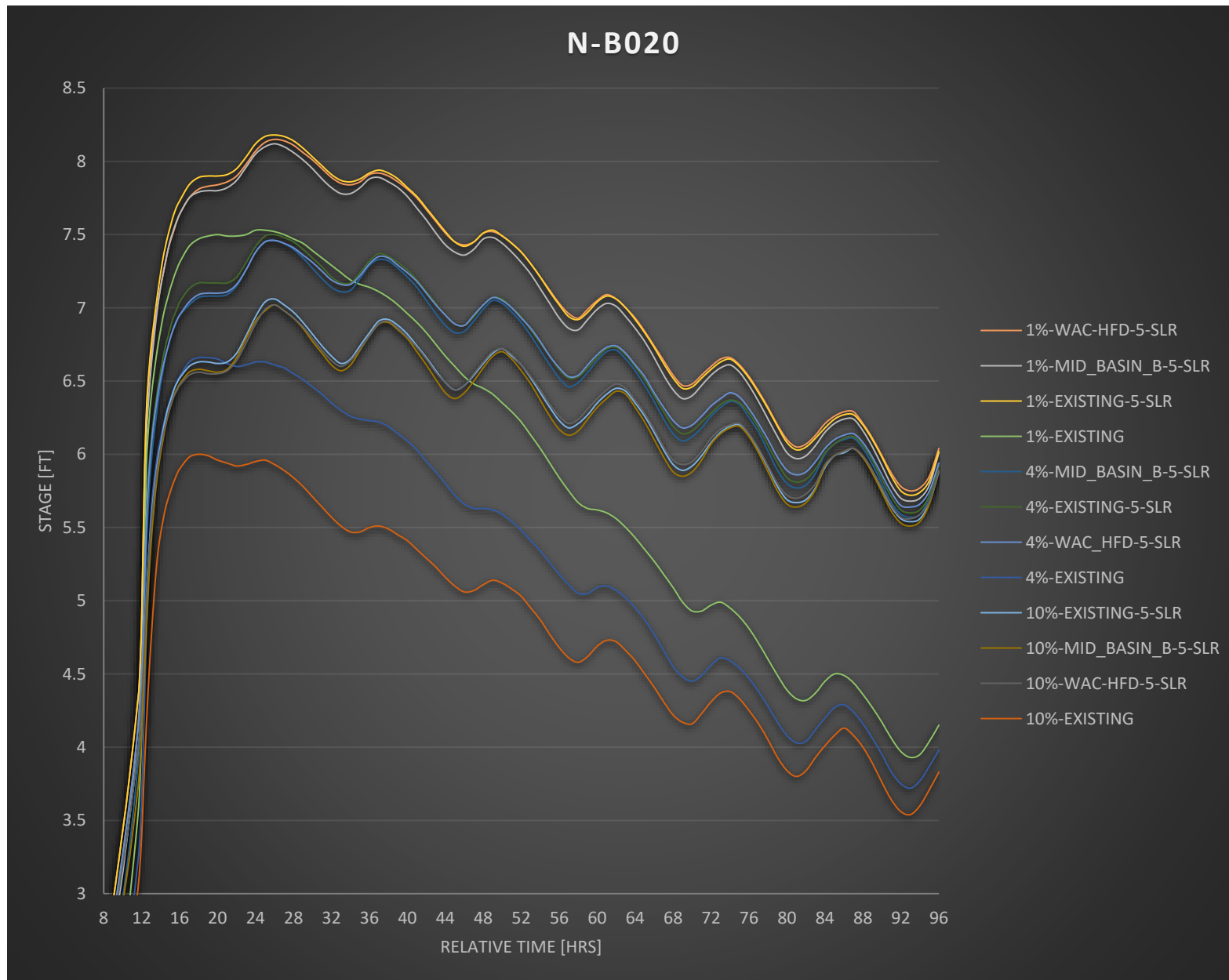


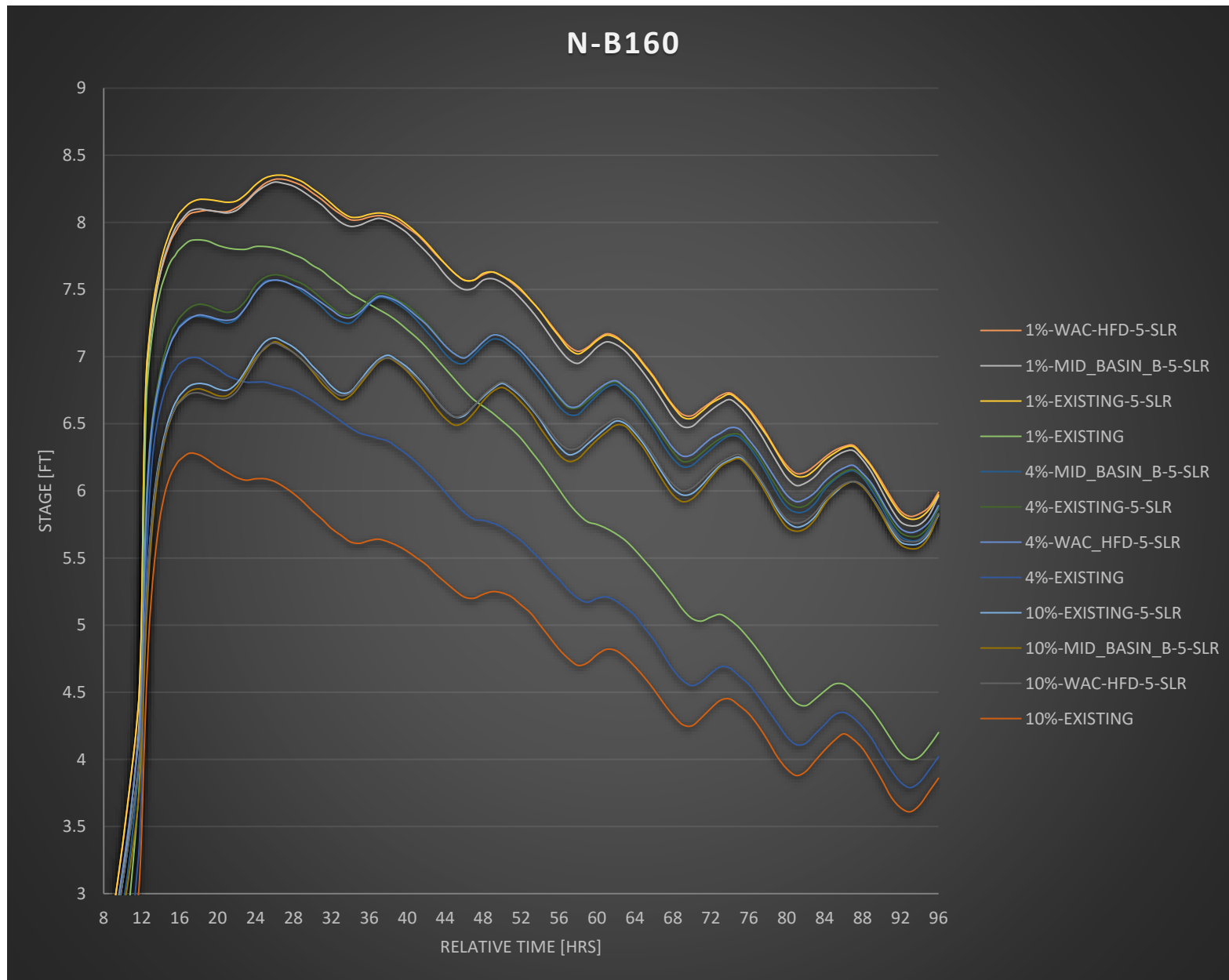


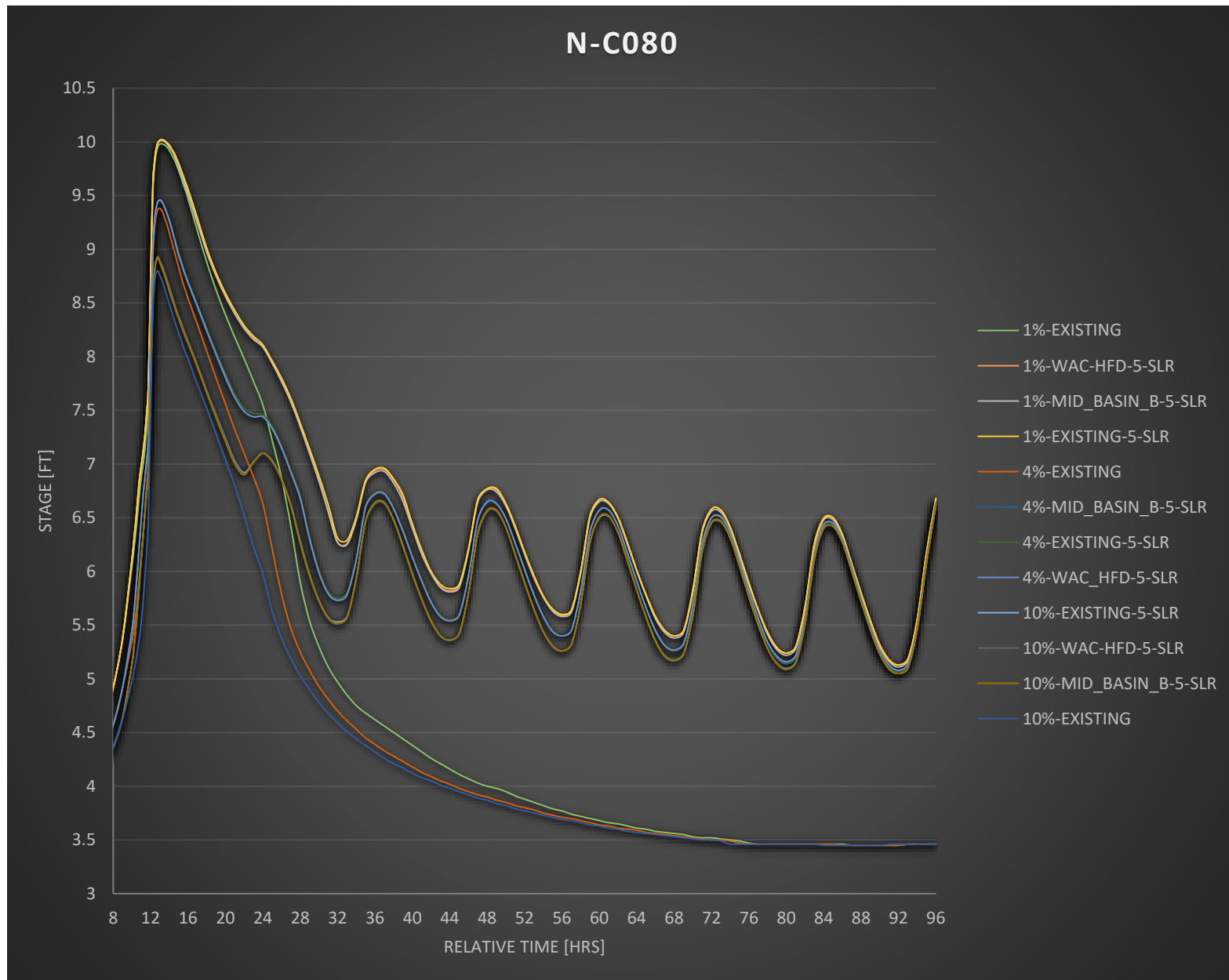


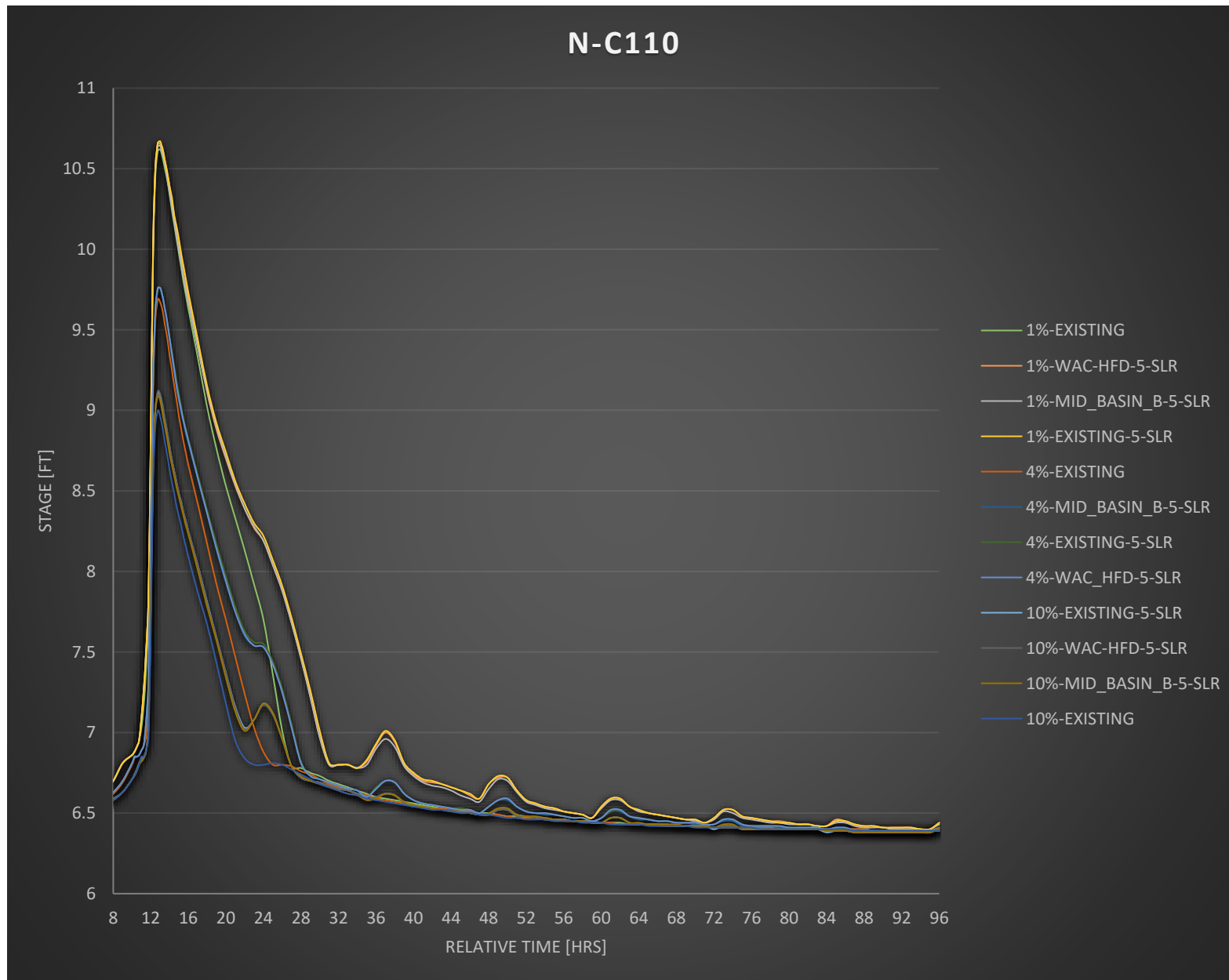


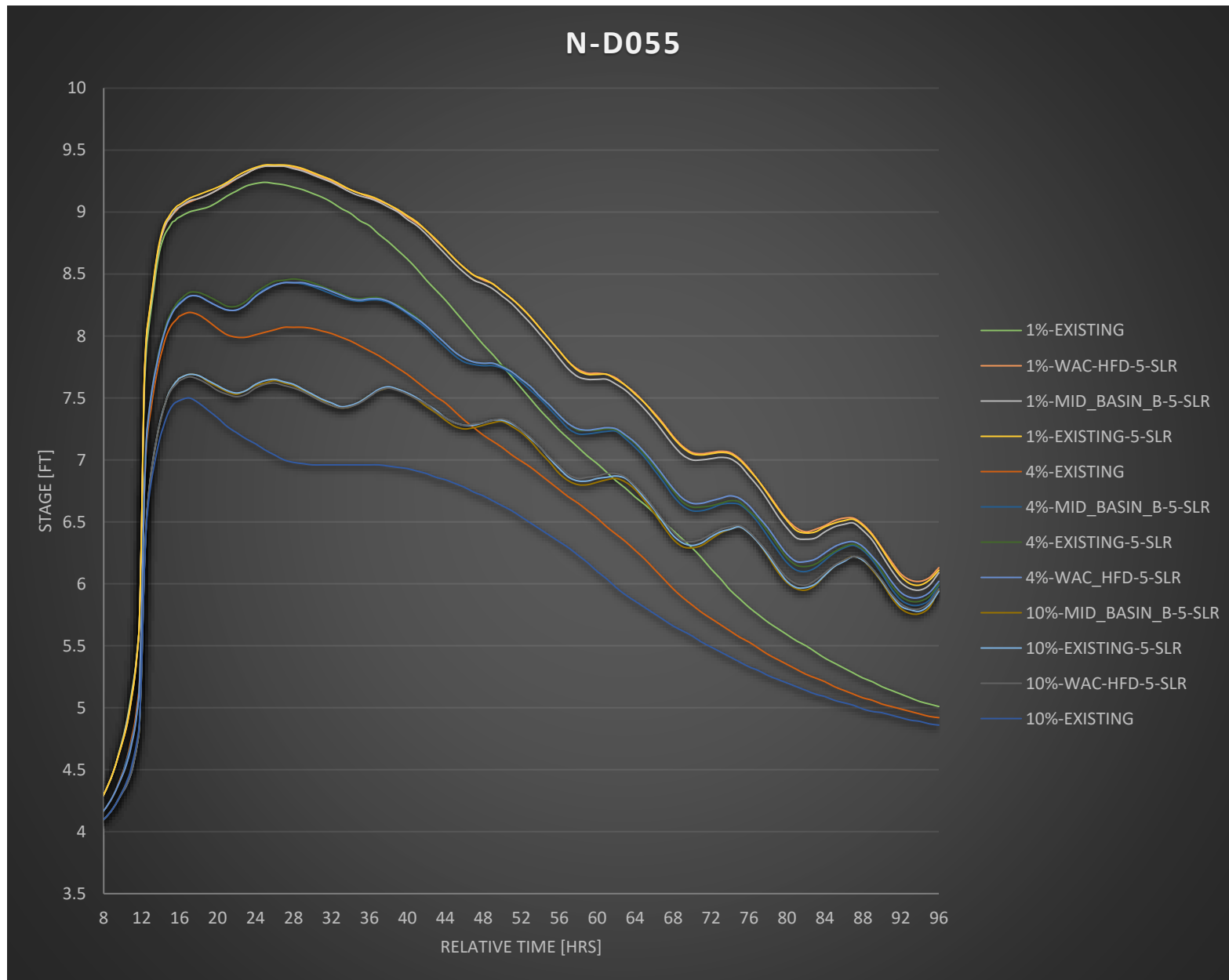


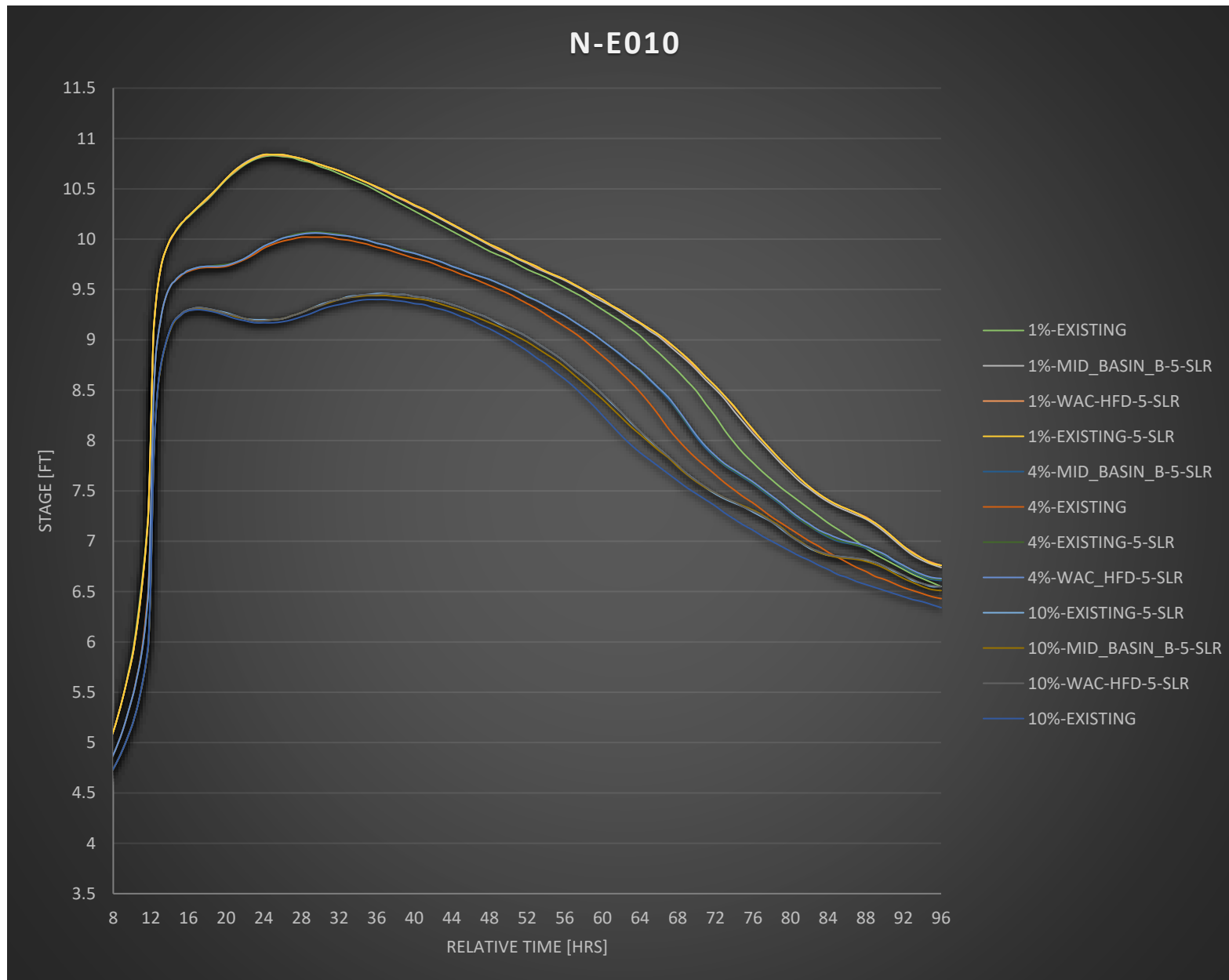


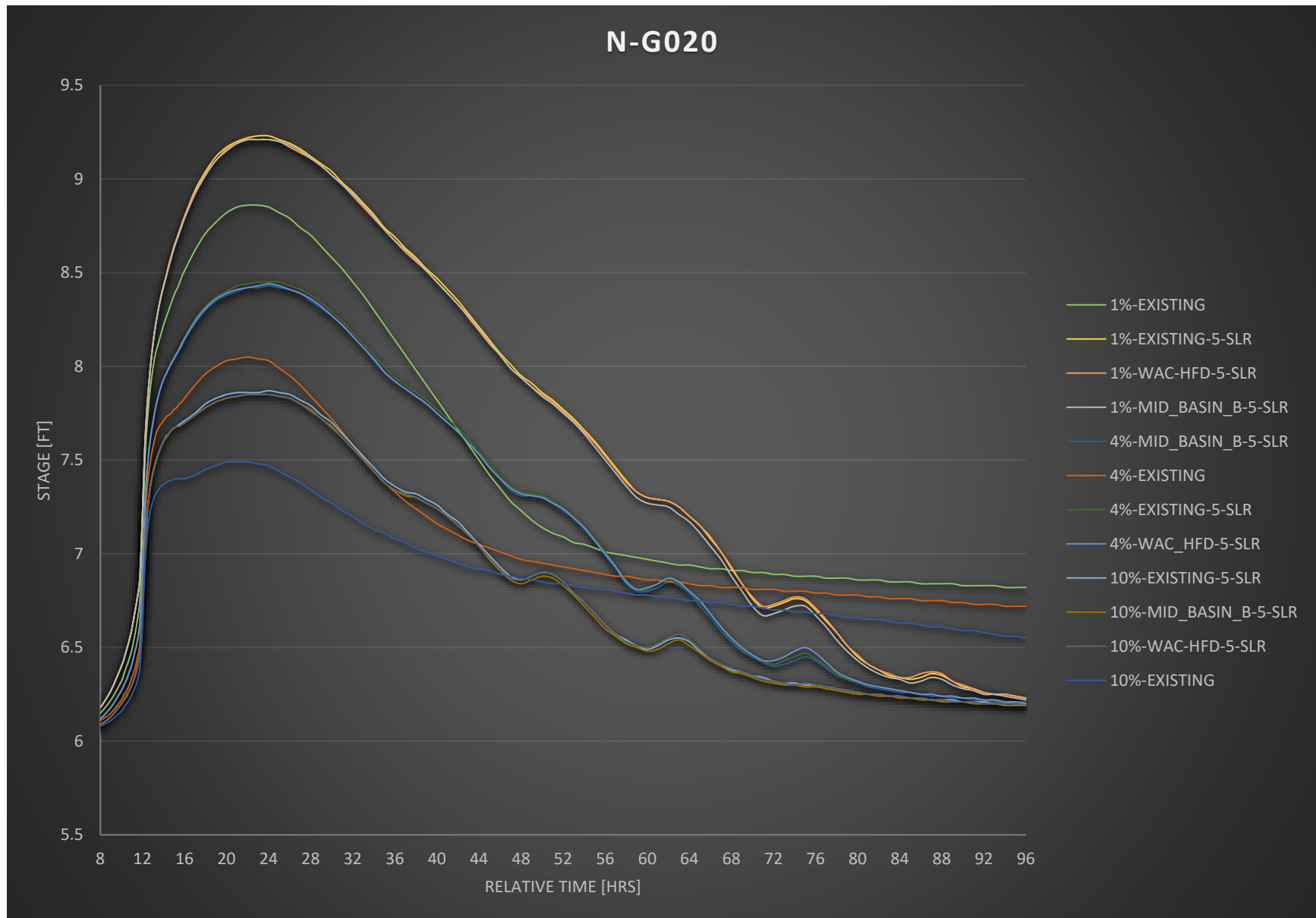




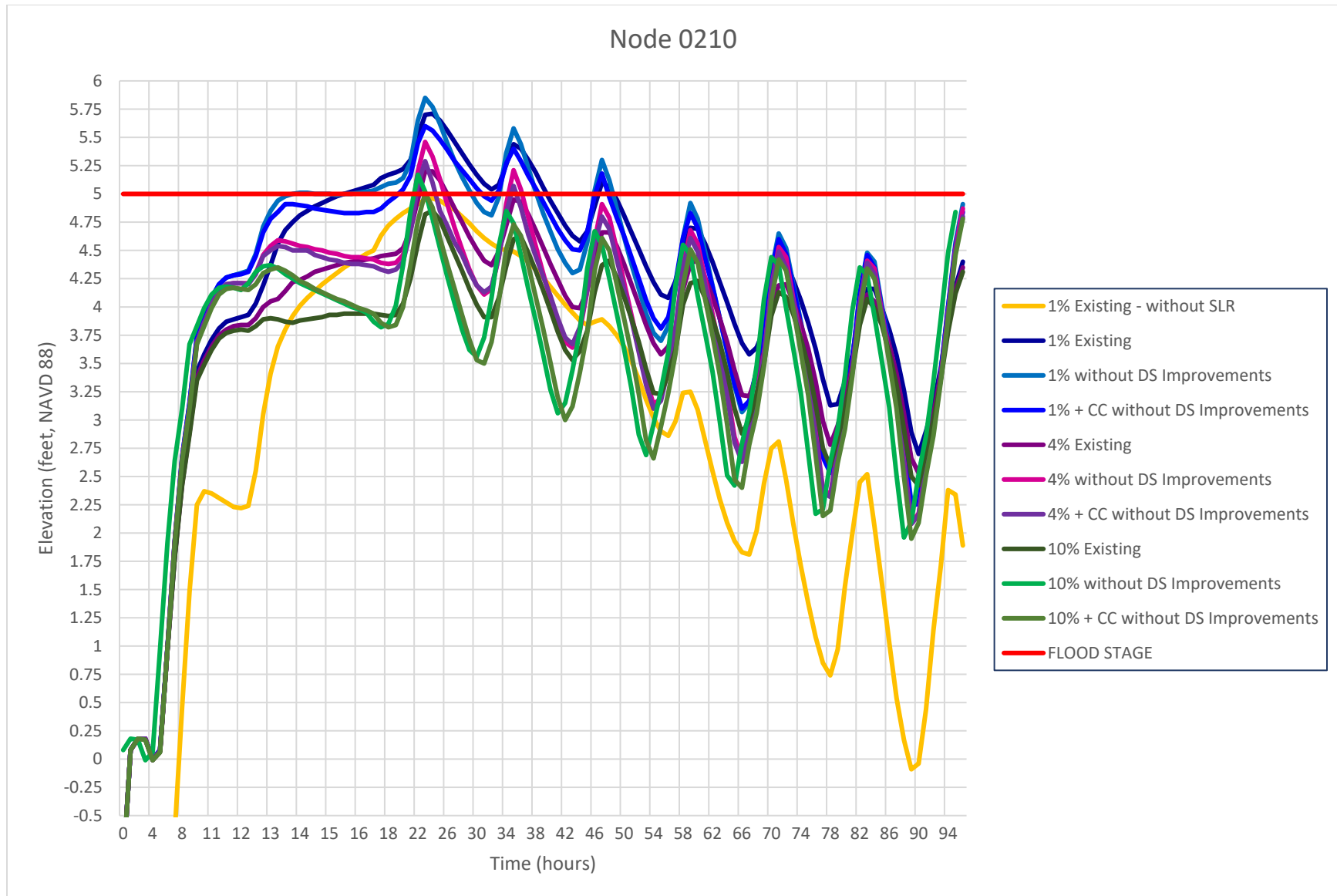


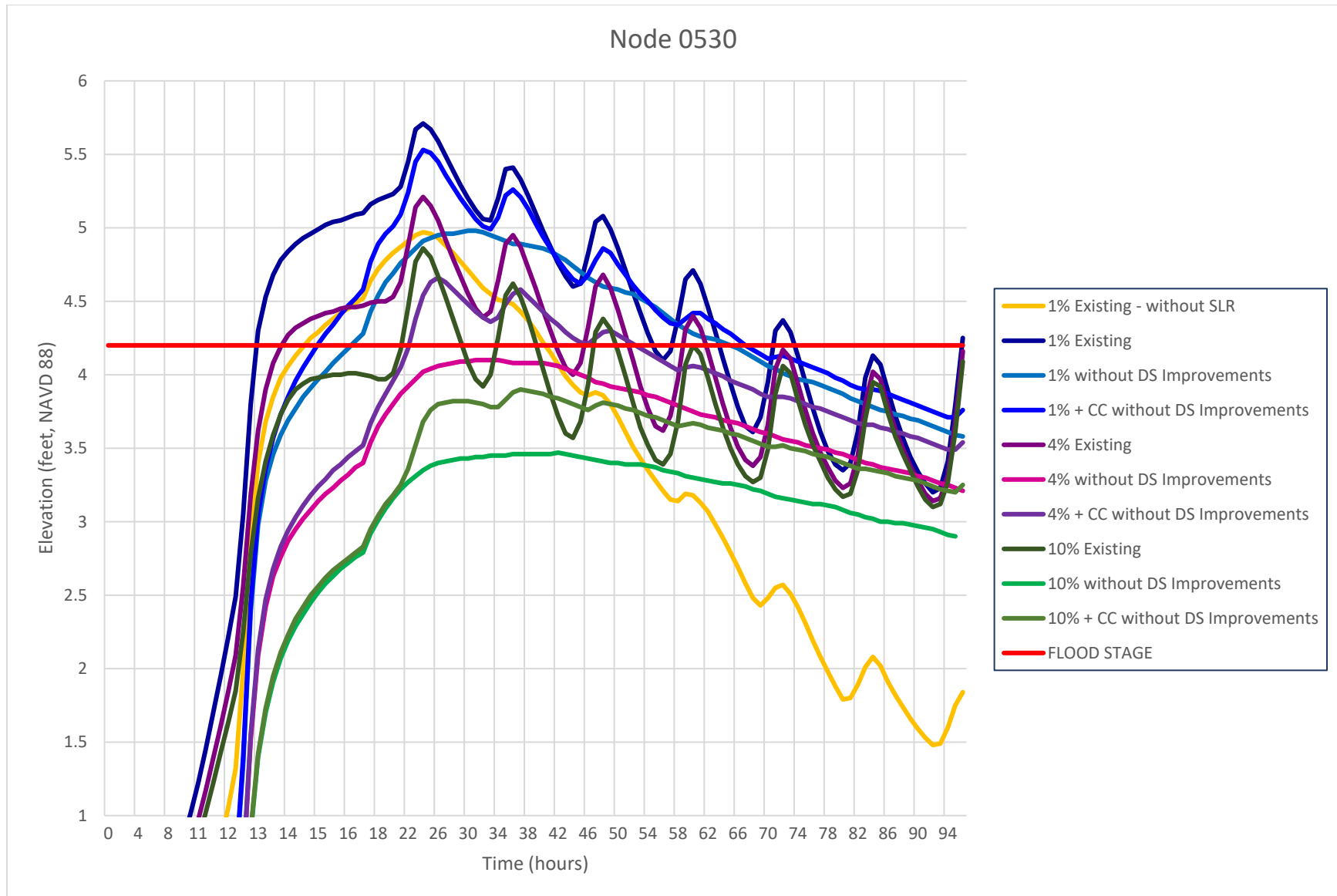


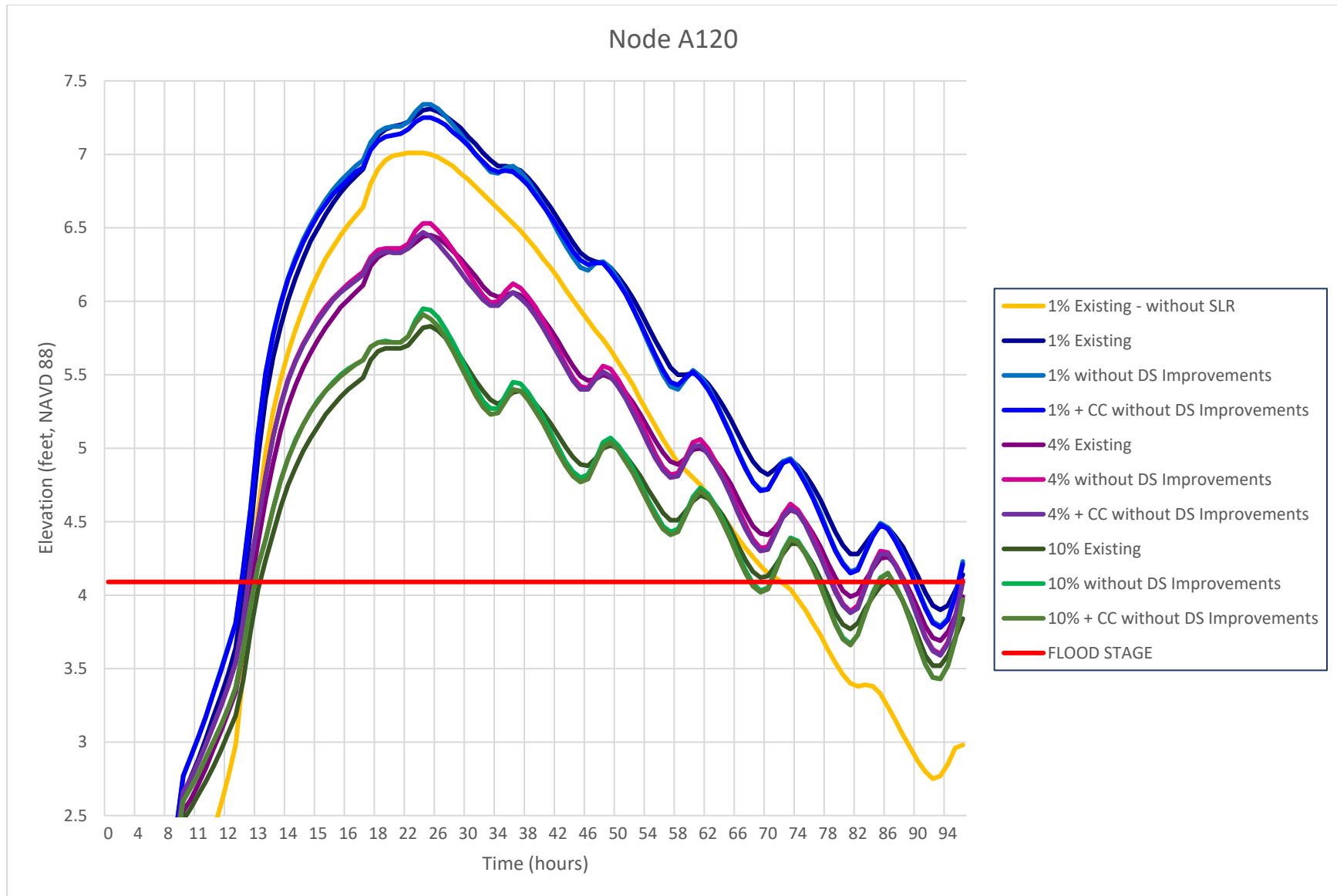


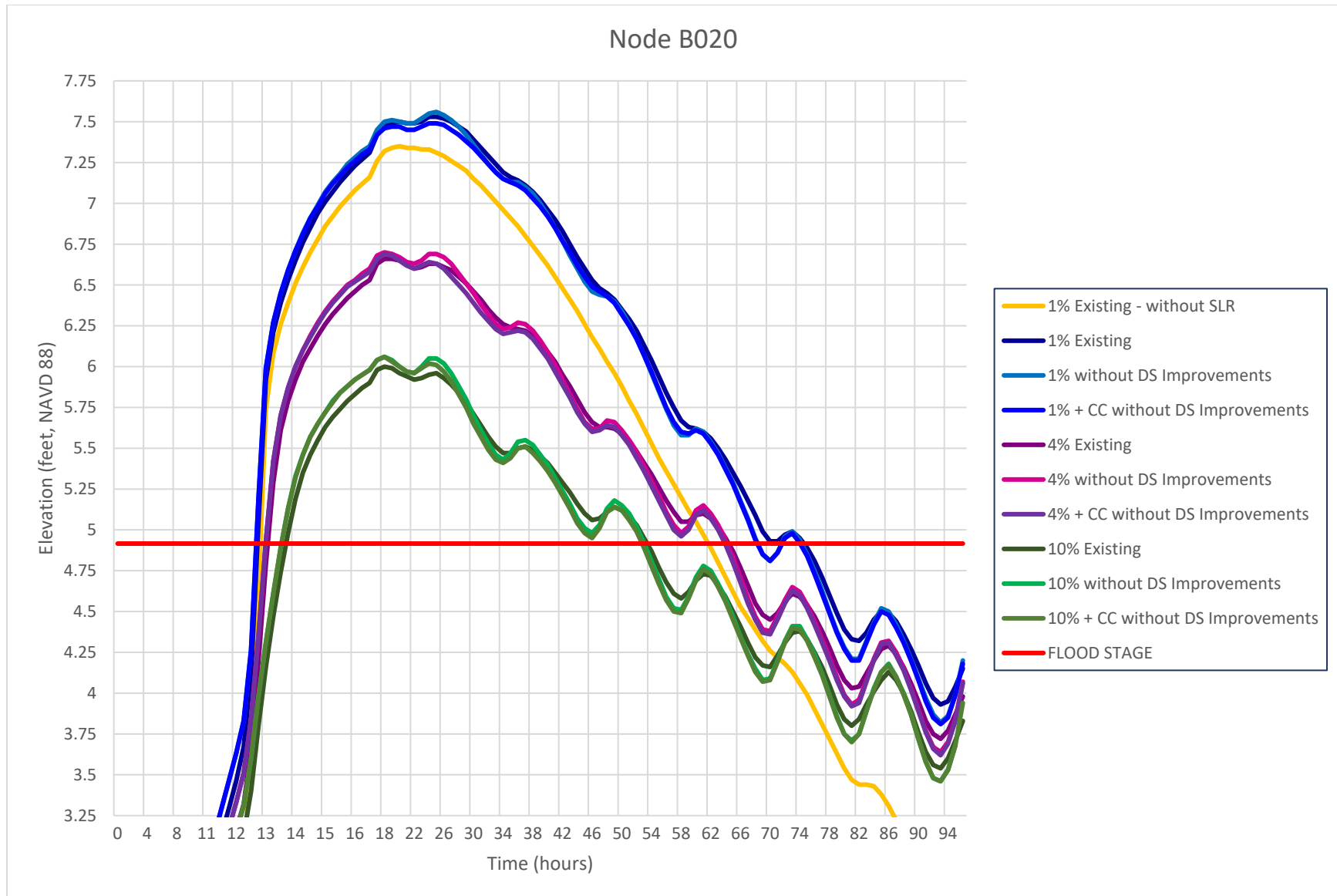


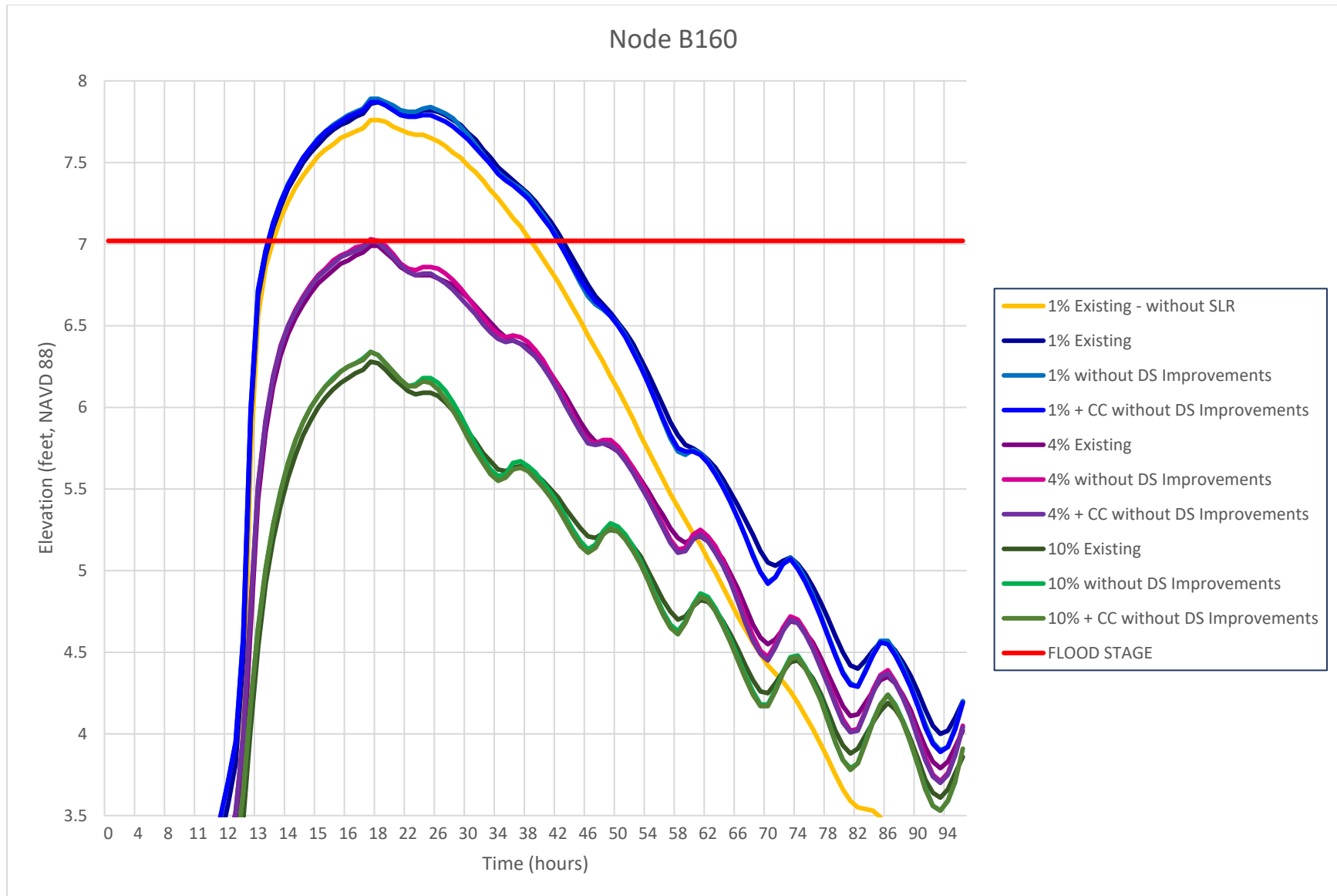
Attachment 1C. Effects of 2.5' Sea Level Rise on the Lake Dotterer Diversion without Downstream Improvements

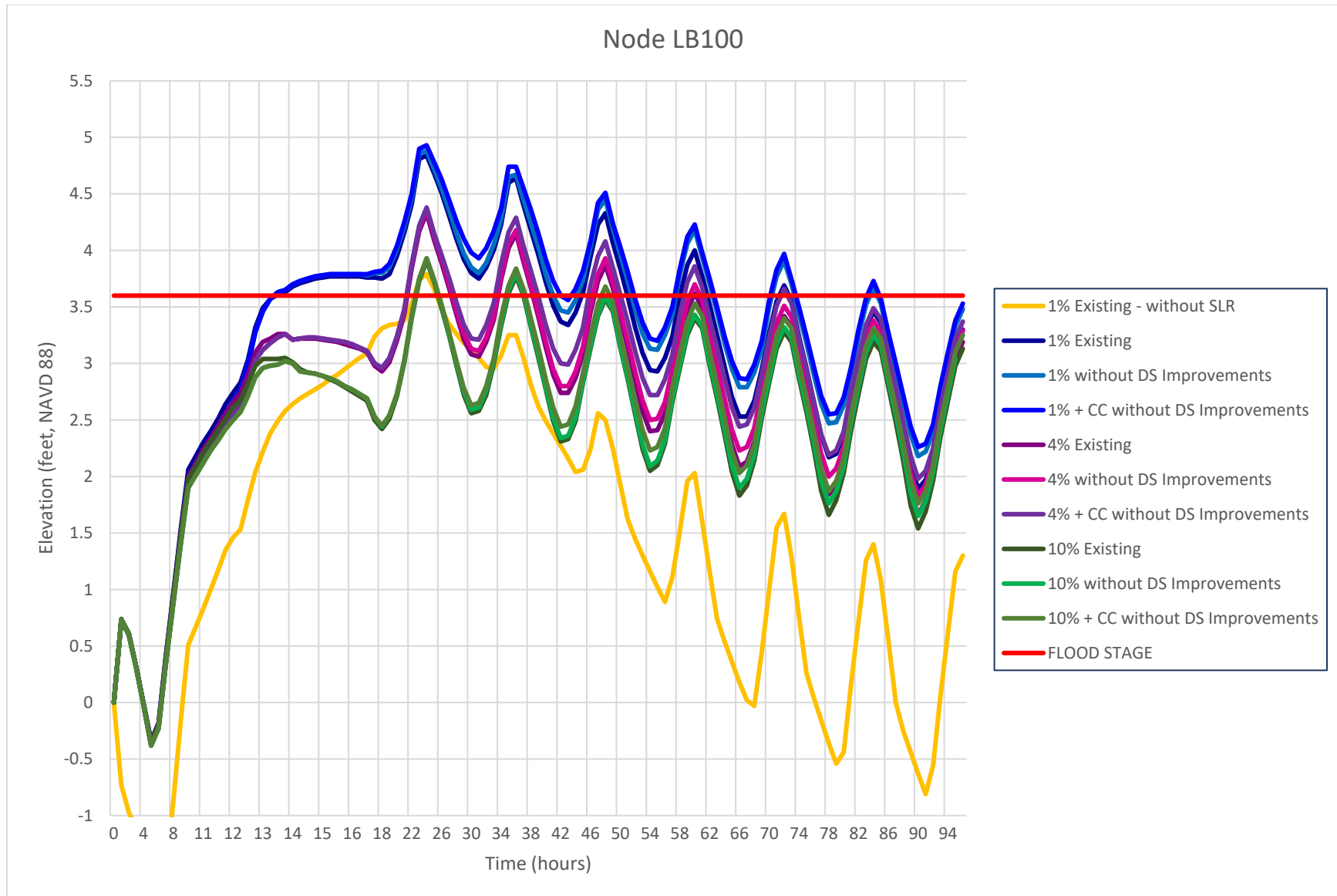


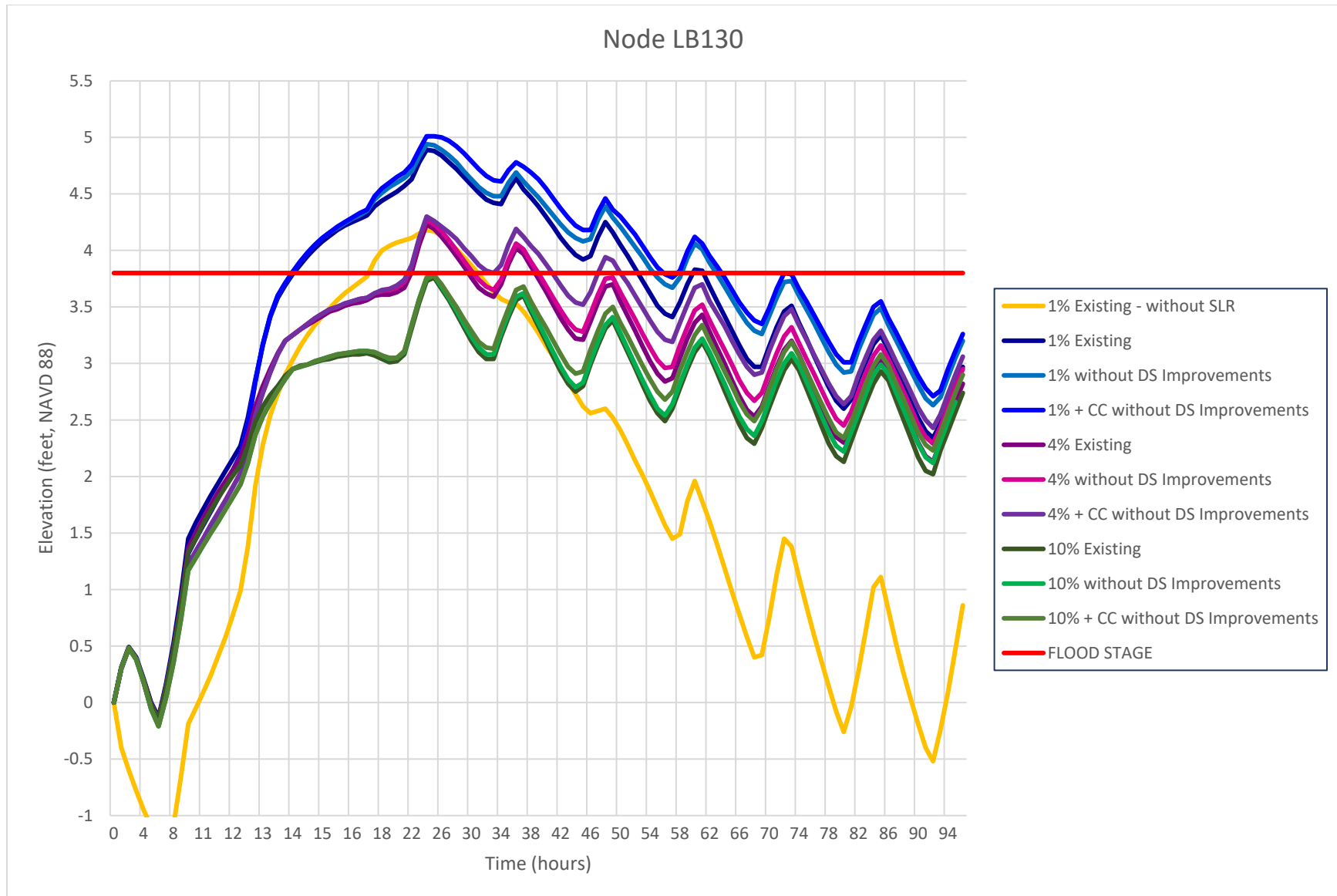


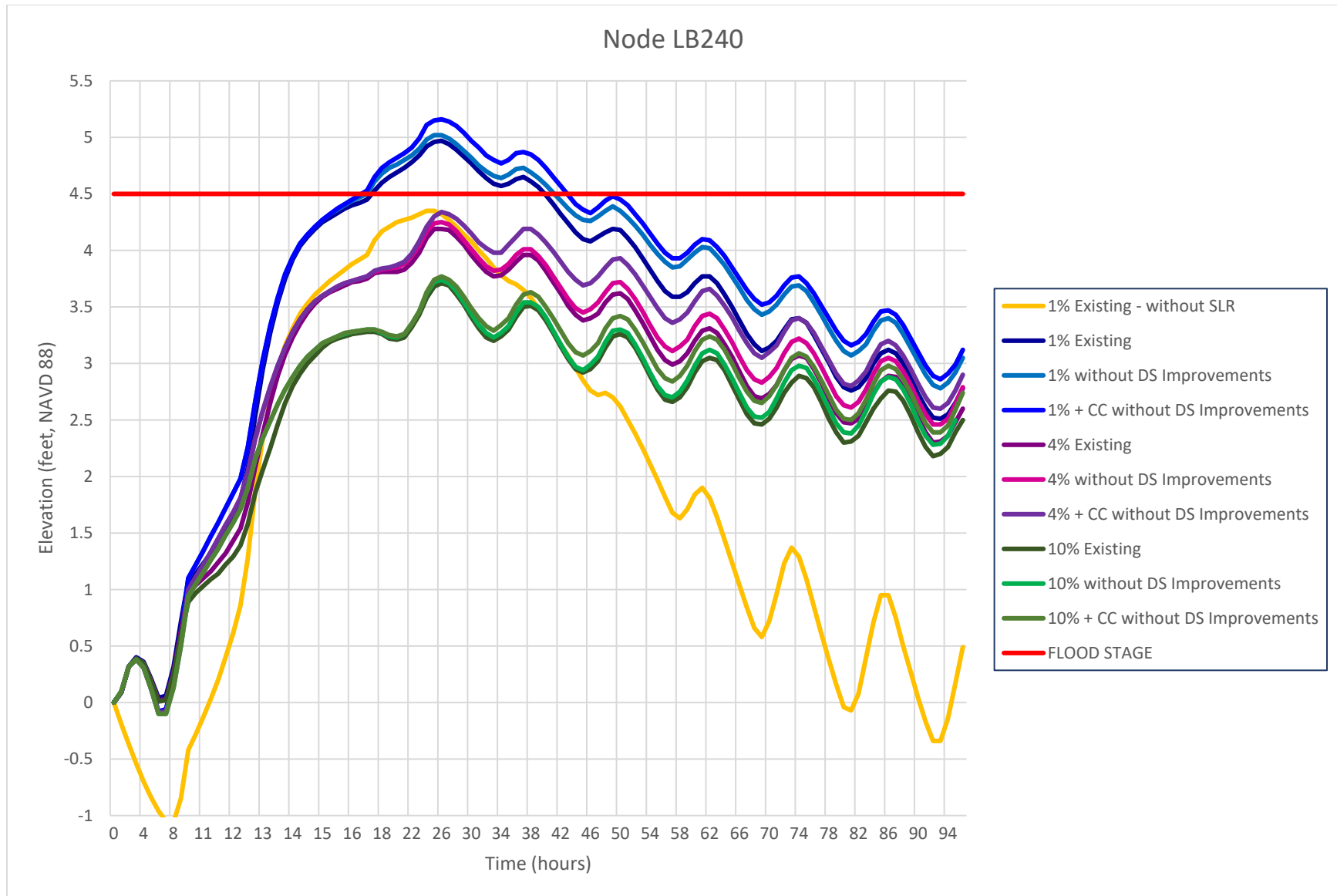


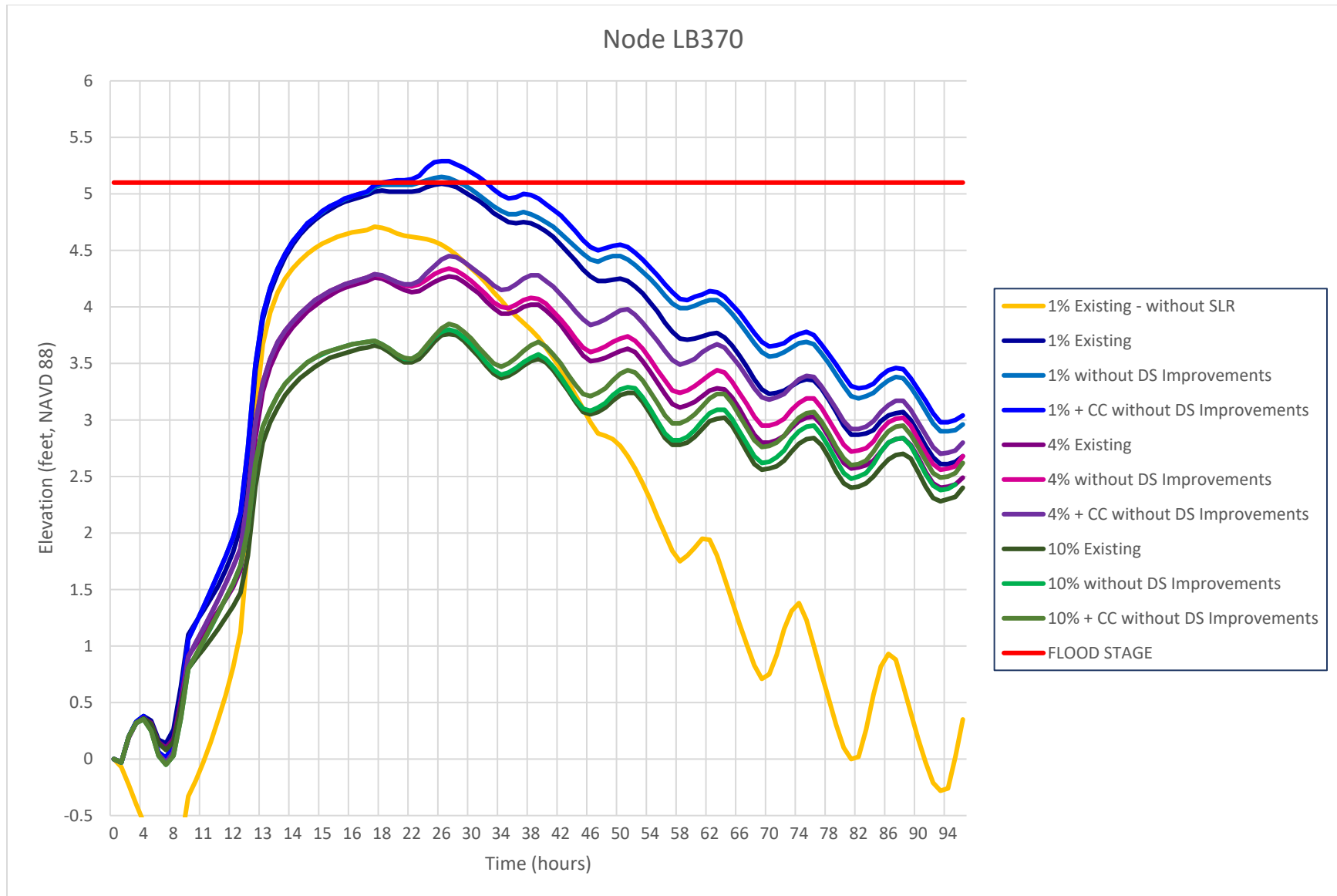


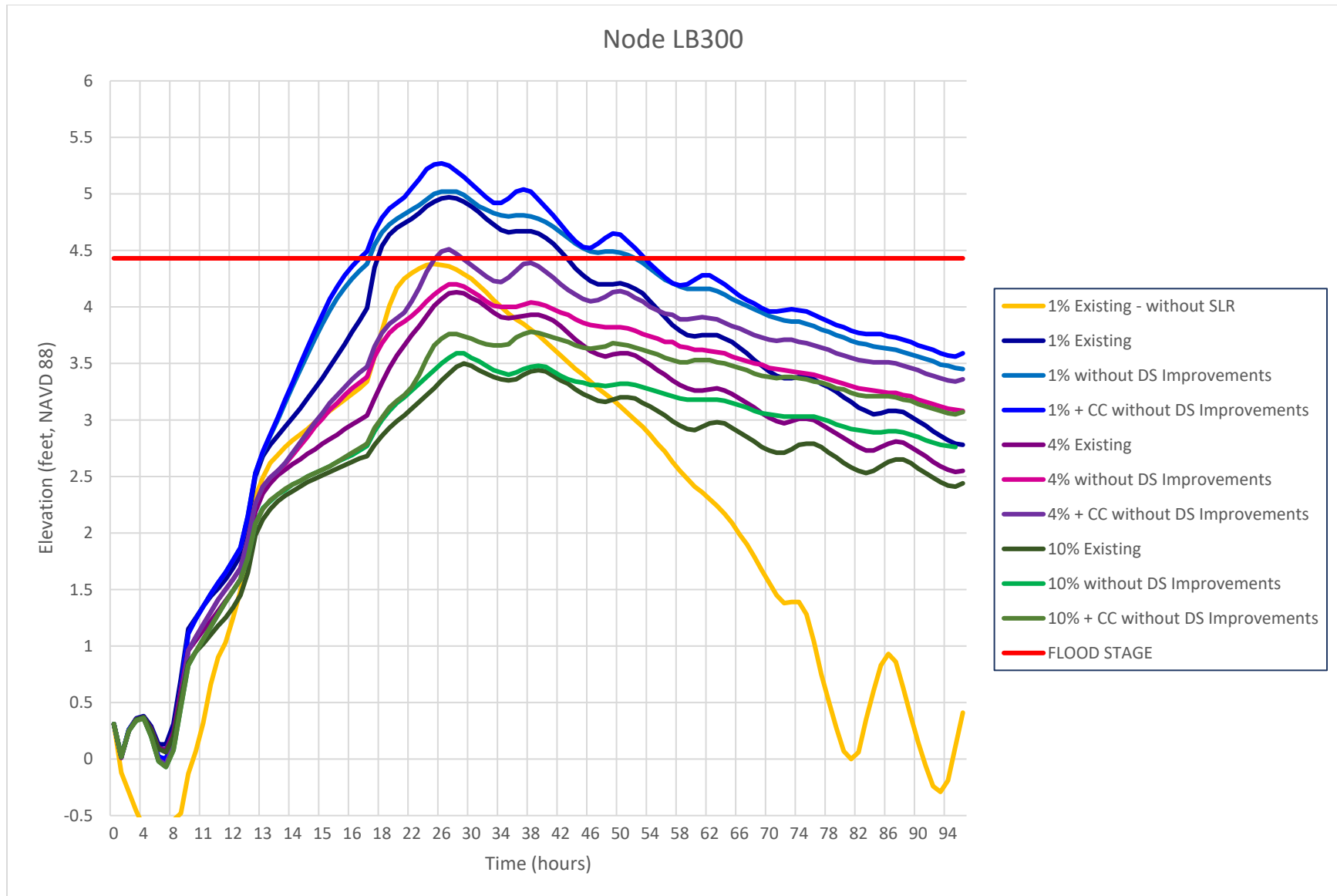




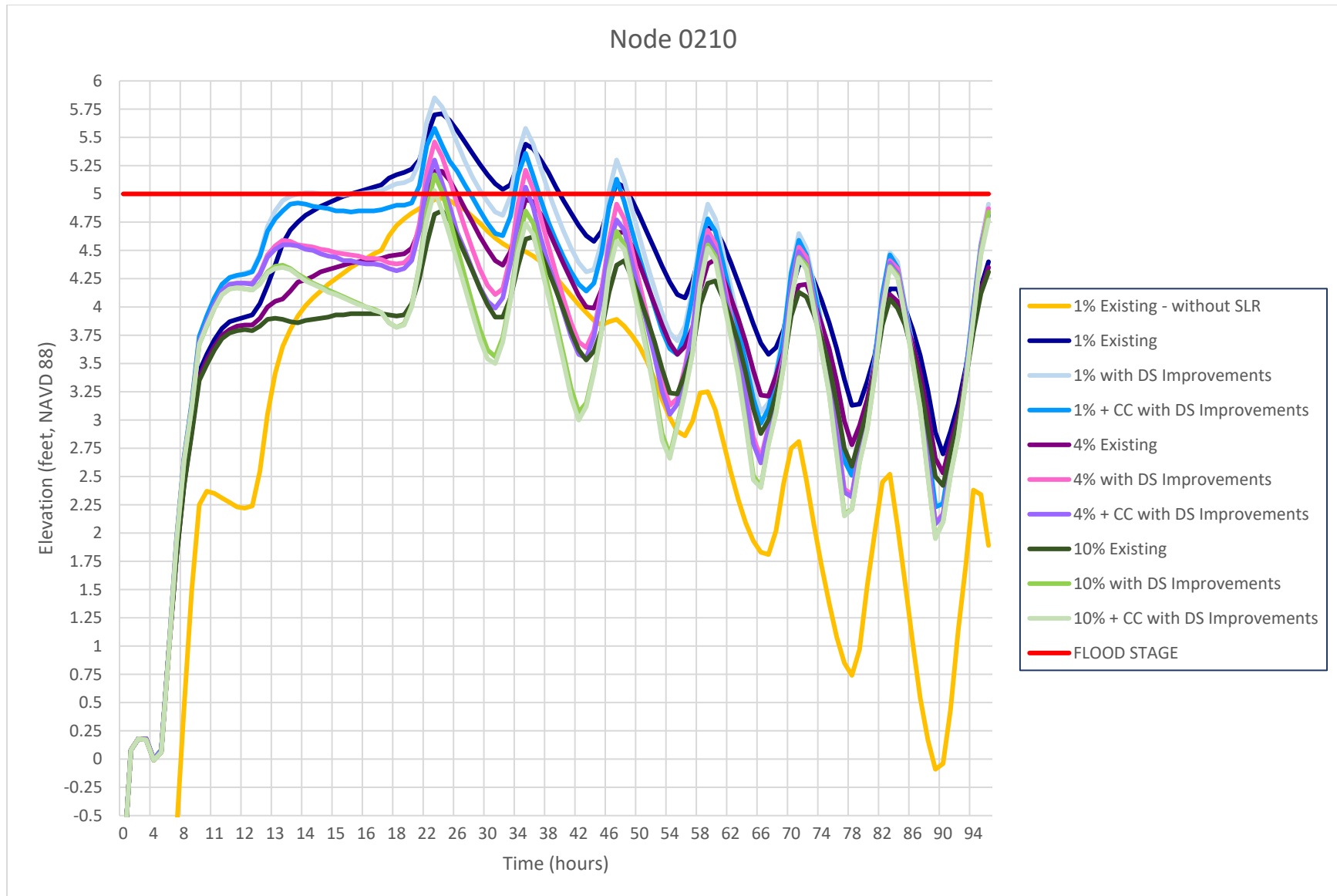


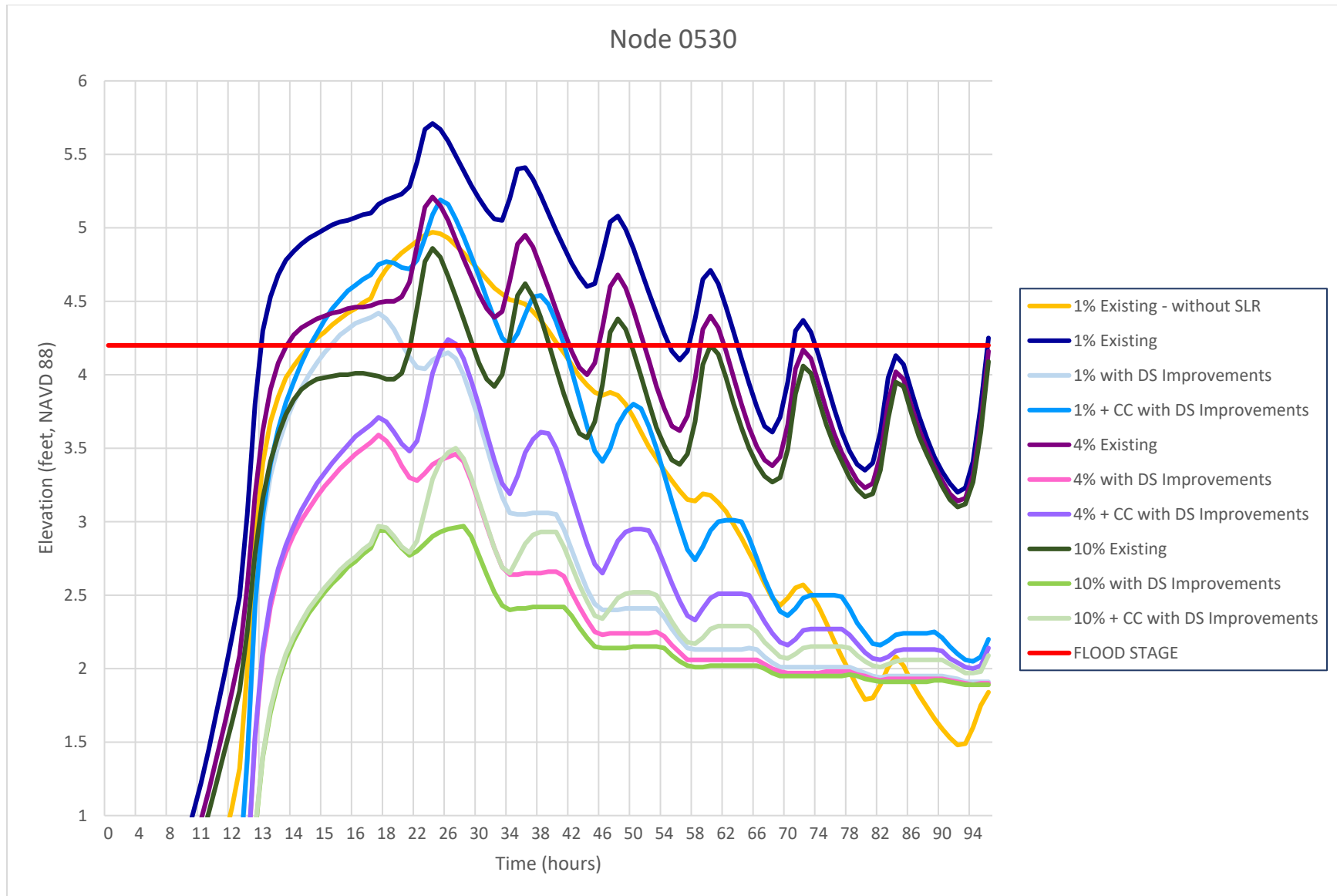


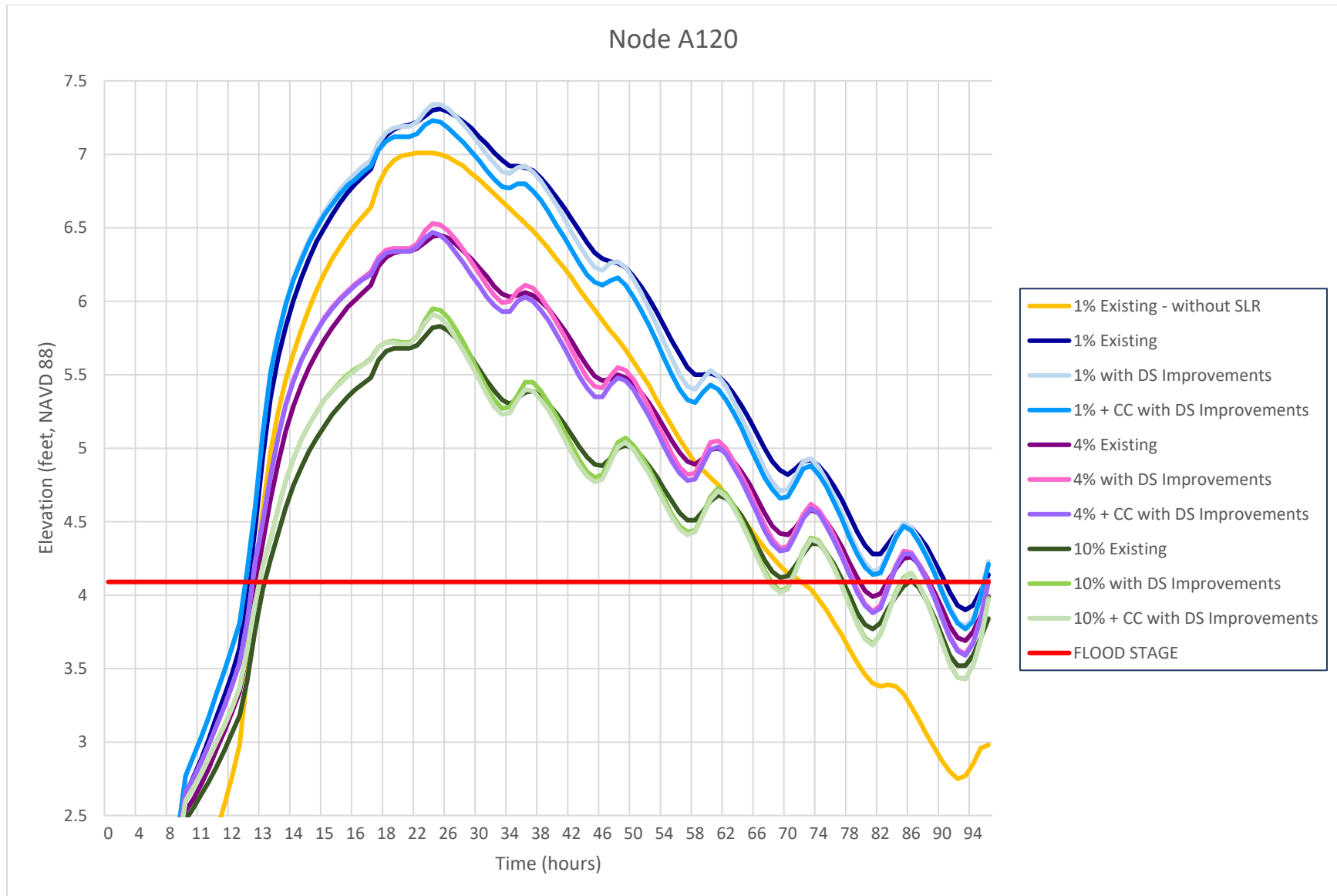


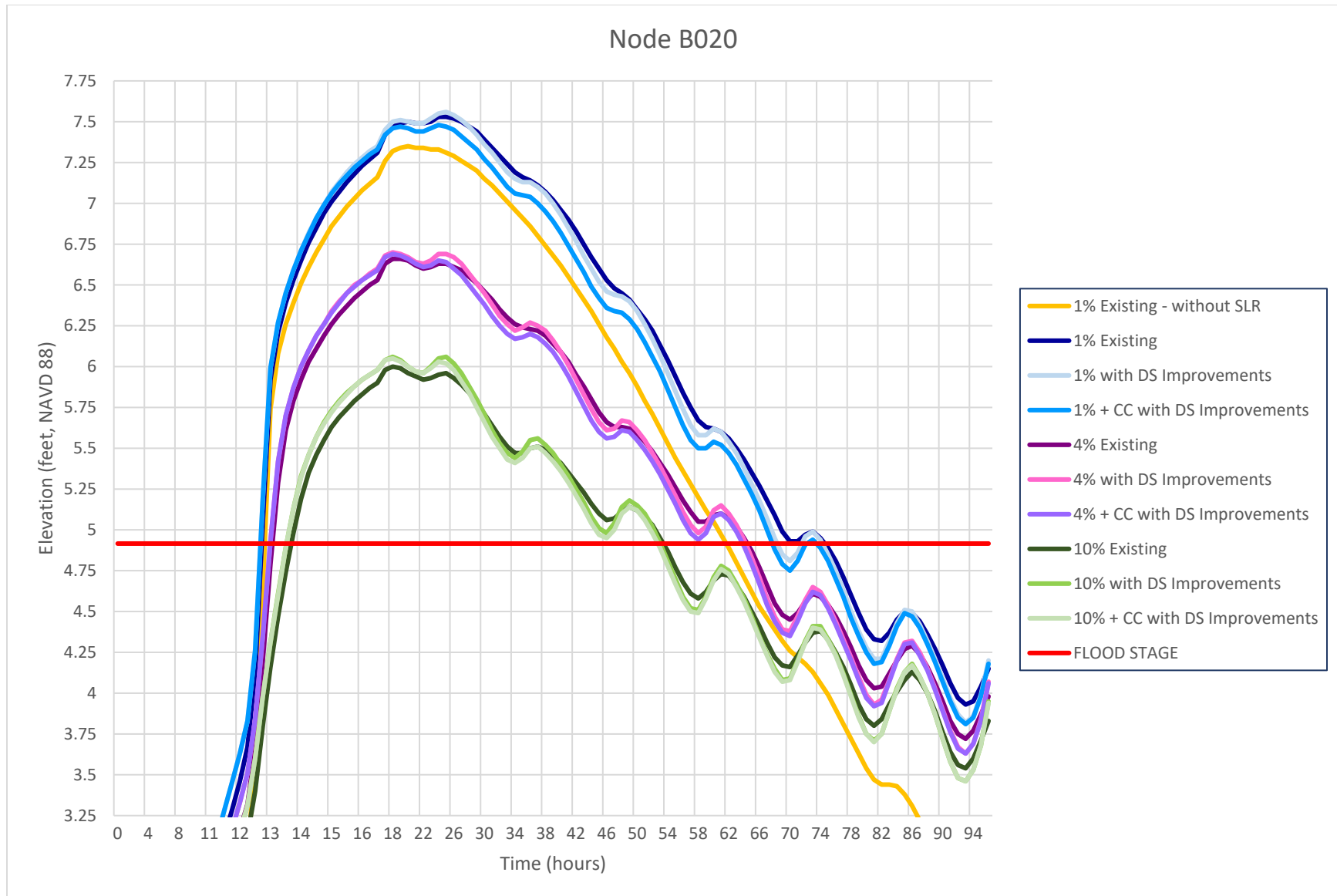


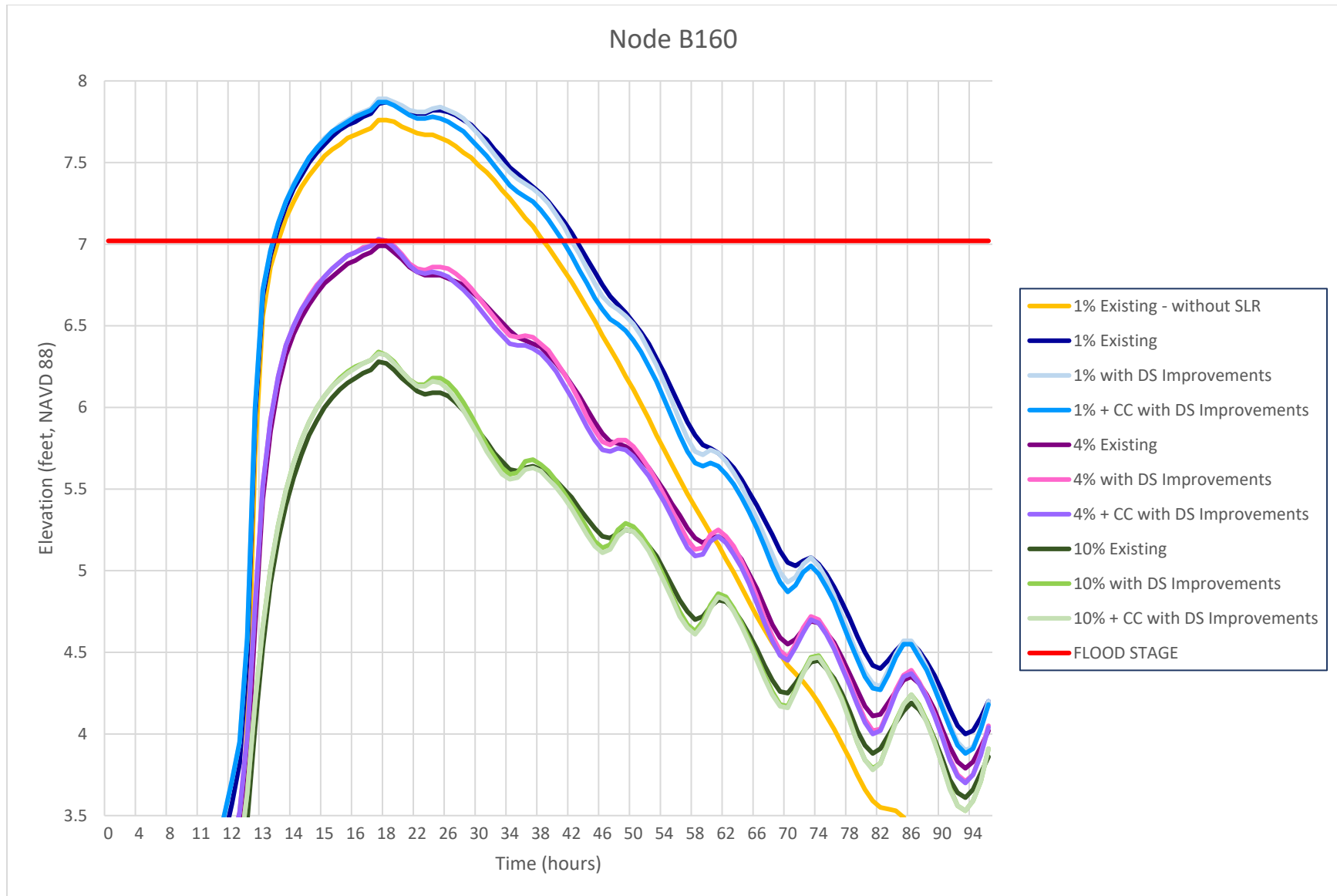
Attachment 1D. Effects of 2.5' Sea Level Rise on the Lake Dotterer Diversion with Downstream Improvements

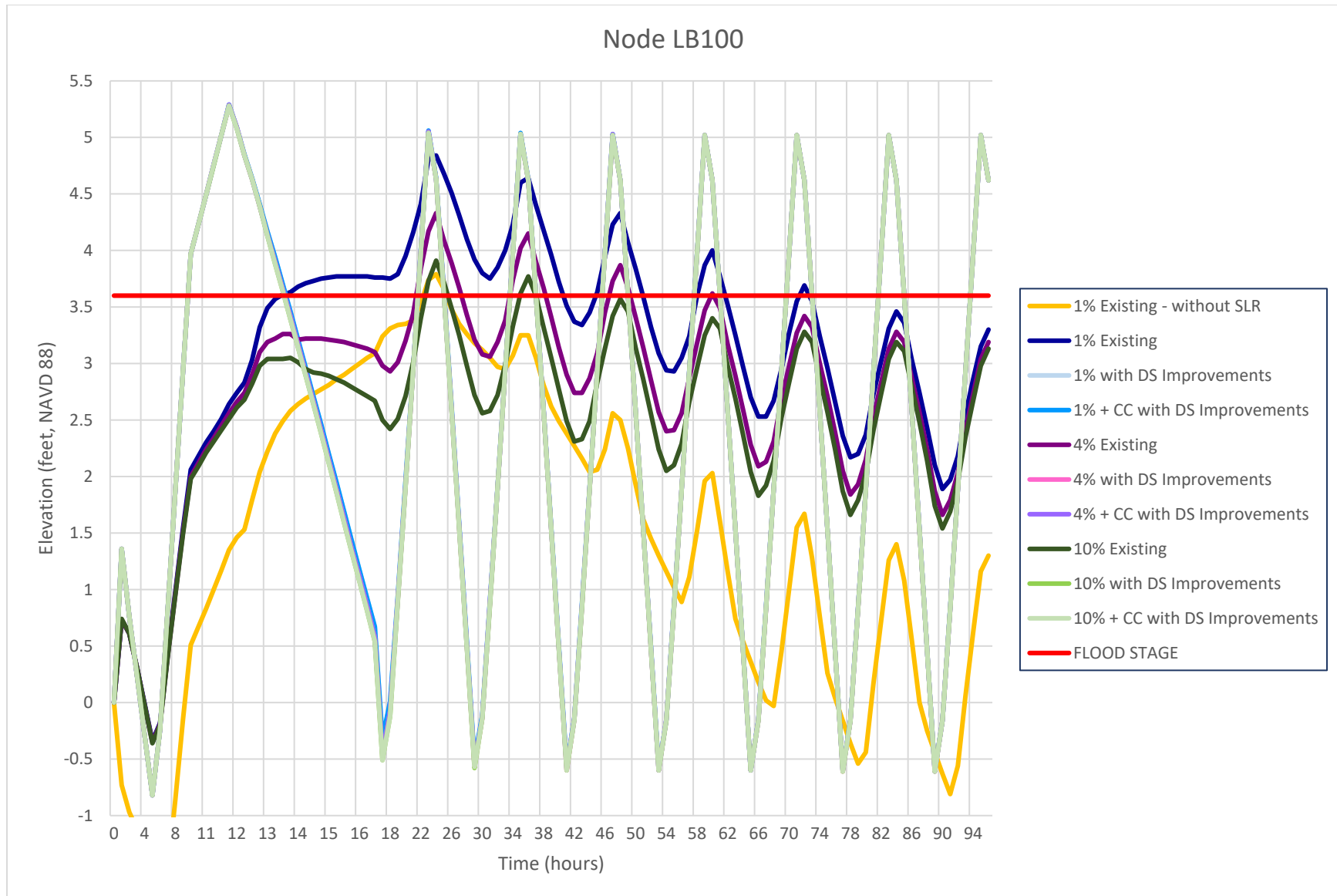


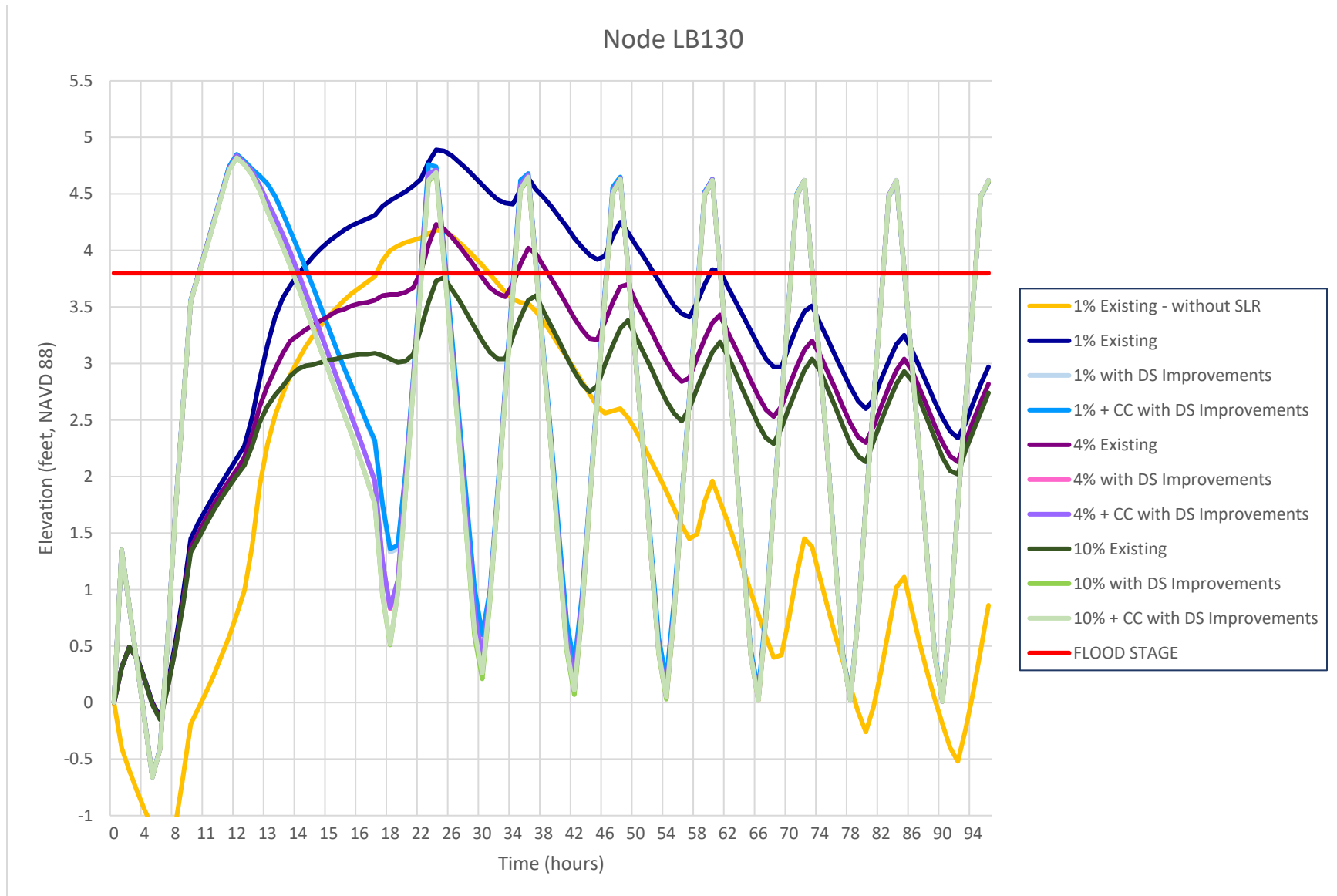


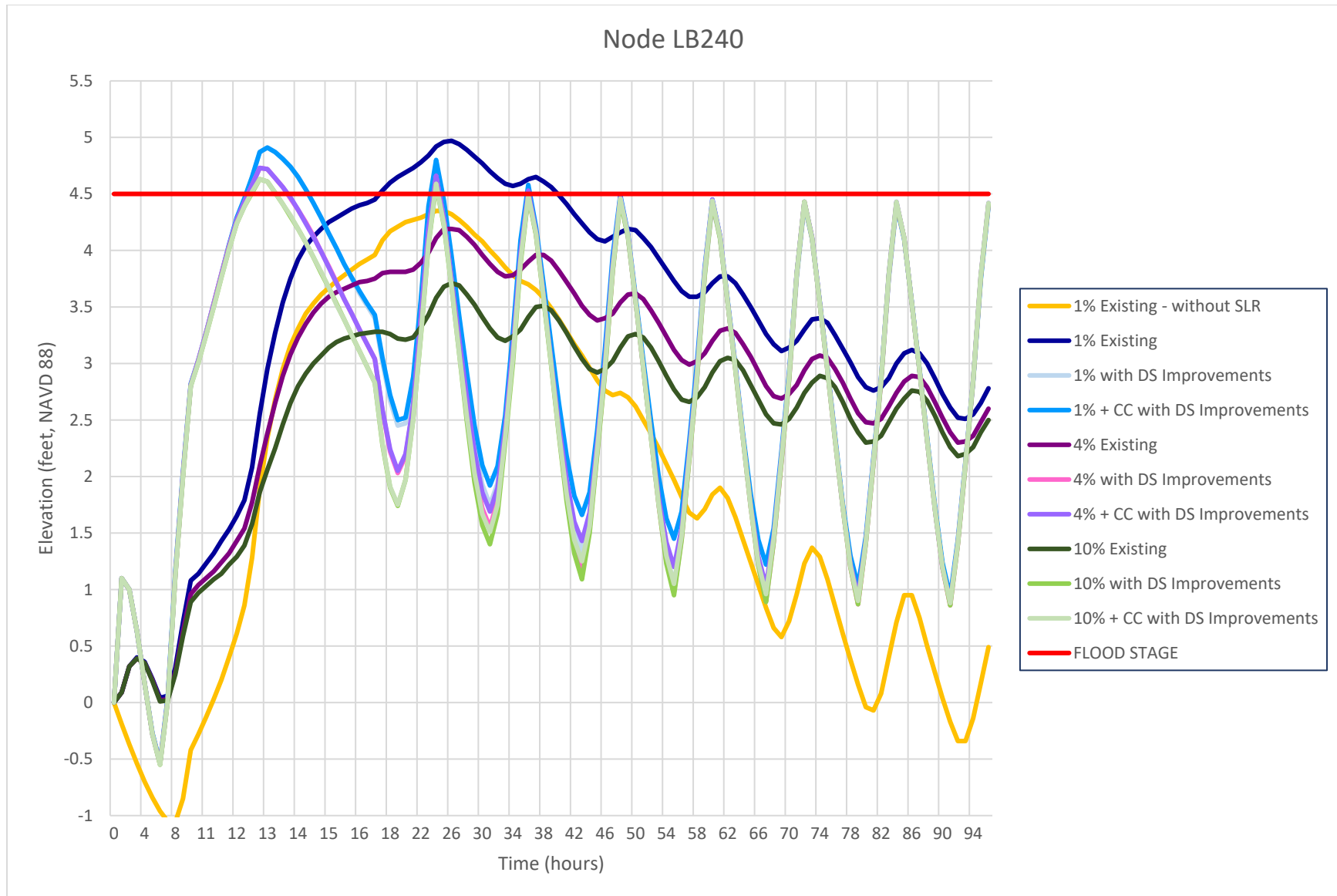


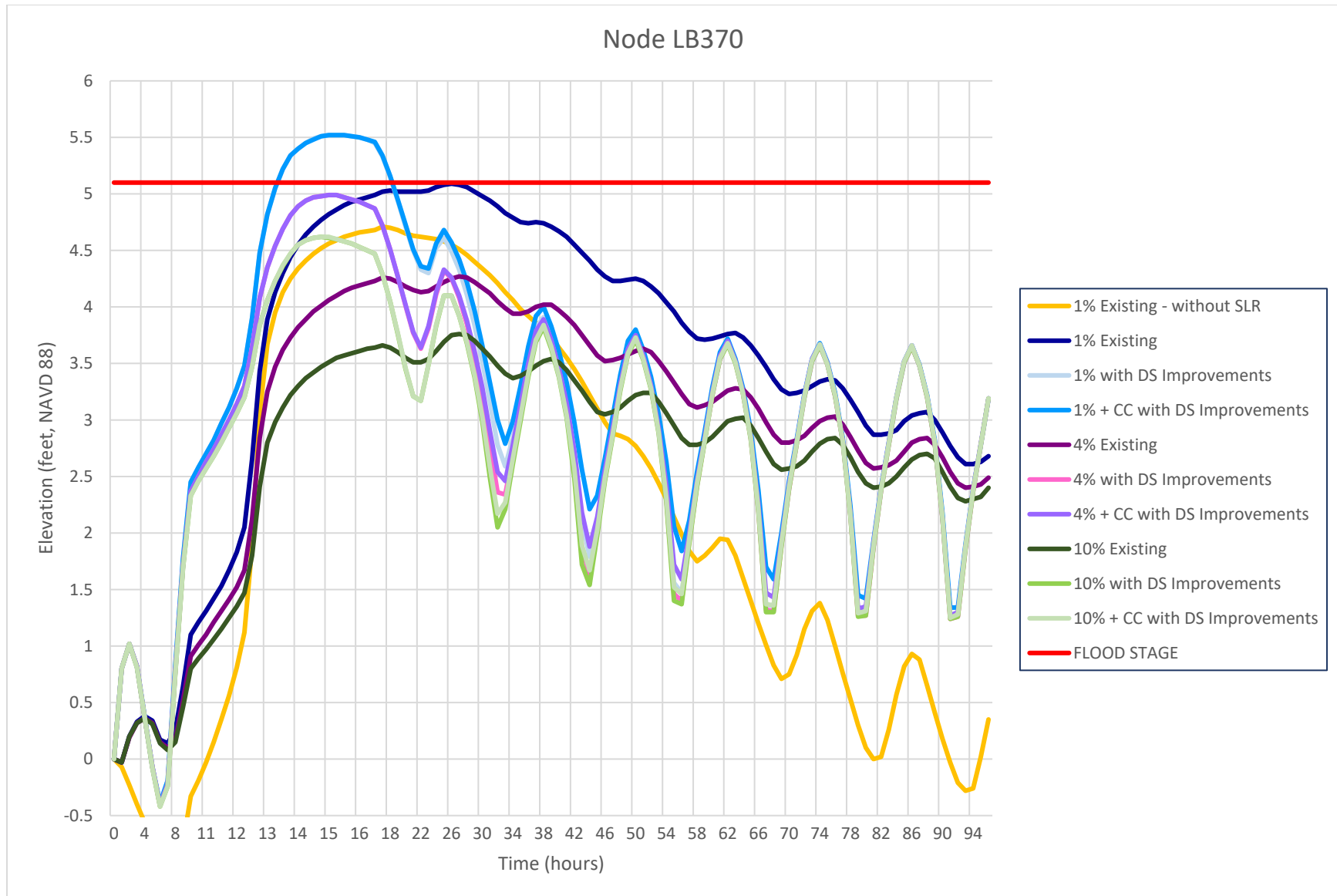


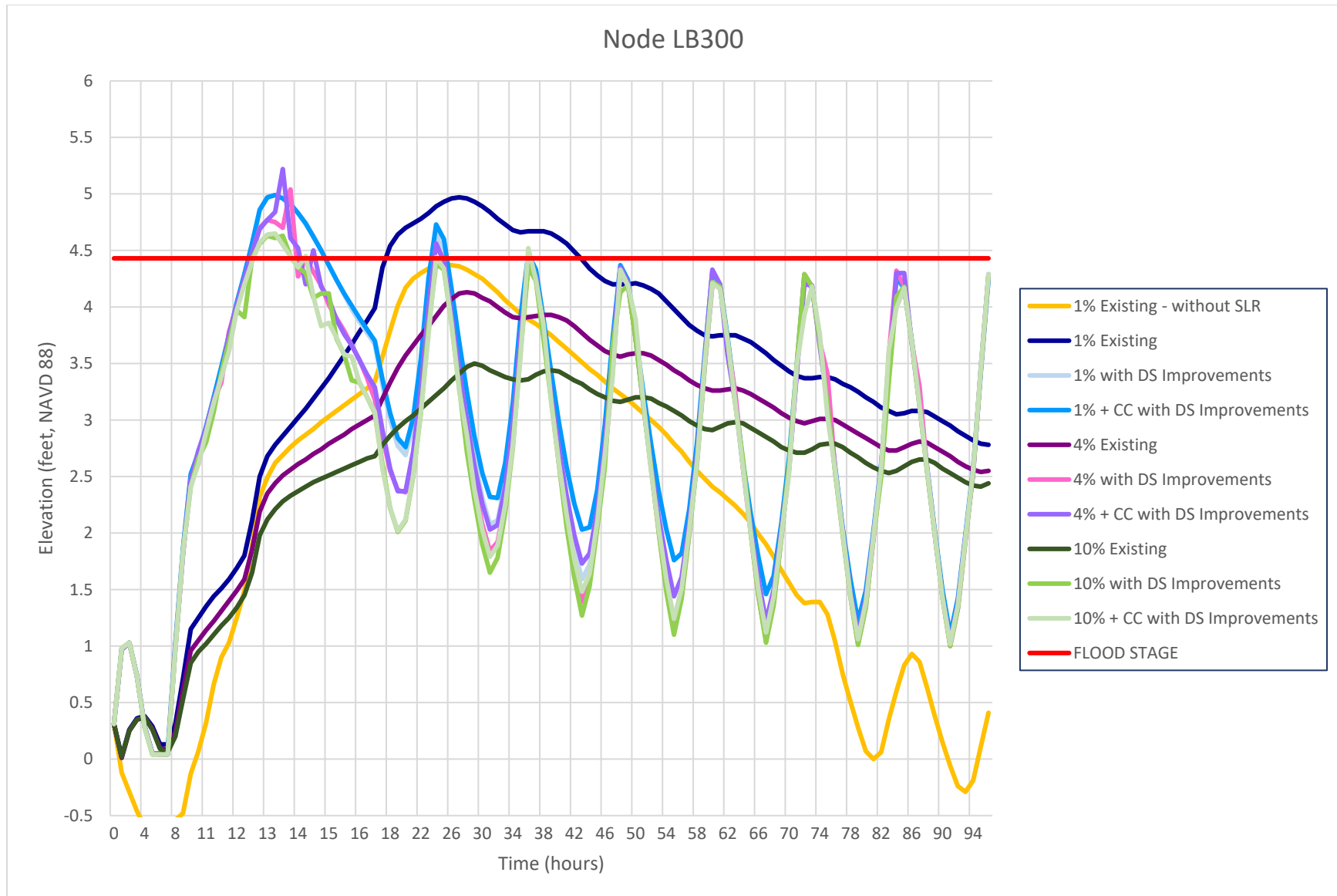




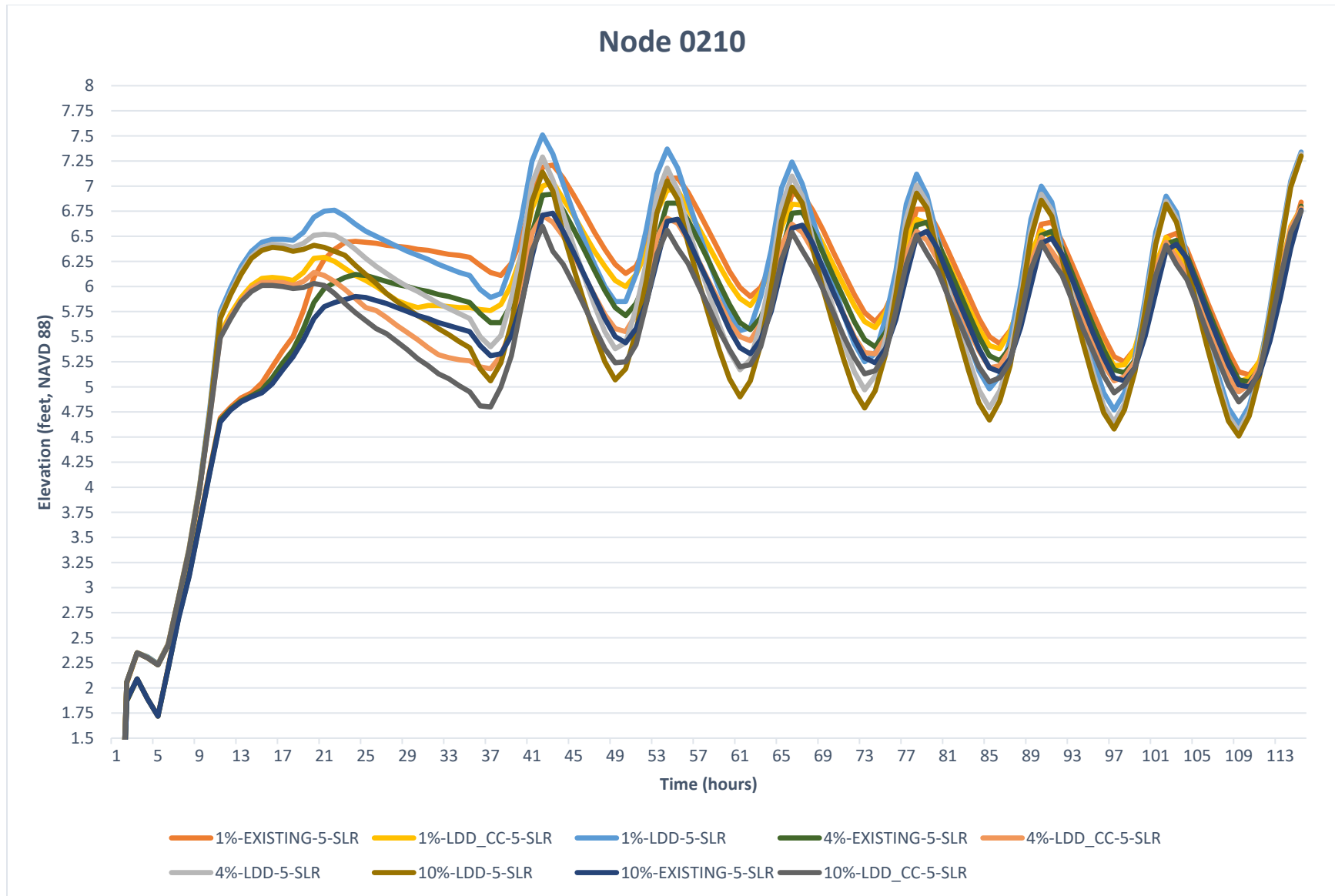


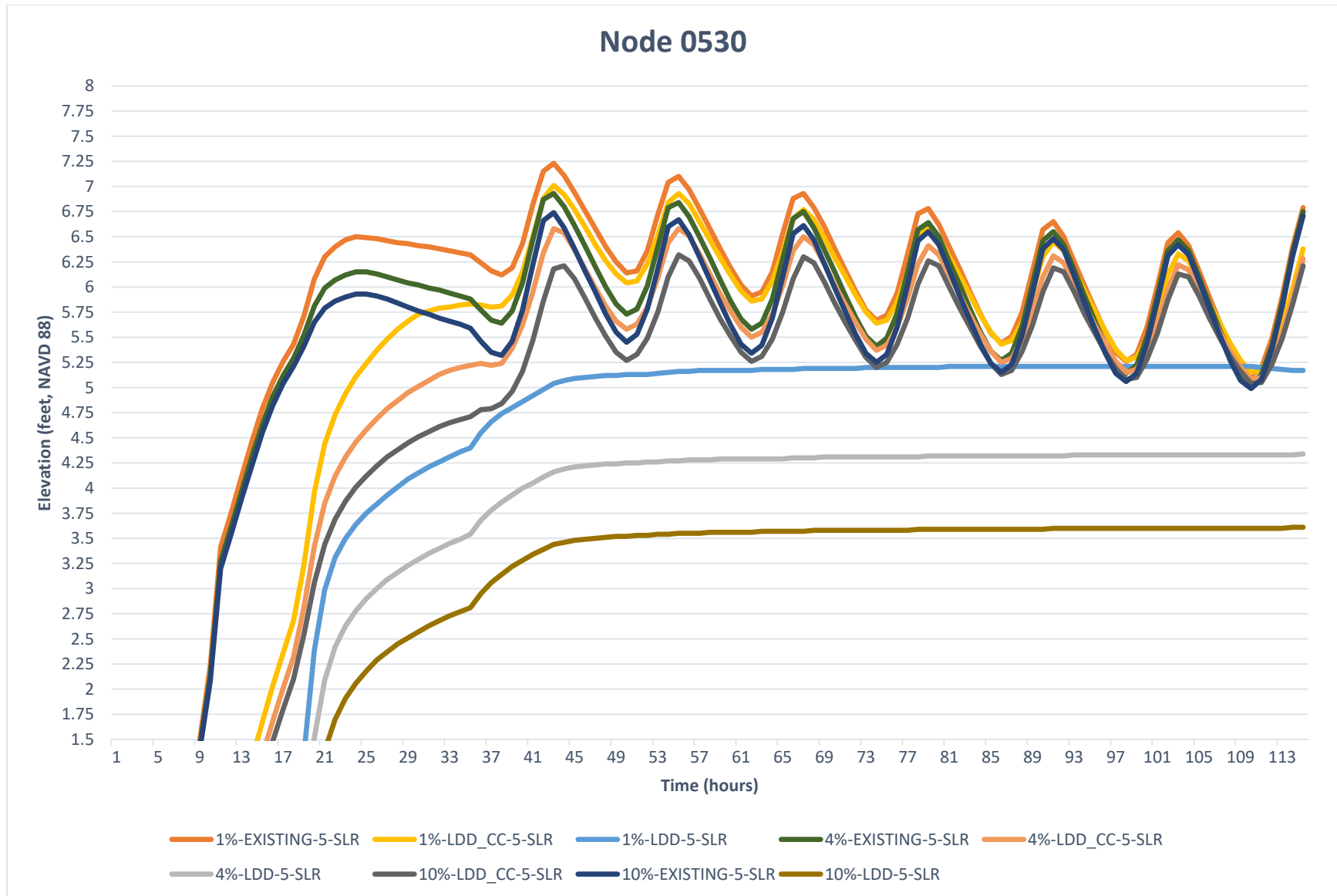


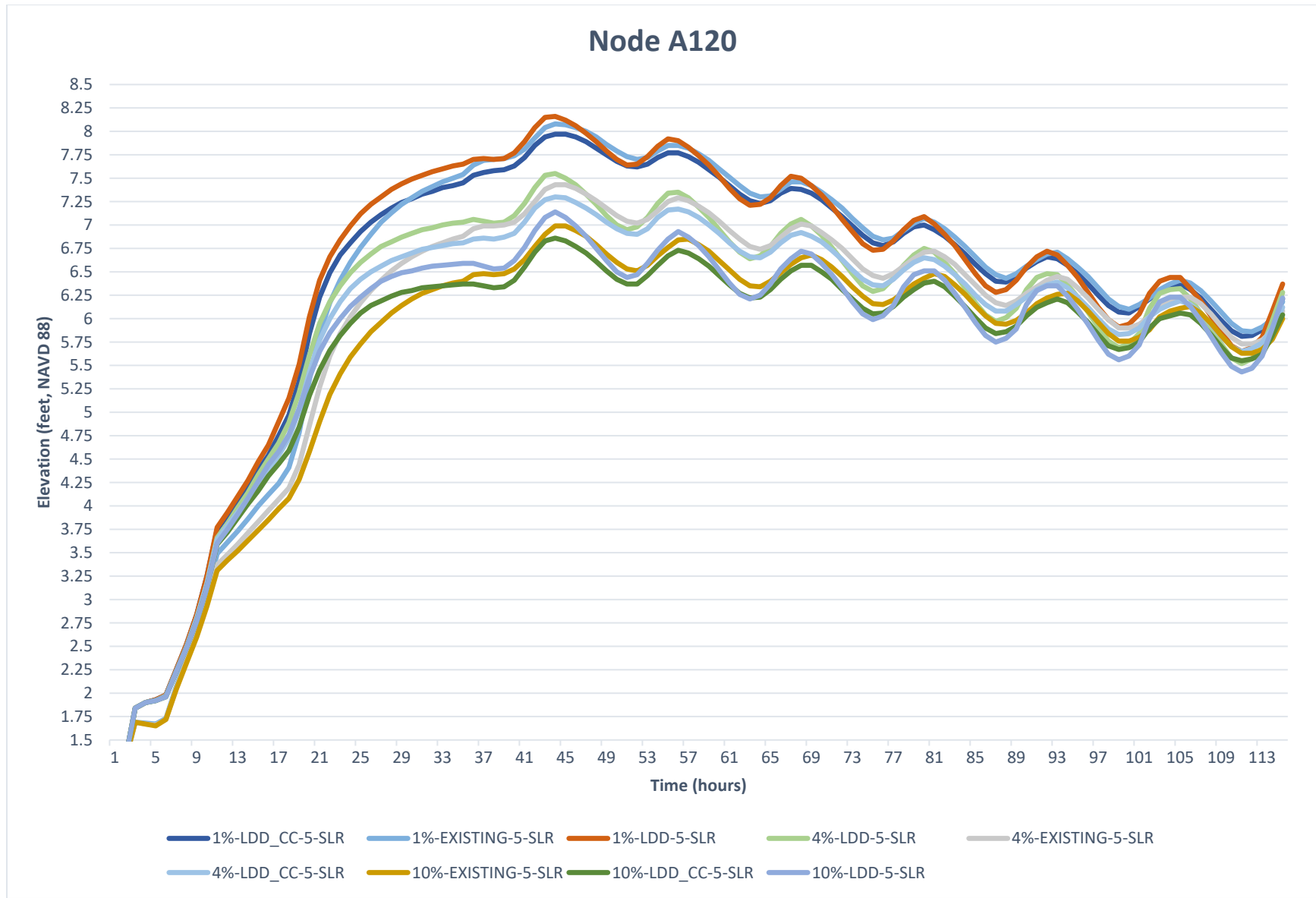


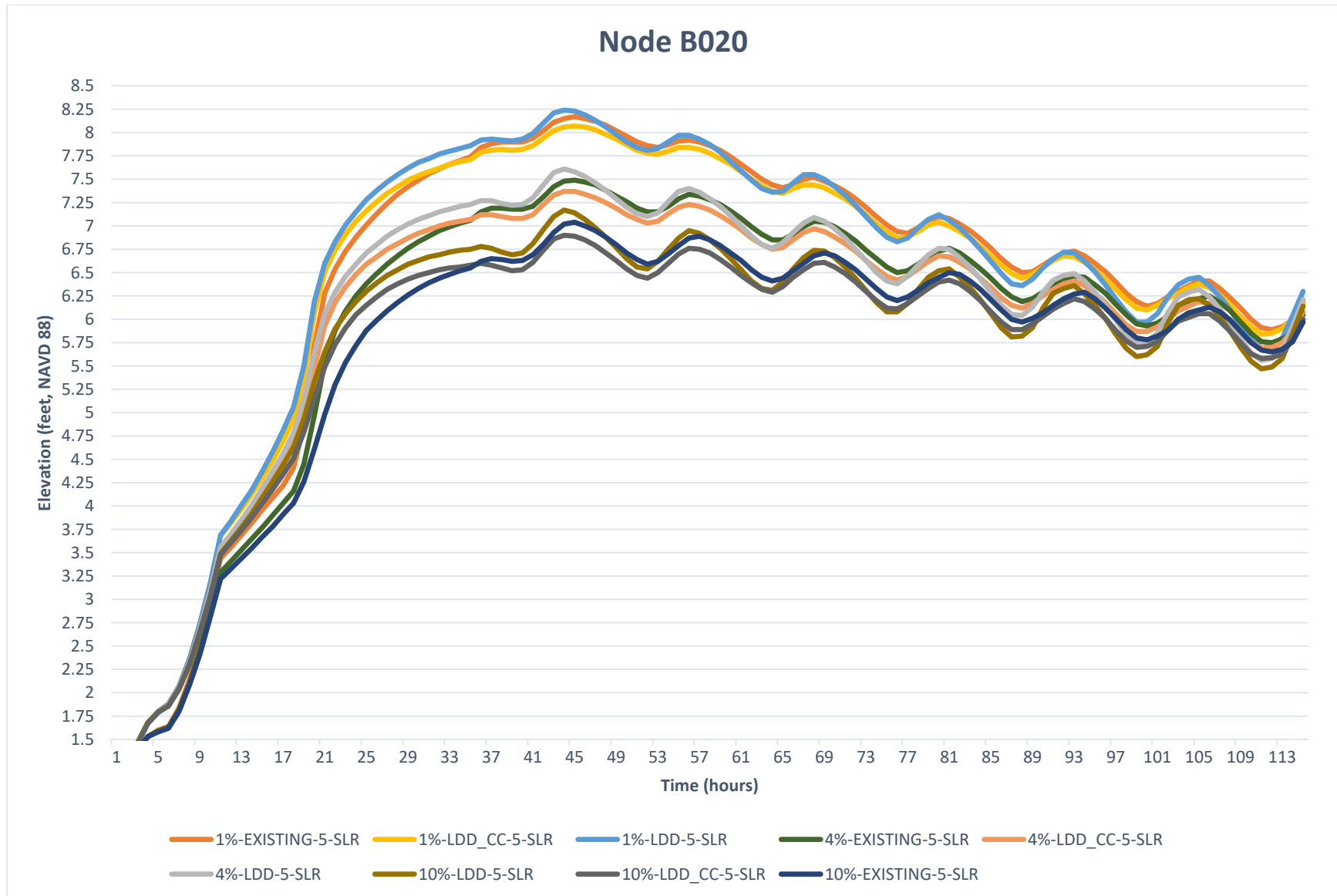


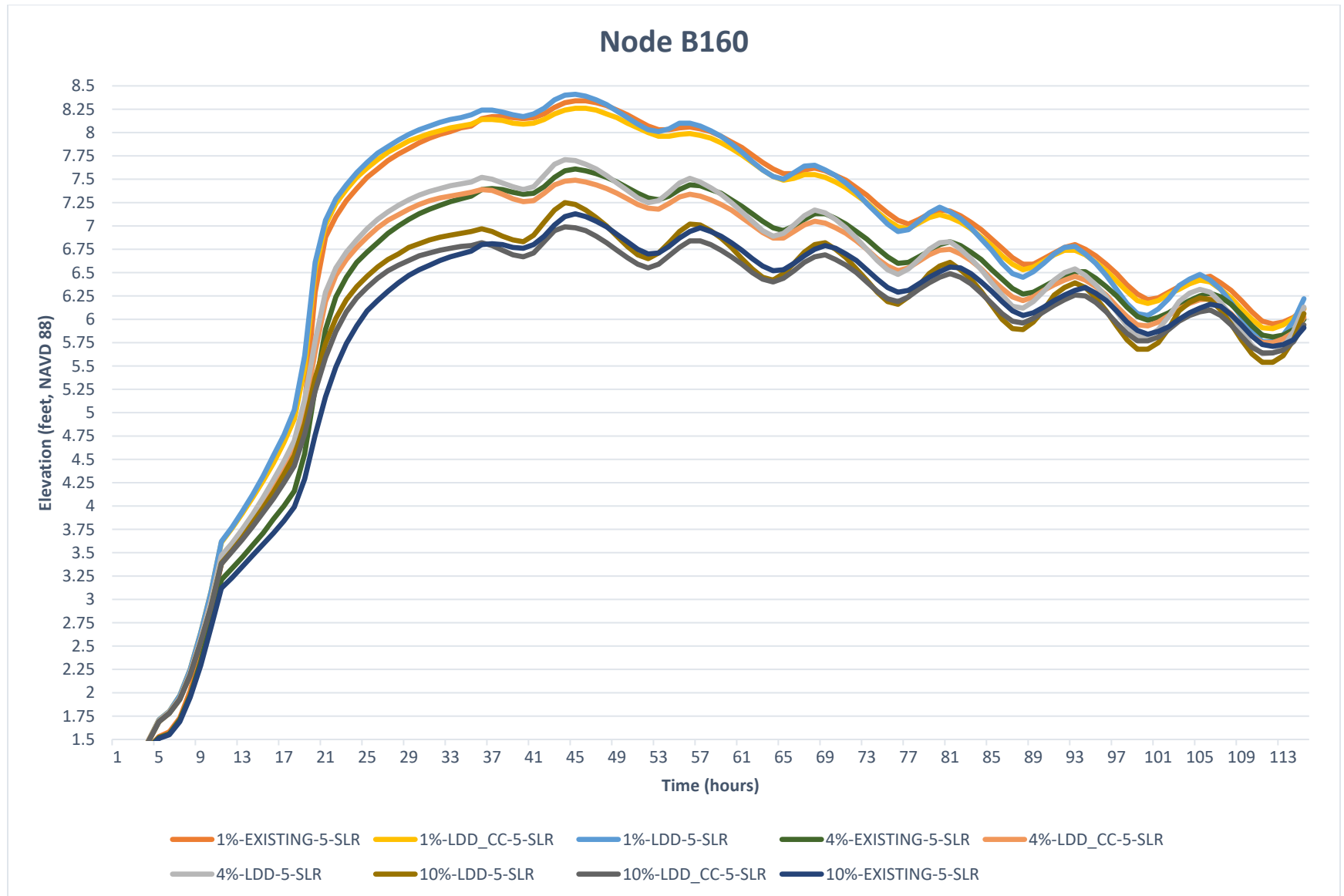
Attachment 1E. Effects of 5.0' Sea Level Rise on the Lake Dotterer Diversion without Downstream Improvements

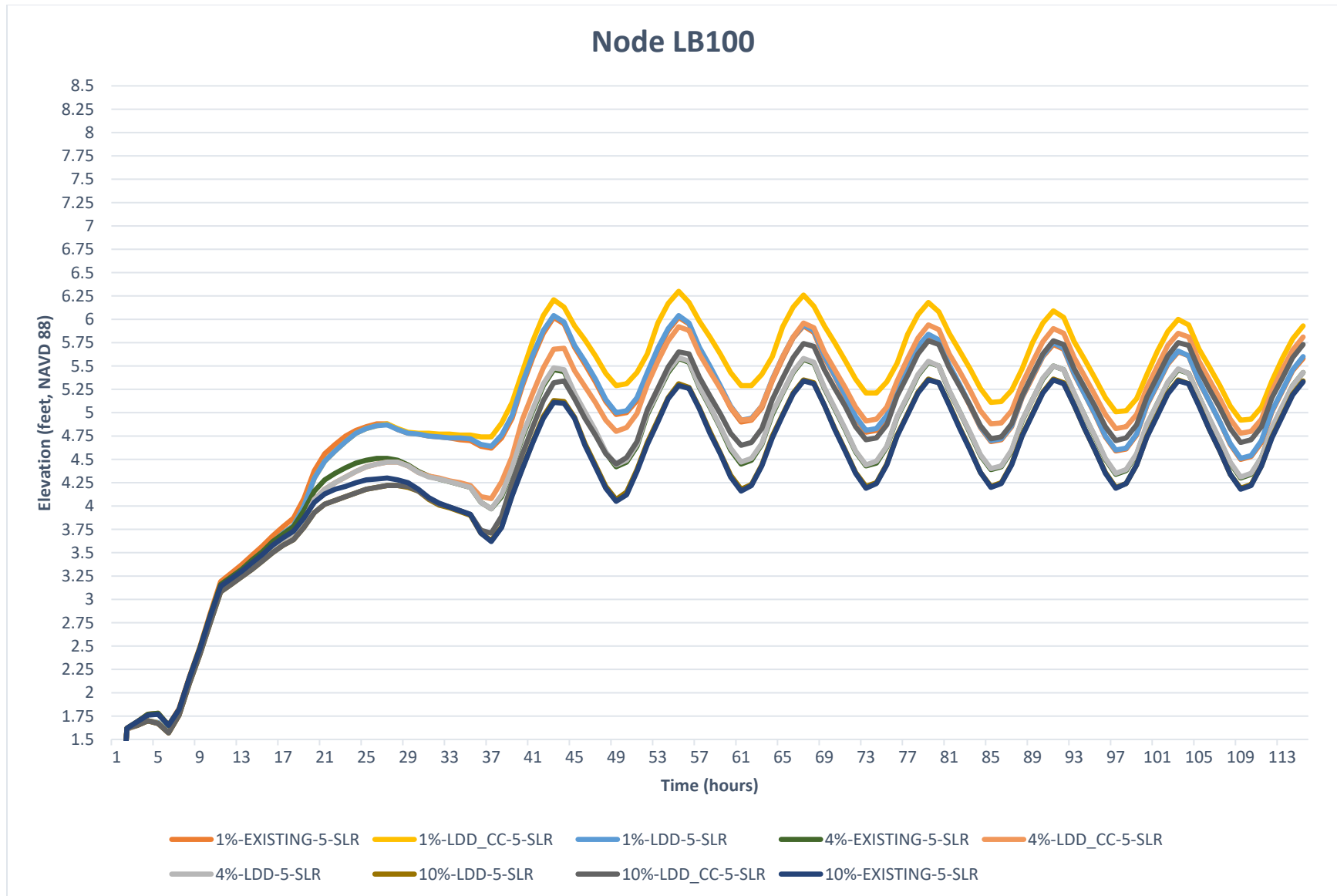


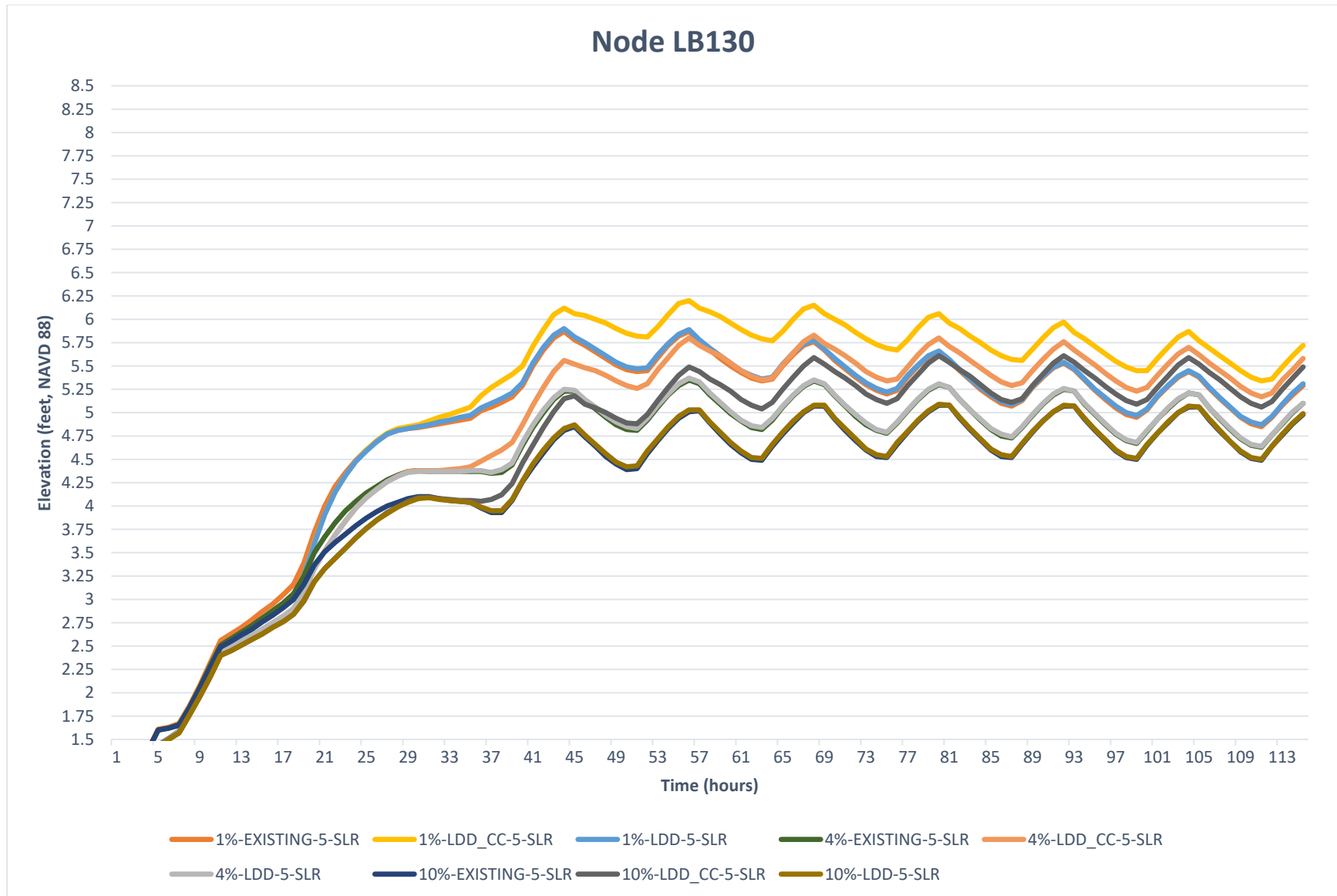


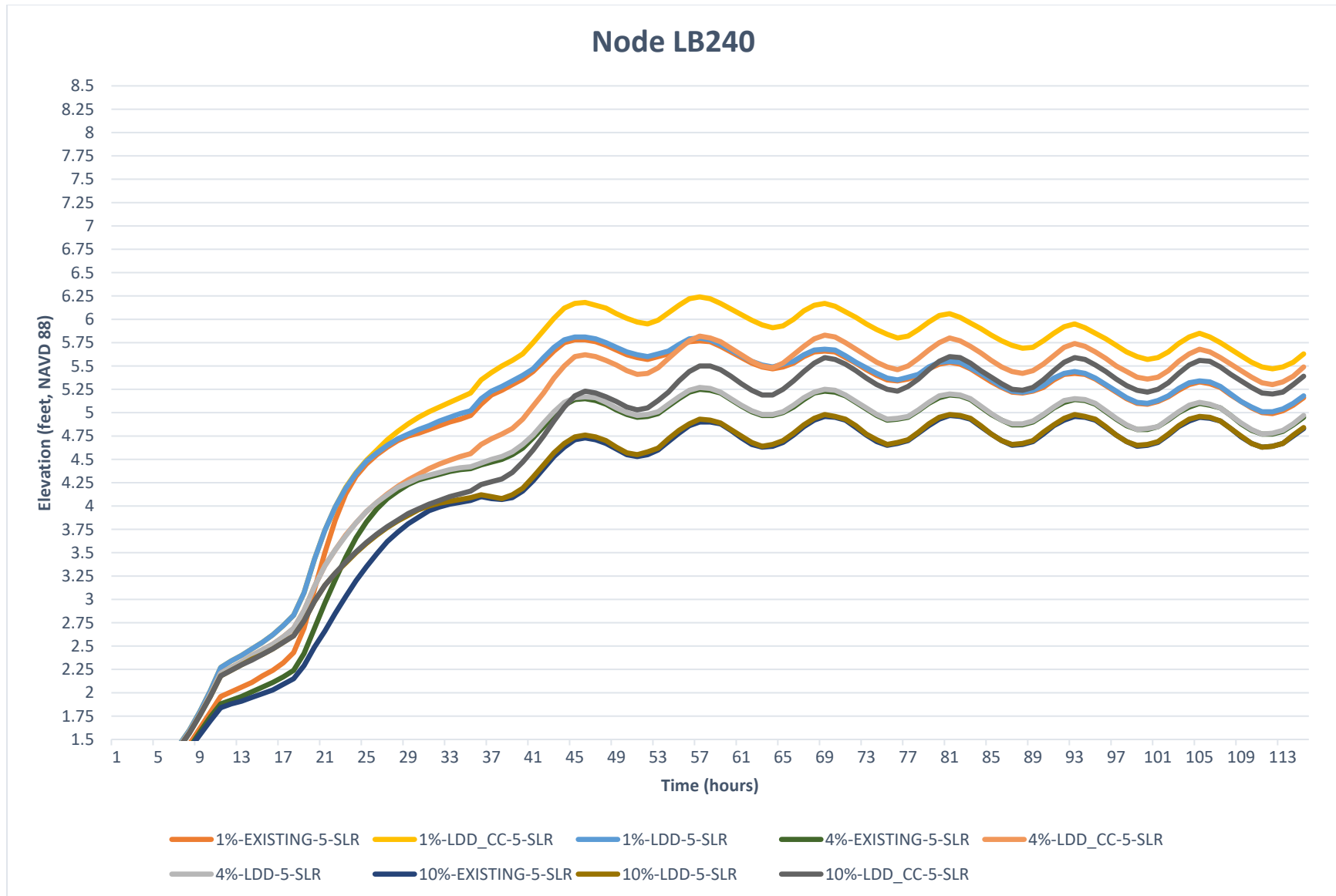


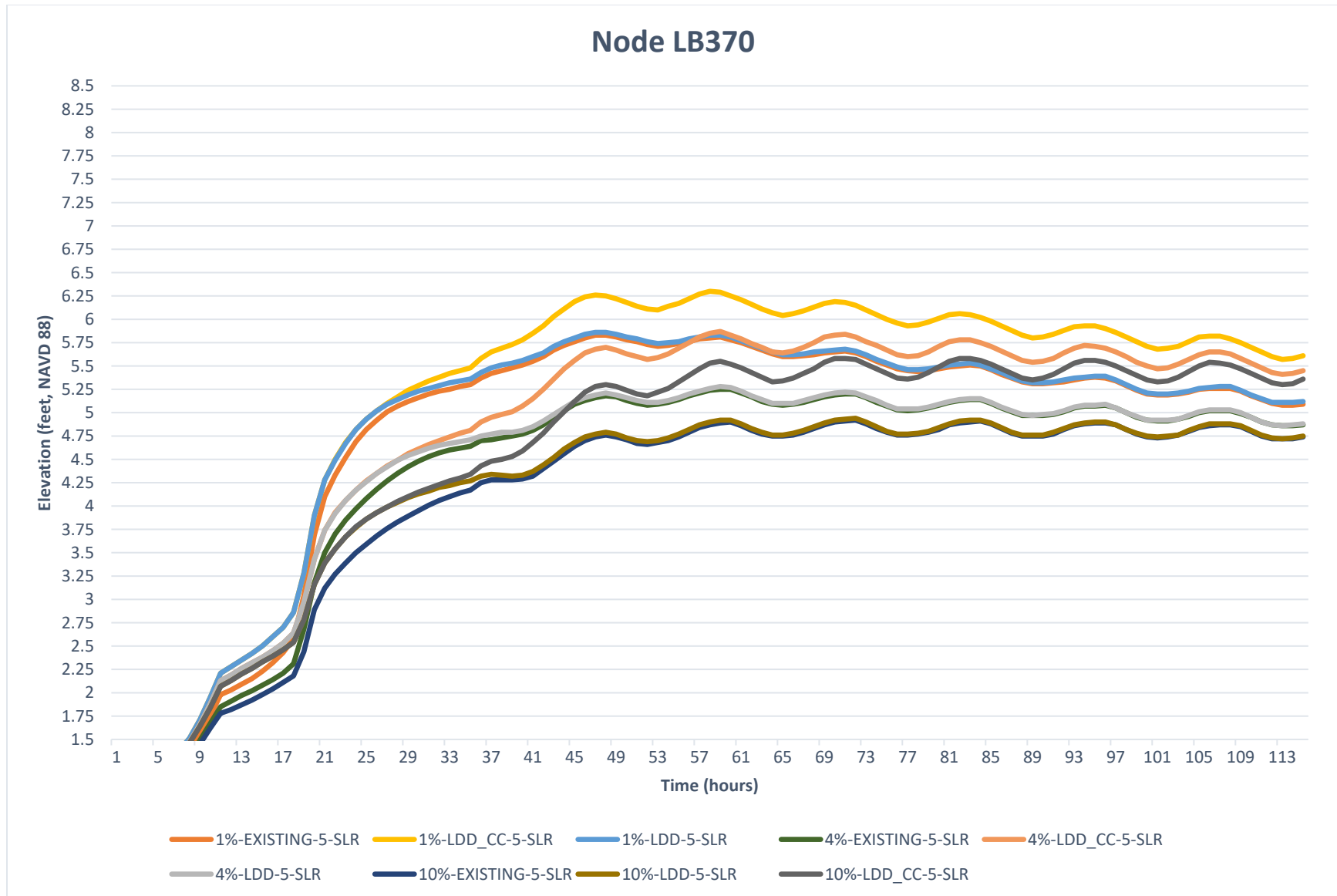


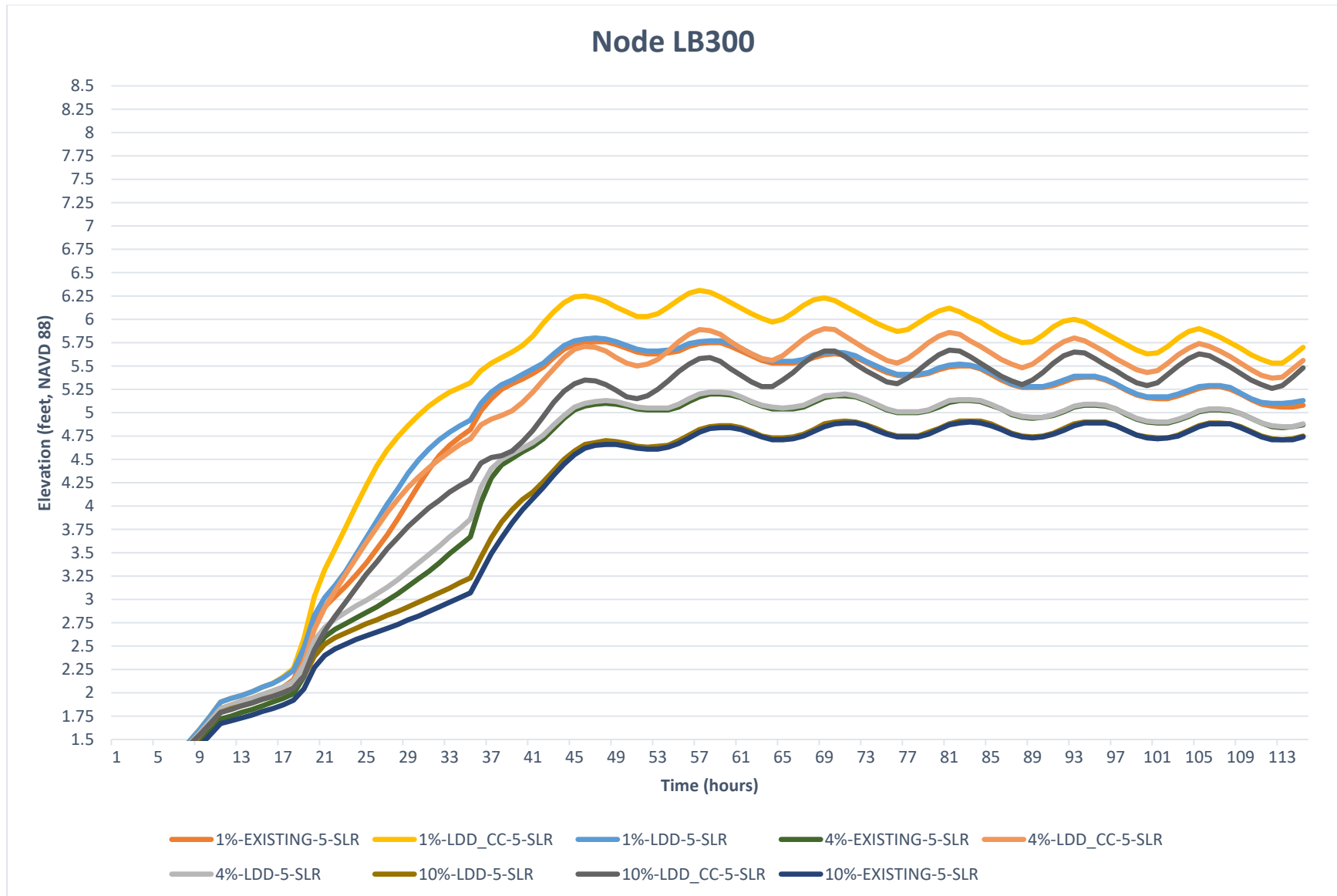




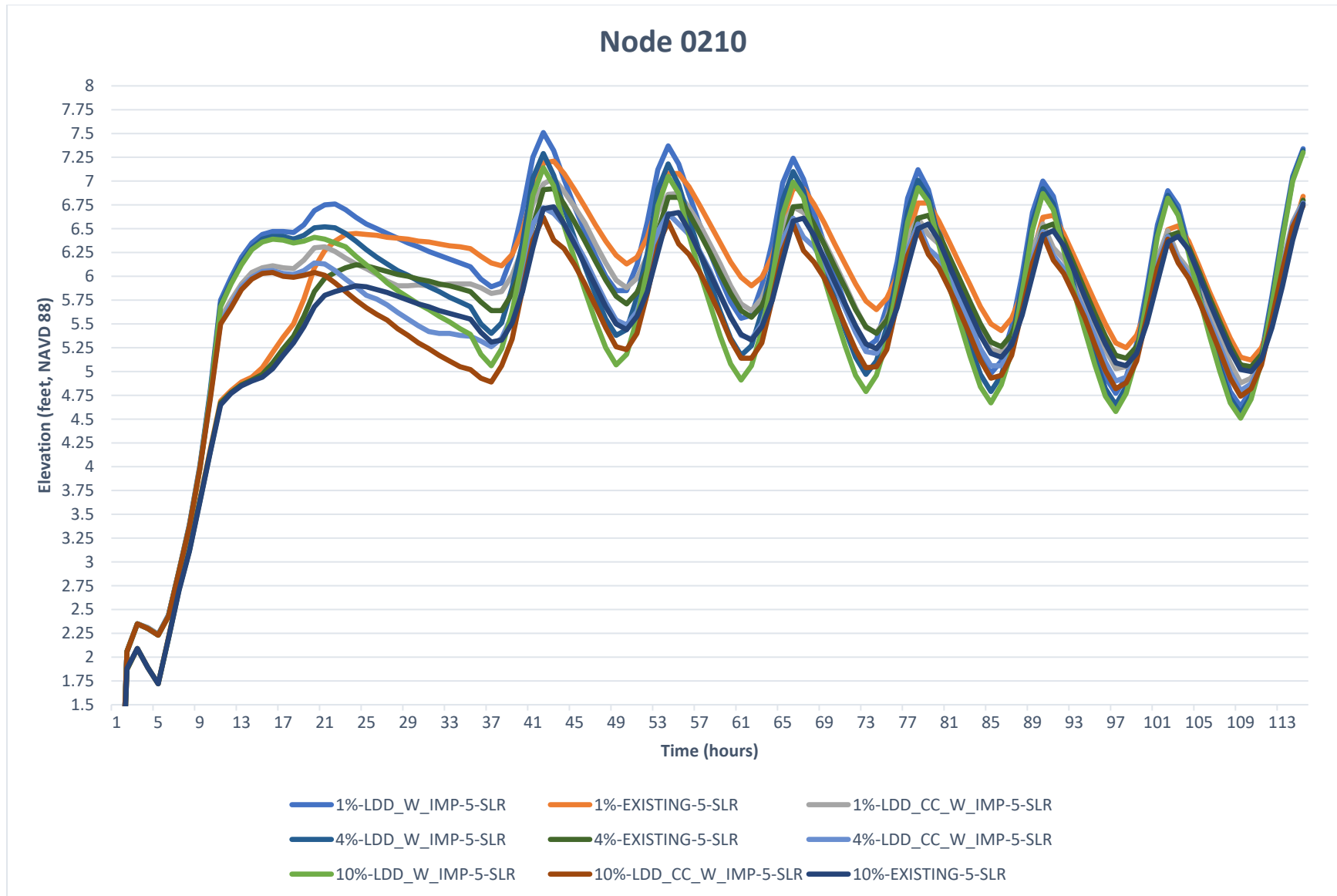


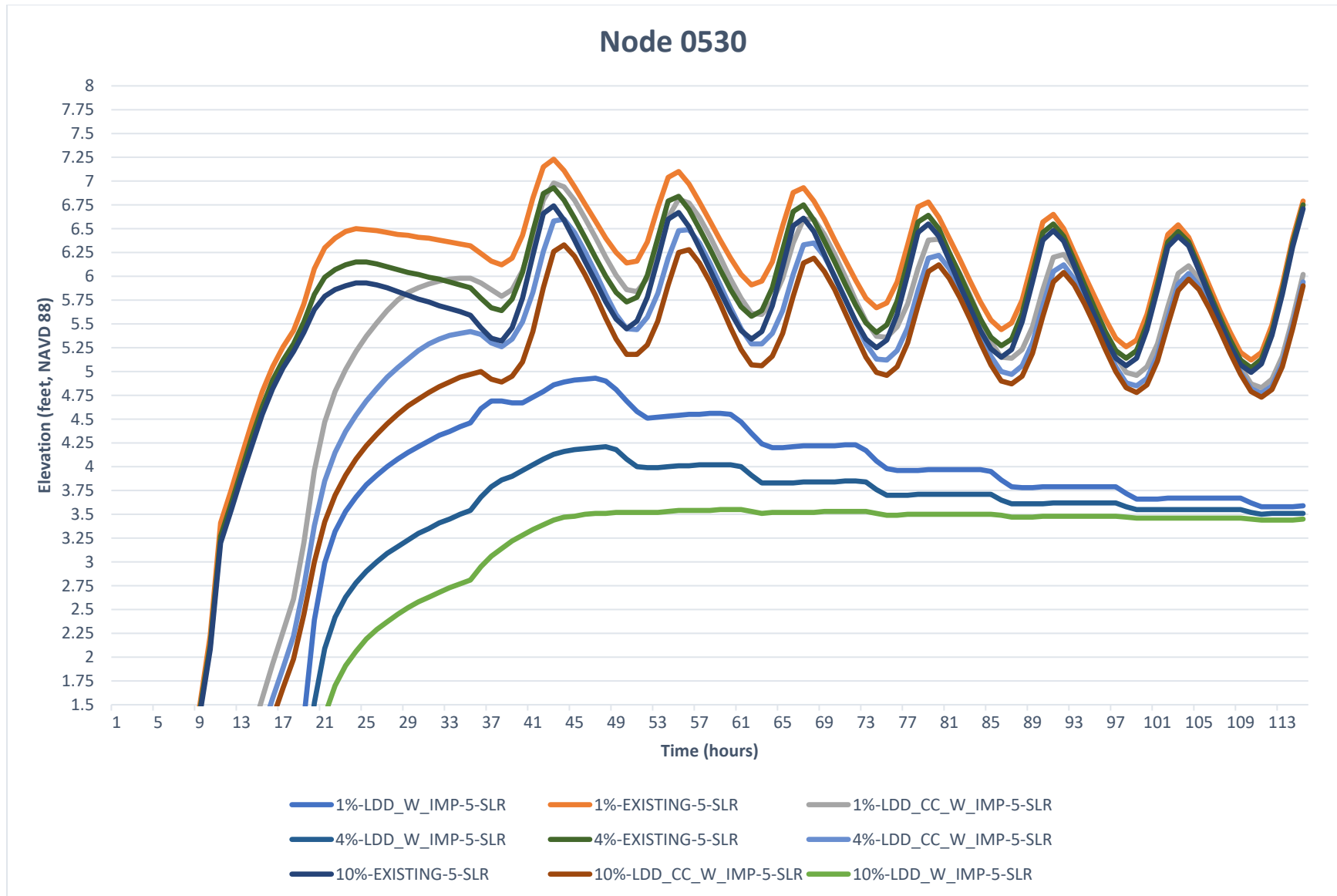


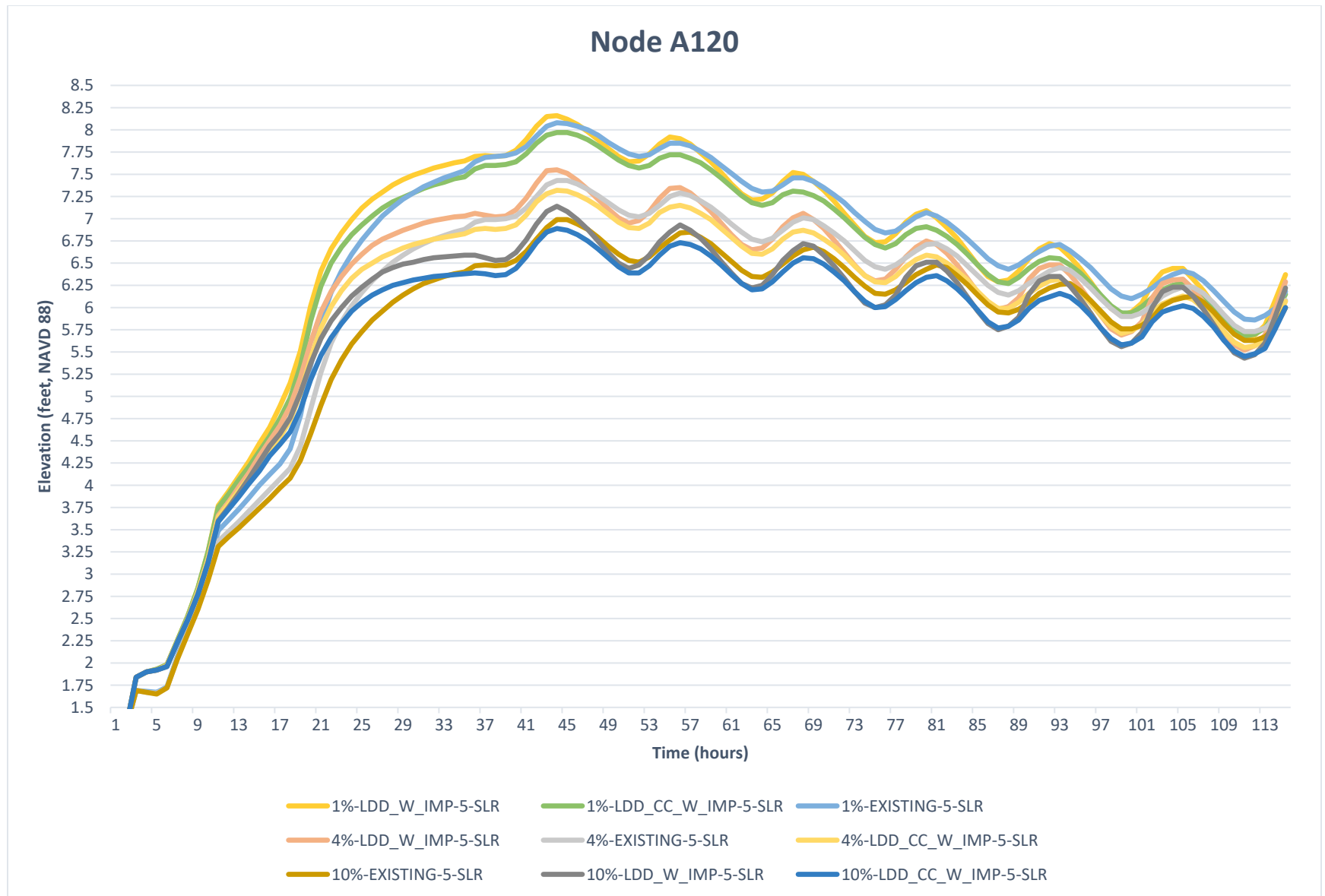


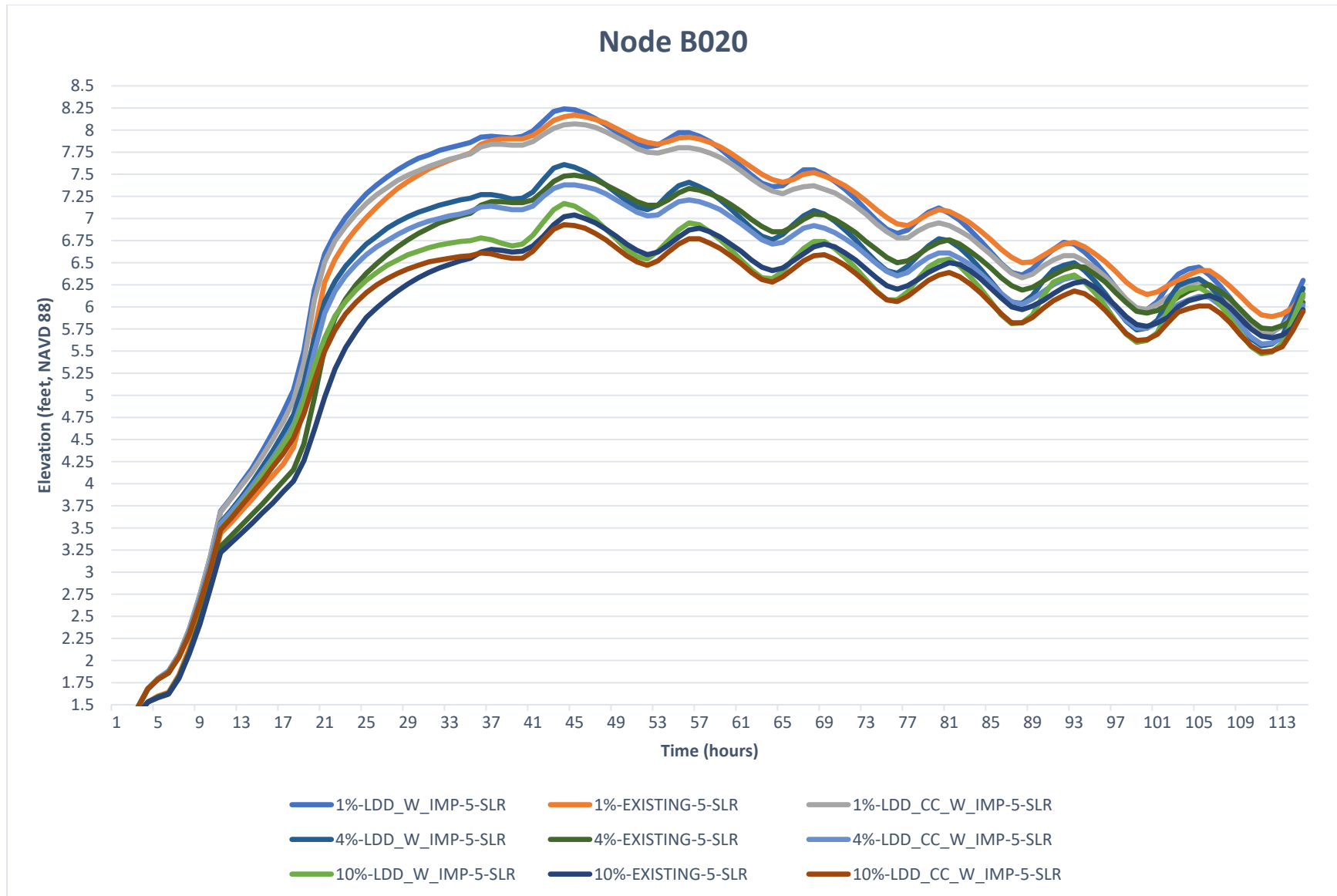


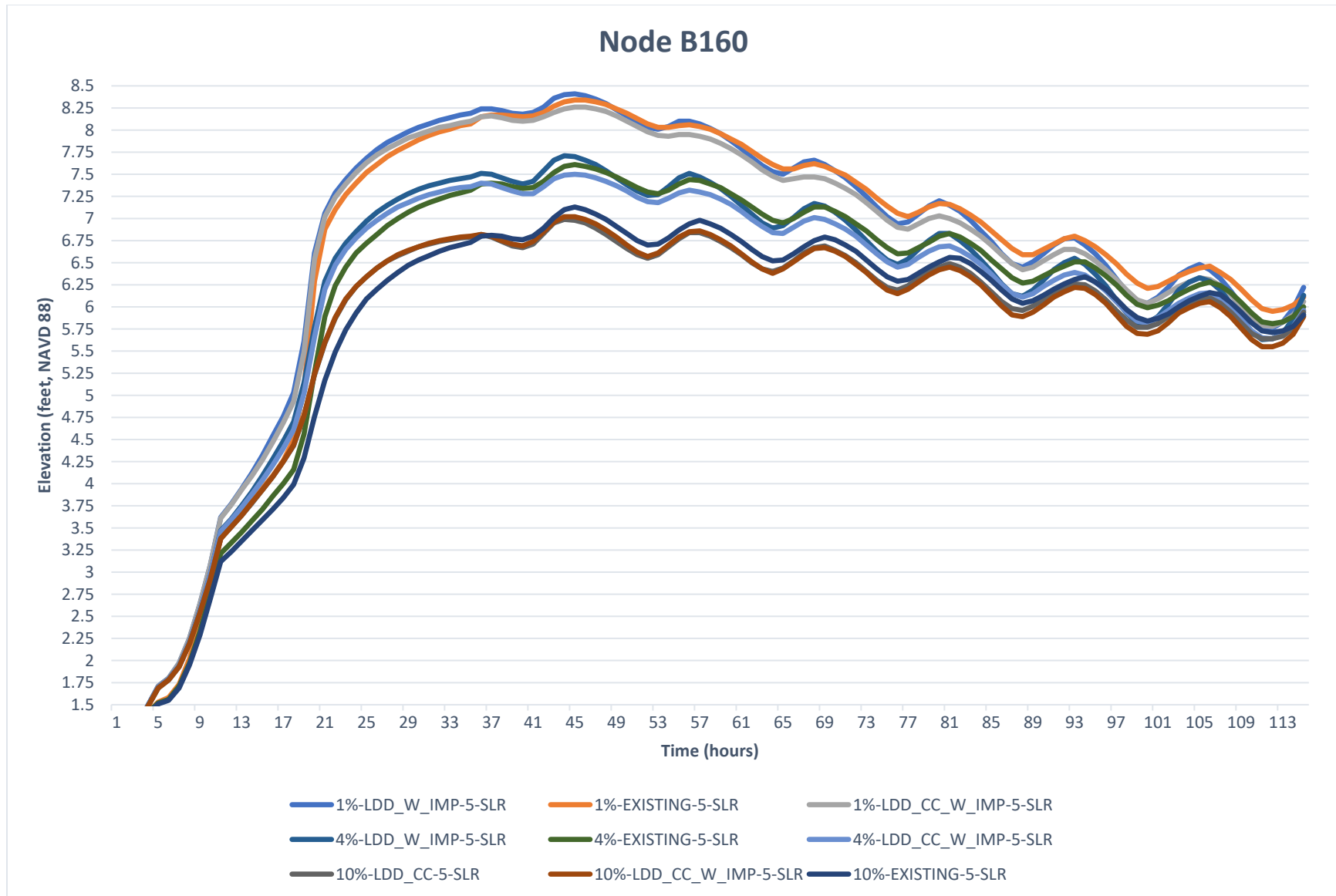
Attachment 1F. Effects of 5.0' Sea Level Rise on the Lake Dotterer Diversion with Downstream Improvements

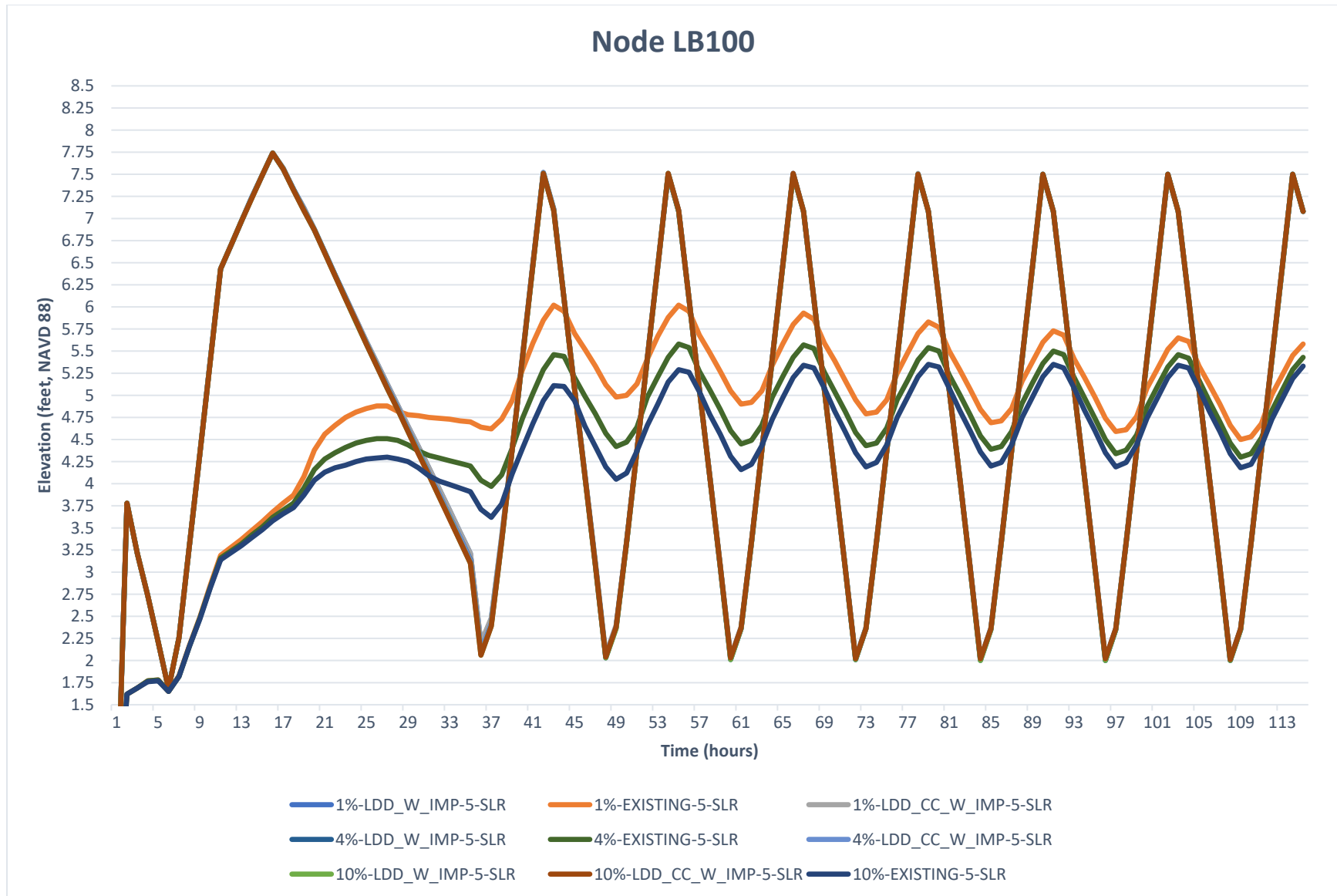


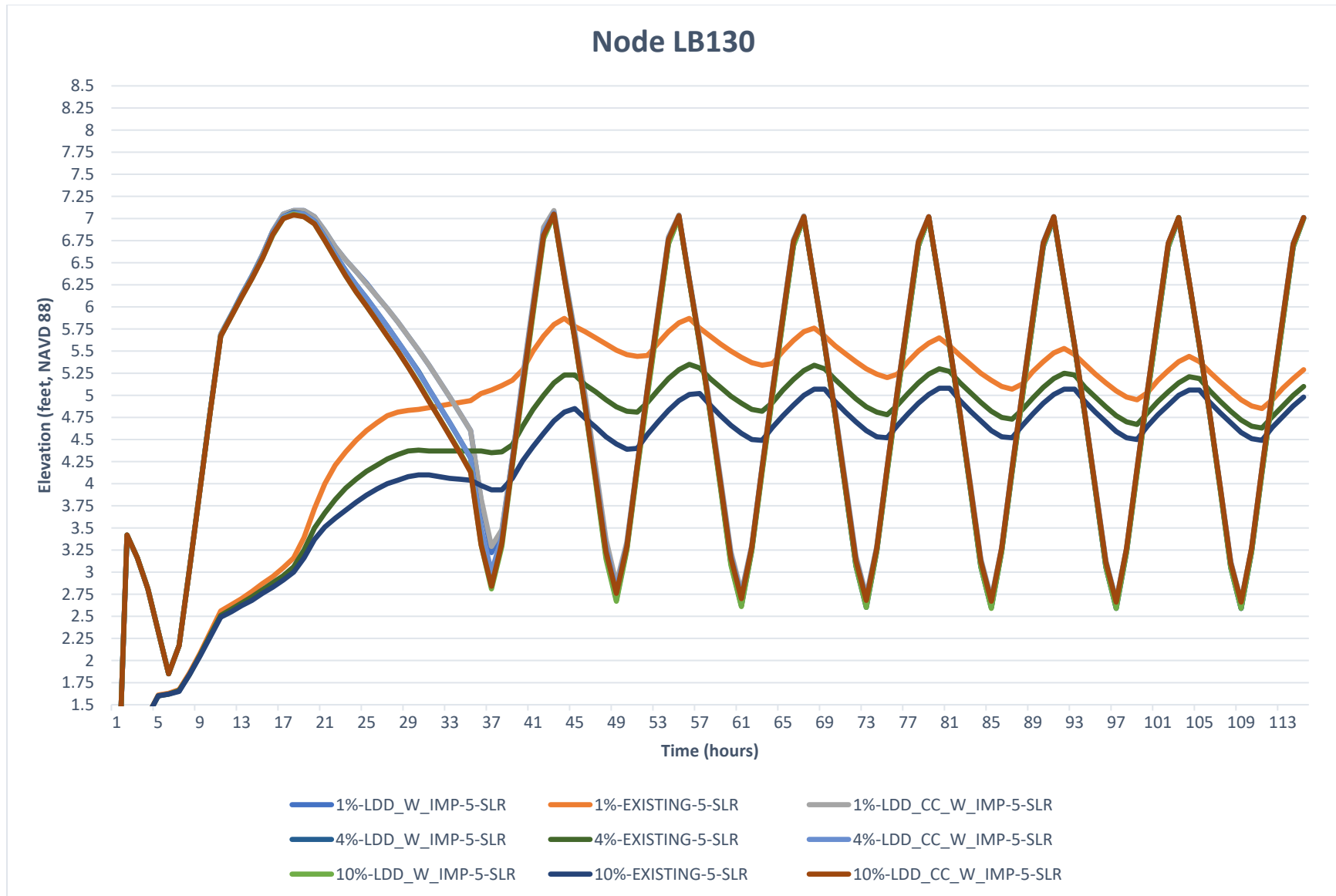


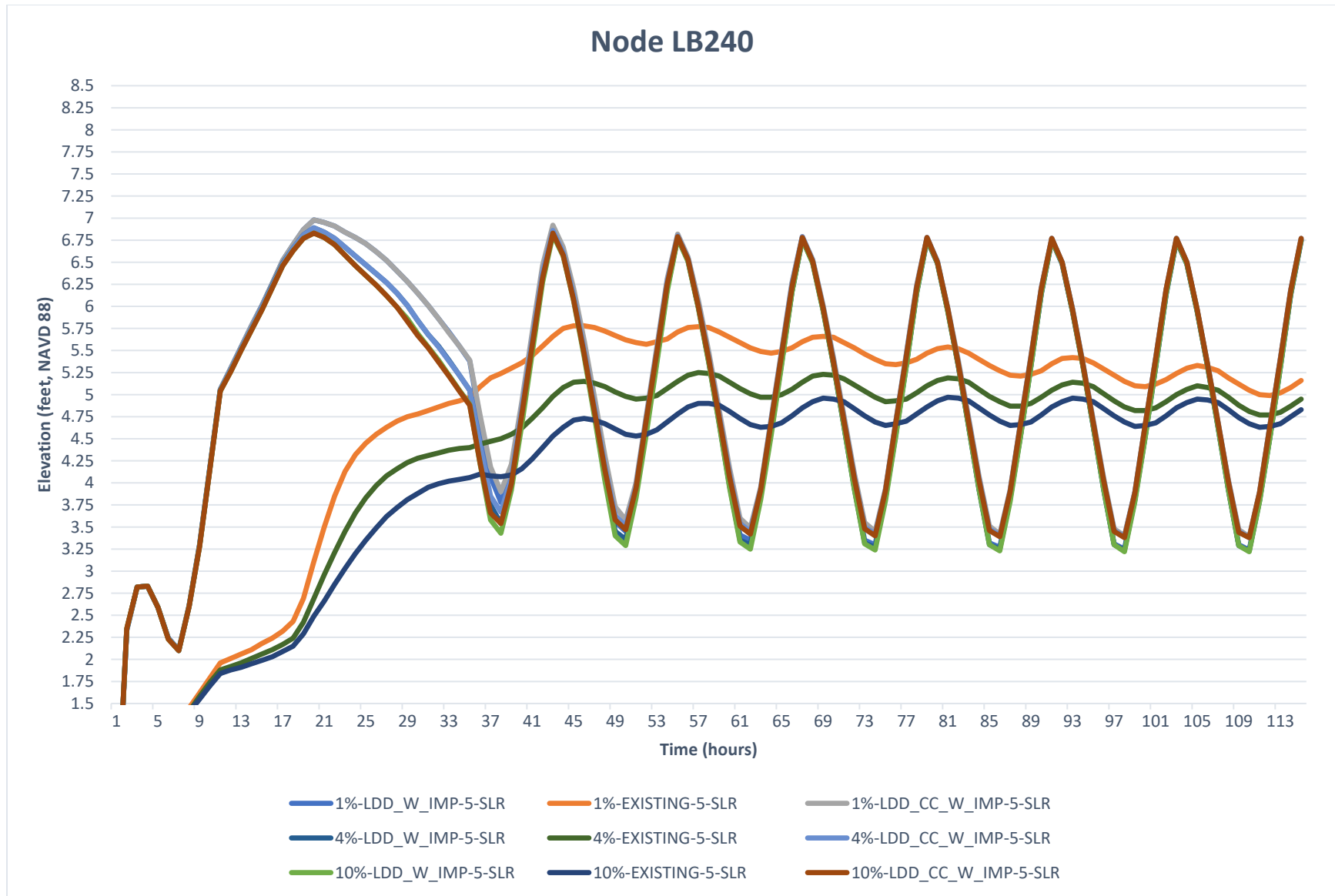


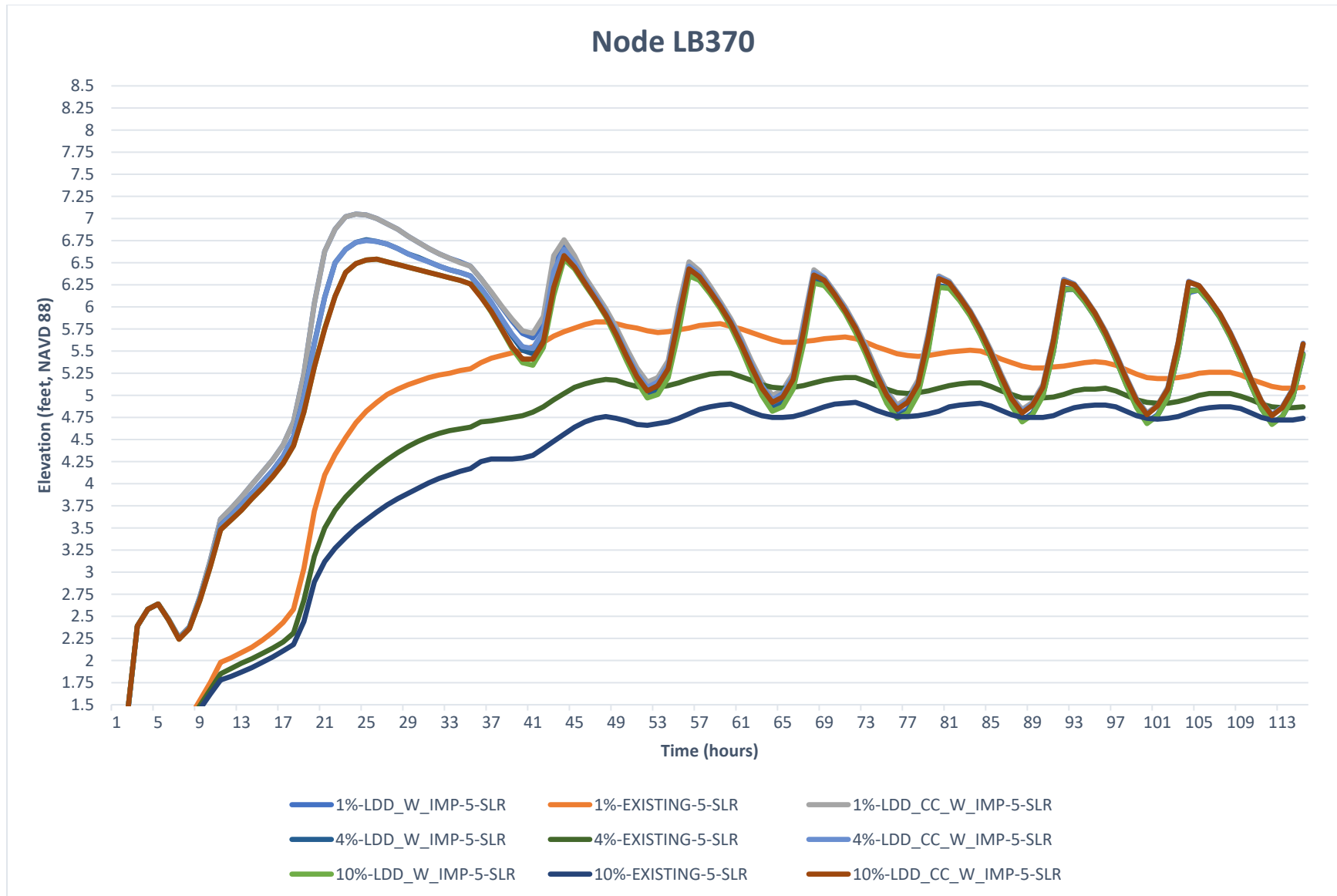


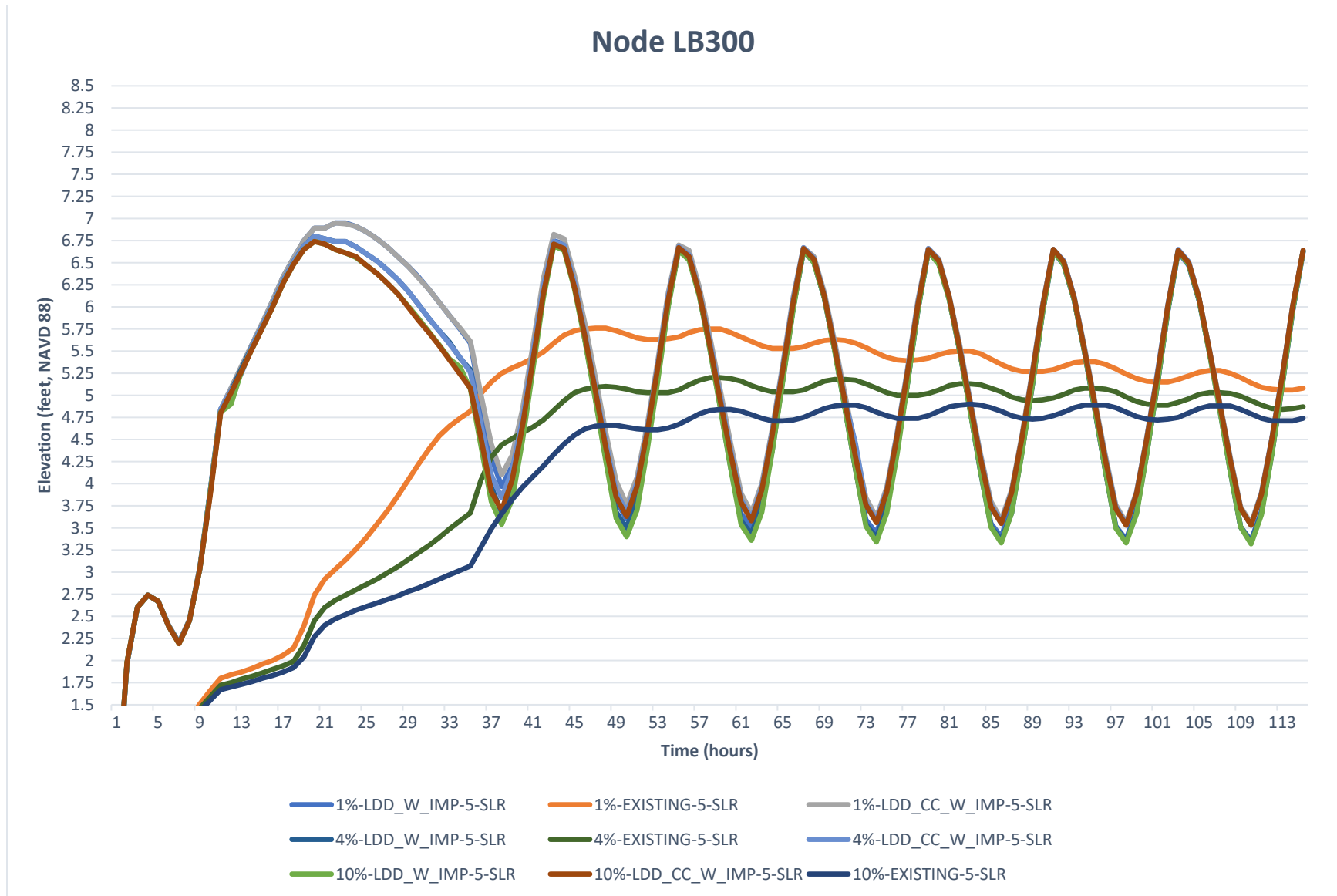


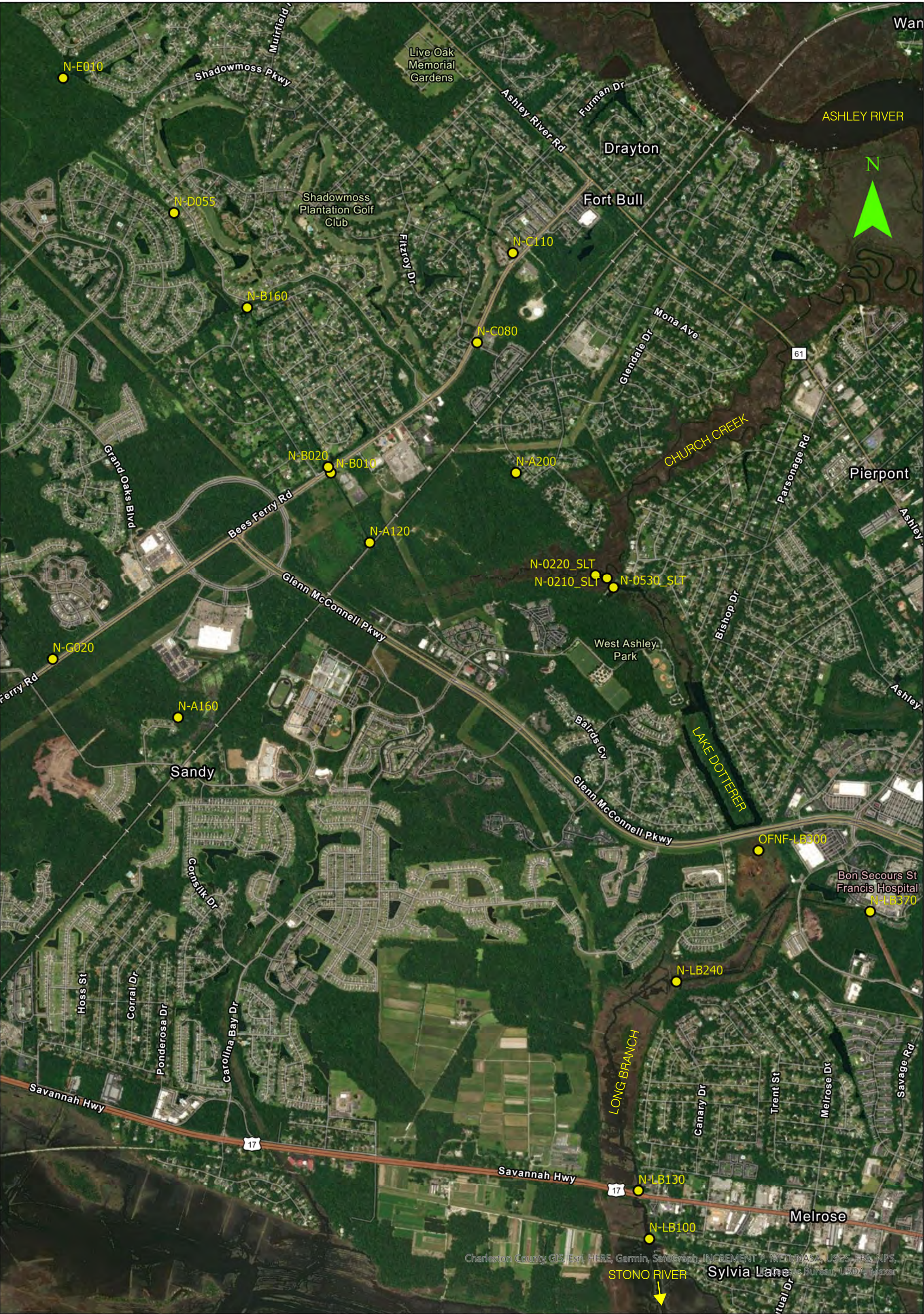












ATTACHMENT 3_ NODE MAP
Sea Level Rise Effects on Proposed Church Creek and Long Branch Drainage Improvements

ATTACHMENT 2

Existing Conditions Peak Staging (ft)					
Simulation	Existing Conditions	MHHW + 2.5'		MHHW + 5.0'	
		WSE (FT)	Δ (FT)	WSE (FT)	Δ (FT)
N-0210					
10% 24-HR	3.58	4.89	1.31	6.75	3.17
4% 24-HR	4.15	5.22	1.07	6.95	2.80
1% 24-HR	4.96	5.71	0.75	7.3	2.34
N-0220					
10% 24-HR	3.65	4.91	1.26	6.74	3.09
4% 24-HR	4.21	5.25	1.04	6.96	2.75
1% 24-HR	5.00	5.75	0.75	7.3	2.30
N-0530					
10% 24- HR	3.59	4.86	1.27	6.74	3.15
4% 24-HR	4.17	5.2	1.03	6.93	2.76
1% 24-HR	4.97	5.7	0.73	7.25	2.28
N-A120					
10% 24- HR	5.39	5.86	0.47	7.02	1.63
4% 24-HR	6.09	6.46	0.37	7.45	1.36
1% 24-HR	7.01	7.31	0.30	8.09	1.08
N-A160					
10% 24- HR	6.72	6.82	0.10	7.36	0.64
4% 24-HR	7.32	7.42	0.10	7.87	0.55
1% 24-HR	8.05	8.18	0.13	8.56	0.51
N-A200					
10% 24- HR	6.10	6.1	0.00	6.65	0.55
4% 24-HR	6.30	6.3	0.00	6.89	0.59
1% 24-HR	6.54	6.54	0.00	7.31	0.77
N-B010					
10% 24- HR	5.78	5.92	0.14	7.05	1.27
4% 24-HR	6.48	6.56	0.08	7.48	1.00
1% 24-HR	7.35	7.45	0.10	8.16	0.81
N-B020					
10% 24- HR	5.78	6	0.22	7.06	1.28
4% 24-HR	6.48	6.66	0.18	7.5	1.02
1% 24-HR	7.35	7.53	0.18	8.18	0.83
N-B160					
10% 24- HR	6.12	6.28	0.16	7.14	1.02
4% 24-HR	6.86	6.98	0.12	7.61	0.75
1% 24-HR	7.77	7.86	0.09	8.36	0.59
N-C080					
10% 24- HR	8.82	8.82	0.00	8.93	0.11
4% 24-HR	9.39	9.39	0.00	9.46	0.07
1% 24-HR	9.98	9.98	0.00	10.02	0.04
N-C110					
10% 24- HR	9.03	9.04	0.01	9.11	0.08
4% 24-HR	9.72	9.71	-0.01	9.77	0.05
1% 24-HR	10.63	10.63	0.00	10.68	0.05
N-D055					
10% 24- HR	7.48	7.52	0.04	7.69	0.21
4% 24-HR	8.17	8.21	0.04	8.46	0.29
1% 24-HR	9.24	9.26	0.02	9.38	0.14
N-E010					
10% 24- HR	9.41	9.41	0.00	9.46	0.05
4% 24-HR	10.03	10.04	0.01	10.07	0.04
1% 24-HR	10.83	10.83	0.00	10.84	0.01
N-G020					
10% 24- HR	7.76	7.77	0.01	7.87	0.11
4% 24-HR	8.29	8.33	0.04	8.45	0.16
1% 24-HR	9.07	9.11	0.04	9.23	0.16
N-LB100					
10% 24- HR	2.58	3.91	1.33	5.36	2.78
4% 24-HR	3.00	4.33	1.33	5.58	2.58
1% 24-HR	3.83	4.94	1.11	6.02	2.19
N-LB130					
10% 24- HR	2.54	3.79	1.25	5.1	2.56
4% 24-HR	3.14	4.25	1.11	5.36	2.22
1% 24-HR	4.19	4.9	0.71	5.87	1.68
N-LB240					
10% 24- HR	2.65	3.71	1.06	4.97	2.32
4% 24-HR	3.31	4.19	0.88	5.25	1.94
1% 24-HR	4.35	4.97	0.62	5.79	1.44
N-LB370					
10% 24- HR	3.14	3.76	0.62	4.92	1.78
4% 24-HR	3.82	4.27	0.45	5.26	1.44
1% 24-HR	4.71	5.09	0.38	5.83	1.12
OFNF-LB300					
10% 24- HR	2.65	3.5	0.85	4.9	2.25
4% 24-HR	3.27	4.13	0.86	5.2	1.93
1% 24-HR	4.38	4.97	0.59	5.77	1.39

Mid Basin Storage Peak Staging (ft)						
Simulation	MHHW + 2.5'			MHHW + 5.0'		
	Future Existing	WSE (FT)	Δ (FT)	Future Existing	WSE (FT)	Δ (FT)
N-0210						
10% 24-HR	4.89	4.88	-0.01	6.75	6.77	0.02
4% 24-HR	5.22	5.21	-0.01	6.95	6.93	-0.02
1% 24-HR	5.71	5.71	0.00	7.30	7.25	-0.05
N-0220						
10% 24-HR	4.91	4.9	-0.01	6.74	6.75	0.01
4% 24-HR	5.25	5.24	-0.01	6.96	6.94	-0.02
1% 24-HR	5.75	5.74	-0.01	7.30	7.27	-0.03
N-0530						
10% 24- HR	4.86	4.85	-0.01	6.74	6.75	0.01
4% 24-HR	5.20	5.18	-0.02	6.93	6.92	-0.01
1% 24-HR	5.70	5.7	0.00	7.25	7.23	-0.02
N-A120						
10% 24- HR	5.86	5.81	-0.05	7.02	6.99	-0.03
4% 24-HR	6.46	6.44	-0.02	7.45	7.43	-0.02
1% 24-HR	7.31	7.31	0.00	8.09	8.07	-0.02
N-A160						
10% 24- HR	6.82	6.78	-0.04	7.36	7.33	-0.03
4% 24-HR	7.42	7.4	-0.02	7.87	7.85	-0.02
1% 24-HR	8.18	8.17	-0.01	8.56	8.55	-0.01
N-A200						
10% 24- HR	6.10	6.1	0.00	6.65	6.66	0.01
4% 24-HR	6.30	6.3	0.00	6.89	6.88	-0.01
1% 24-HR	6.54	6.54	0.00	7.31	7.29	-0.02
N-B010						
10% 24- HR	5.92	5.83	-0.09	7.05	7.01	-0.04
4% 24-HR	6.56	6.46	-0.10	7.48	7.44	-0.04
1% 24-HR	7.45	7.33	-0.12	8.16	8.09	-0.07
N-B020						
10% 24- HR	6.00	5.89	-0.11	7.06	7.02	-0.04
4% 24-HR	6.66	6.54	-0.12	7.50	7.46	-0.04
1% 24-HR	7.53	7.43	-0.10	8.18	8.12	-0.06
N-B160						
10% 24- HR	6.28	6.14	-0.14	7.14	7.11	-0.03
4% 24-HR	6.98	6.86	-0.12	7.61	7.57	-0.04
1% 24-HR	7.86	7.76	-0.10	8.36	8.3	-0.06
N-C080						
10% 24- HR	8.82	8.81	-0.01	8.93	8.92	-0.01
4% 24-HR	9.39	9.4	0.01	9.46	9.46	0.00
1% 24-HR	9.98	9.98	0.00	10.02	10.01	-0.01
N-C110						
10% 24- HR	9.04	9	-0.04	9.11	9.1	-0.01
4% 24-HR	9.71	9.72	0.01	9.77	9.77	0.00
1% 24-HR	10.63	10.65	0.02	10.68	10.65	-0.03
N-D055						
10% 24- HR	7.52	7.5	-0.02	7.69	7.69	0.00
4% 24-HR	8.21	8.17	-0.04	8.46	8.43	-0.03
1% 24-HR	9.26	9.25	-0.01	9.38	9.37	-0.01
N-E010						
10% 24- HR	9.41	9.4	-0.01	9.46	9.44	-0.02
4% 24-HR	10.04	10.04	0.00	10.07	10.06	-0.01
1% 24-HR	10.83	10.82	-0.01	10.84	10.84	0.00
N-G020						
10% 24- HR	7.77	7.75	-0.02	7.87	7.85	-0.02
4% 24-HR	8.33	8.31	-0.02	8.45	8.43	-0.02
1% 24-HR	9.11	9.09	-0.02	9.23	9.21	-0.02

West Ashley Circle Storage with Hickory Farms Diversion Peak Staging (ft)						
Simulation	MHHW + 2.5'			MHHW + 5.0'		
	Future Existing	WSE (FT)	Δ (FT)	Future Existing	WSE (FT)	Δ (FT)
N-0210						
10% 24-HR	4.89	4.88	-0.01	6.75	6.77	0.02
4% 24-HR	5.22	5.21	-0.01	6.95	6.93	-0.02
1% 24-HR	5.71	5.71	0.00	7.30	7.25	-0.05
N-0220						
10% 24-HR	4.91	4.9	-0.01	6.74	6.75	0.01
4% 24-HR	5.25	5.24	-0.01	6.96	6.94	-0.02
1% 24-HR	5.75	5.74	-0.01	7.30	7.27	-0.03
N-0530						
10% 24- HR	4.86	4.85	-0.01	6.74	6.75	0.01
4% 24-HR	5.20	5.18	-0.02	6.93	6.92	-0.01
1% 24-HR	5.70	5.7	0.00	7.25	7.23	-0.02
N-A120						
10% 24- HR	5.86	5.81	-0.05	7.02	6.99	-0.03
4% 24-HR	6.46	6.44	-0.02	7.45	7.43	-0.02
1% 24-HR	7.31	7.31	0.00	8.09	8.07	-0.02
N-A160						
10% 24- HR	6.82	6.78	-0.04	7.36	7.33	-0.03
4% 24-HR	7.42	7.4	-0.02	7.87	7.85	-0.02
1% 24-HR	8.18	8.17	-0.01	8.56	8.55	-0.01
N-A200						
10% 24- HR	6.10	6.1	0.00	6.65	6.66	0.01
4% 24-HR	6.30	6.3	0.00	6.89	6.88	-0.01
1% 24-HR	6.54	6.54	0.00	7.31	7.29	-0.02
N-B010						
10% 24- HR	5.92	5.83	-0.09	7.05	7.01	-0.04
4% 24-HR	6.56	6.46	-0.10	7.48	7.44	-0.04
1% 24-HR	7.45	7.33	-0.12	8.16	8.09	-0.07
N-B020						
10% 24- HR	6.00	5.89	-0.11	7.06	7.02	-0.04
4% 24-HR	6.66	6.54	-0.12	7.50	7.46	-0.04
1% 24-HR	7.53	7.43	-0.10	8.18	8.12	-0.06
N-B160						
10% 24- HR	6.28	6.14	-0.14	7.14	7.11	-0.03
4% 24-HR	6.98	6.86	-0.12	7.61	7.57	-0.04
1% 24-HR	7.86	7.76	-0.10	8.36	8.3	-0.06
N-C080						
10% 24- HR	8.82	8.81	-0.01	8.93	8.92	-0.01
4% 24-HR	9.39	9.4	0.01	9.46	9.46	0.00
1% 24-HR	9.98	9.98	0.00	10.02	10.01	-0.01
N-C110						
10% 24- HR	9.04	9	-0.04	9.11	9.1	-0.01
4% 24-HR	9.71	9.72	0.01	9.77	9.77	0.00
1% 24-HR	10.63	10.65	0.02	10.68	10.65	-0.03
N-D055						
10% 24- HR	7.52	7.5	-0.02	7.69	7.69	0.00
4% 24-HR	8.21	8.17	-0.04	8.46	8.43	-0.03
1% 24-HR	9.26	9.25	-0.01	9.38	9.37	-0.01
N-E010						
10% 24- HR	9.41	9.4	-0.01	9.46	9.44	-0.02
4% 24-HR	10.04	10.04	0.00	10.07	10.06	-0.01
1% 24-HR	10.83	10.82	-0.01	10.84	10.84	0.00
N-G020						
10% 24- HR	7.77	7.75	-0.02	7.87	7.85	-0.02
4% 24-HR	8.33	8.31	-0.02	8.45	8.43	-0.02
1% 24-HR	9.11	9.09	-0.02	9.23	9.21	-0.02

Mid Basin and West Ashley Circle Storage Peak Staging (ft)						
Simulation	MHHW + 2.5'			MHHW + 5.0'		
	Future Existing	WSE (FT)	Δ (FT)	Future Existing	WSE (FT)	Δ (FT)
N-0210						
10% 24-HR	4.89	4.84	-0.05	6.75	6.73	-0.02
4% 24-HR	5.22	5.18	-0.04	6.95	6.91	-0.04
1% 24-HR	5.71	5.67	-0.04	7.30	7.23	-0.07
N-0220						
10% 24-HR	4.91	4.87	-0.04	6.74	6.71	-0.03
4% 24-HR	5.25	5.21	-0.04	6.96	6.92	-0.04
1% 24-HR	5.75	5.7	-0.05	7.30	7.25	-0.05
N-0530						
10% 24- HR	4.86	4.81	-0.05	6.74	6.72	-0.02
4% 24-HR	5.20	5.16	-0.04	6.93	6.9	-0.03
1% 24-HR	5.70	5.66	-0.04	7.25	7.21	-0.04
N-A120						
10% 24- HR	5.86	5.77	-0.09	7.02	6.94	-0.08
4% 24-HR	6.46	6.39	-0.07	7.45	7.38	-0.07
1% 24-HR	7.31	7.25	-0.06	8.09	8.04	-0.05
N-A160						
10% 24- HR	6.82	6.77	-0.05	7.36	7.3	-0.06
4% 24-HR	7.42	7.38	-0.04	7.87	7.83	-0.04
1% 24-HR	8.18	8.14	-0.04	8.56	8.52	-0.04
N-A200						
10% 24- HR	6.10	6.1	0.00	6.65	6.63	-0.02
4% 24-HR	6.30	6.3	0.00	6.89	6.87	-0.02
1% 24-HR	6.54	6.54	0.00	7.31	7.27	-0.04
N-B010						
10% 24- HR	5.92	5.79	-0.13	7.05	6.95	-0.10
4% 24-HR	6.56	6.41	-0.15	7.48	7.4	-0.08
1% 24-HR	7.45	7.28	-0.17	8.16	8.06	-0.10
N-B020						
10% 24- HR	6.00	5.85	-0.15	7.06	6.96	-0.10
4% 24-HR	6.66	6.49	-0.17	7.50	7.42	-0.08
1% 24-HR	7.53	7.38	-0.15	8.18	8.08	-0.10
N-B160						
10% 24- HR	6.28	6.07	-0.21	7.14	7.05	-0.09
4% 24-HR	6.98	6.77	-0.21	7.61	7.53	-0.08
1% 24-HR	7.86	7.67	-0.19	8.36	8.26	-0.10
N-C080						
10% 24- HR	8.82	8.82	0.00	8.93	8.93	0.00
4% 24-HR	9.39	9.39	0.00	9.46	9.46	0.00
1% 24-HR	9.98	9.98	0.00	10.02	10.01	-0.01
N-C110						
10% 24- HR	9.04	9.03	-0.01	9.11	9.12	0.01
4% 24-HR	9.71	9.72	0.01	9.77	9.76	-0.01
1% 24-HR	10.63	10.62	-0.01	10.68	10.66	-0.02
N-D055						
10% 24- HR	7.52	7.47	-0.05	7.69	7.65	-0.04
4% 24-HR	8.21	8.15	-0.06	8.46	8.41	-0.05
1% 24-HR	9.26	9.24	-0.02	9.38	9.36	-0.02
N-E010						
10% 24- HR	9.41	9.42	0.01	9.46	9.44	-0.02
4% 24-HR	10.04	10.03	-0.01	10.07	10.06	-0.01
1% 24-HR	10.83	10.83	0.00	10.84	10.84	0.00
N-G020						
10% 24- HR	7.77	7.75	-0.02	7.87	7.84	-0.03
4% 24-HR	8.33	8.31	-0.02	8.45	8.43	-0.02
1% 24-HR	9.11	9.1	-0.01	9.23	9.21	-0.02

Lake Dotterer Flow Restoration with Downstream Improvements Peak Staging (ft)						
Simulation	MHHW + 2.5'			MHHW + 5.0'		
	Future Existing	WSE (FT)	Δ (FT)	Future Existing	WSE (FT)	Δ (FT)
N-0210						
10% 24-HR	4.89	5.18	0.29	6.76	7.3	0.54
4% 24-HR	5.23	5.5	0.27	6.95	7.32	0.37
1% 24-HR	5.72	5.85	0.13	7.26	7.52	0.26
N-0530						
10% 24- HR	4.86	2.97	-1.89	6.74	3.55	-3.19
4% 24-HR	5.21	3.59	-1.62	6.93	4.21	-2.72
1% 24-HR	5.71	4.42	-1.29	7.24	4.93	-2.31
N-A120						
10% 24- HR	5.83	5.95	0.12	7.00	7.14	0.14
4% 24-HR	6.45	6.54	0.09	7.44	7.56	0.12
1% 24-HR	7.31	7.35	0.04	8.08	8.16	0.08
N-B020						
10% 24- HR	6.00	6.06	0.06	7.04	7.17	0.13
4% 24-HR	6.66	6.7	0.04	7.50	7.61	0.11
1% 24-HR	7.53	7.56	0.03	8.17	8.24	0.07
N-B160						
10% 24- HR	6.28	6.34	0.06	7.13	7.26	0.13
4% 24-HR	6.99	7.04	0.05	7.61	7.71	0.10
1% 24-HR	7.87	7.89	0.02	8.35	8.41	0.06
N-LB100						
10% 24- HR	3.91	5.31	1.40	5.36	7.77	2.41
4% 24-HR	4.33	5.31	0.98	5.58	7.77	2.19
1% 24-HR	4.94	5.32	0.38	6.02	7.77	1.75
N-LB130						
10% 24- HR	3.79	4.92	1.13	5.1	7.18	2.08
4% 24-HR	4.25	4.97	0.72	5.36	7.21	1.85
1% 24-HR	4.90	5.03	0.13	5.87	7.23	1.36
N-LB240						
10% 24- HR	3.71	4.65	0.94	4.97	6.83	1.86
4% 24-HR	4.19	4.75	0.56	5.25	6.89	1.64
1% 24-HR	4.97	4.91	-0.06	5.79	6.98	1.19
N-LB370						
10% 24- HR	3.76	4.62	0.86	4.92	6.55	1.63
4% 24-HR	4.27	4.99	0.72	5.26	6.76	1.50
1% 24-HR	5.09	5.52	0.43	5.83	7.05	1.22
OFNF-LB300						
10% 24- HR	3.50	5.06	1.56	4.9	6.75	1.85
4% 24-HR	4.13	5.3	1.17	5.2	6.81	1.61
1% 24-HR	4.97	4.99	0.02	5.77	6.96	1.19

Lake Dotterer Flow Restoration without Downstream Improvements Peak Staging (ft)						
Simulation	MHHW + 2.5'			MHHW + 5.0'		
	Future Existing	WSE (FT)	Δ (FT)	Future Existing	WSE (FT)	Δ (FT)
N-0210						
10% 24-HR	4.89	5.17	0.28	6.76	7.3	0.54
4% 24-HR	5.23	5.47	0.24	6.95	7.32	0.37
1% 24-HR	5.72	5.85	0.13	7.26	7.52	0.26
N-0530						
10% 24- HR	4.86	3.47	-1.39	6.74	3.61	-3.13
4% 24-HR	5.21	4.11	-1.10	6.93	4.34	-2.59
1% 24-HR	5.71	4.98	-0.73	7.24	5.21	-2.03
N-A120						
10% 24- HR	5.83	5.95	0.12	7.00	7.14	0.14
4% 24-HR	6.45	6.54	0.09	7.44	7.56	0.12
1% 24-HR	7.31	7.35	0.04	8.08	8.16	0.08
N-B020						
10% 24- HR	6.00	6.06	0.06	7.04	7.17	0.13
4% 24-HR	6.66	6.7	0.04	7.50	7.61	0.11
1% 24-HR	7.53	7.56	0.03	8.17	8.24	0.07
N-B160						
10% 24- HR	6.28	6.34	0.06	7.13	7.26	0.13
4% 24-HR	6.99	7.03	0.04	7.61	7.71	0.10
1% 24-HR	7.87	7.89	0.02	8.35	8.41	0.06
N-LB100						
10% 24- HR	3.91	3.93	0.02	5.36	5.37	0.01
4% 24-HR	4.33	4.36	0.03	5.58	5.59	0.01
1% 24-HR	4.94	4.99	0.05	6.02	6.05	0.03
N-LB130						
10% 24- HR	3.79	3.81	0.02	5.1	5.10	0.00
4% 24-HR	4.25	4.29	0.04	5.36	5.38	0.02
1% 24-HR	4.90	4.95	0.05	5.87	5.90	0.03
N-LB240						
10% 24- HR	3.71	3.74	0.03	4.97	4.98	0.01
4% 24-HR	4.19	4.25	0.06	5.25	5.27	0.02
1% 24-HR	4.97	5.03	0.06	5.79	5.82	0.03
N-LB370						
10% 24- HR	3.76	3.8	0.04	4.92	4.94	0.02
4% 24-HR	4.27	4.34	0.07	5.26	5.28	0.02
1% 24-HR	5.09	5.15	0.06	5.83	5.87	0.04
OFNF-LB300						
10% 24- HR	3.50	3.6	0.10	4.9	4.91	0.01
4% 24-HR	4.13	4.2	0.07	5.2	5.22	0.02
1% 24-HR	4.97	5.03	0.06	5.77	5.80	0.03

Lake Dotterer Flow Restoration with Downstream Improvements and Connection to Church Creek Peak Staging (ft)						
Simulation	MHHW + 2.5'			MHHW + 5.0'		
	Future Existing	WSE (FT)	Δ (FT)	Future Existing	WSE (FT)	Δ (FT)
N-0210						
10% 24-HR	4.89	5.08	0.19	6.76	6.77	0.01
4% 24-HR	5.23	5.35	0.12	6.95	6.79	-0.16
1% 24-HR	5.72	5.61	-0.11	7.26	7.04	-0.22
N-0530						
10% 24- HR	4.86	3.5	-1.36	6.74	6.33	-0.41
4% 24-HR	5.21	4.24	-0.97	6.93	6.62	-0.31
1% 24-HR	5.71	5.2	-0.51	7.24	6.98	-0.26
N-A120						
10% 24- HR	5.83	5.91	0.08	7.00	6.89	-0.11
4% 24-HR	6.45	6.47	0.02	7.44	7.32	-0.12
1% 24-HR	7.31	7.23	-0.08	8.08	7.97	-0.11
N-B020						
10% 24- HR	6.00	6.05	0.05	7.04	6.93	-0.11
4% 24-HR	6.66	6.69	0.03	7.50	7.39	-0.11
1% 24-HR	7.53	7.48	-0.05	8.17	8.07	-0.10
N-B160						
10% 24- HR	6.28	6.34	0.06	7.13	7.02	-0.11
4% 24-HR	6.99	7.03	0.04	7.61	7.5	-0.11
1% 24-HR	7.87	7.88	0.01	8.35	8.26	-0.09
N-LB100						
10% 24- HR	3.91	5.31	1.40	5.36	7.77	2.41
4% 24-HR	4.33	5.32	0.99	5.58	7.78	2.20
1% 24-HR	4.94	5.32	0.38	6.02	7.78	1.76
N-LB130						
10% 24- HR	3.79	4.93	1.14	5.1	7.20	2.10
4% 24-HR	4.25	4.98	0.73	5.36	7.23	1.87
1% 24-HR	4.90	5.05	0.15	5.87	7.26	1.39
N-LB240						
10% 24- HR	3.71	4.65	0.94	4.97	6.84	1.87
4% 24-HR	4.19	4.75	0.56	5.25	6.89	1.64
1% 24-HR	4.97	4.91	-0.06	5.79	6.98	1.19
N-LB370						
10% 24- HR	3.76	4.62	0.86	4.92	6.58	1.66
4% 24-HR	4.27	4.99	0.72	5.26	6.76	1.50
1% 24-HR	5.09	5.52	0.43	5.83	7.05	1.22
OFNF-LB300						
10% 24- HR	3.50	5.08	1.58	4.9	6.74	1.84
4% 24-HR	4.13	5.37	1.24	5.2	6.81	1.61
1% 24-HR	4.97	4.99	0.02	5.77	6.96	1.19

Lake Dotterer Flow Restoration without Downstream Improvements with Connection to Church Creek Peak Staging (ft)						
Simulation	MHHW + 2.5'			MHHW + 5.0'		
	Future Existing	WSE (FT)	Δ (FT)	Future Existing	WSE (FT)	Δ (FT)
N-0210						
10% 24-HR	4.89	5.05	0.16	6.76	6.78	0.02
4% 24-HR	5.23	5.34	0.11	6.95	6.8	-0.15
1% 24-HR	5.72	5.61	-0.11	7.26	7.07	-0.19
N-0530						
10% 24- HR	4.86	3.9	-0.96	6.74	6.32	-0.42
4% 24-HR	5.21	4.67	-0.54	6.93	6.59	-0.34
1% 24-HR	5.71	5.53	-0.18	7.24	7.01	-0.23
N-A120						
10% 24- HR	5.83	5.91	0.08	7.00	6.86	-0.14
4% 24-HR	6.45	6.47	0.02	7.44	7.3	-0.14
1% 24-HR	7.31	7.26	-0.05	8.08	7.98	-0.10
N-B020						
10% 24- HR	6.00	6.06	0.06	7.04	6.91	-0.13
4% 24-HR	6.66	6.69	0.03	7.50	7.37	-0.13
1% 24-HR	7.53	7.49	-0.04	8.17	8.07	-0.10
N-B160						
10% 24- HR	6.28	6.34	0.06	7.13	7	-0.13
4% 24-HR	6.99	7.02	0.03	7.61	7.49	-0.12
1% 24-HR	7.87	7.88	0.01	8.35	8.26	-0.09
N-LB100						
10% 24- HR	3.91	3.93	0.02	5.36	5.77	0.41
4% 24-HR	4.33	4.38	0.05	5.58	5.96	0.38
1% 24-HR	4.94	5.03	0.09	6.02	6.30	0.28
N-LB130						
10% 24- HR	3.79	3.82	0.03	5.1	5.62	0.52
4% 24-HR	4.25	4.31	0.06	5.36	5.83	0.47
1% 24-HR	4.90	5.02	0.12	5.87	6.21	0.34
N-LB240						
10% 24- HR	3.71	3.77	0.06	4.97	5.61	0.64
4% 24-HR	4.19	4.34	0.15	5.25	5.83	0.58
1% 24-HR	4.97	5.16	0.19	5.79	6.24	0.45
N-LB370						
10% 24- HR	3.76	3.85	0.09	4.92	5.59	0.67
4% 24-HR	4.27	4.45	0.18	5.26	5.87	0.61
1% 24-HR	5.09	5.3	0.21	5.83	6.30	0.47
OFNF-LB300						
10% 24- HR	3.50	3.8	0.30	4.9	5.68	0.78
4% 24-HR	4.13	4.53	0.40	5.2	5.90	0.70
1% 24-HR	4.97	5.27	0.30	5.77	6.31	0.54