APPENDIX J

HEC RESSIM AND CHEOPS COMPARISON SUMMARY

Appendix J
HEC ResSim and CHEOPS Comparison Summary

Model Setup and Type Background

Overall the Computer Hydro-Electric Operations and Planning Software (CHEOPS) and U.S. Army Corps of Engineers (USACE) Hydrologic Engineering Center's Reservoir System Simulation (HEC-ResSim) results are very similar. Table J-1 shows a comparison of the CHEOPS and ResSim gross generation for Alternative 2 (A2) and Alternative 3 (A3). This comparison shows that the unit operations compare favorably between the two models. Figures J-1 and J-2 compare the CHEOPS and ResSim daily discharge durations from J. Strom Thurmond (JST) for the A2 and A3. These figures show the similarity of water allocation through the basin between the two models. Figures J-1 and J-2 display a comparison of CHEOPS and ResSim scenario results with water use that is projected into the future and historical hydrology. Each hydrologic year modeled corresponds to a projected withdrawal (water use) year, as summarized in Table J-2.

Table J-1

Annual Average Gross Generation (MWh) Historical Hydrology and Projecting Withdrawals								
		Bad Creek	**Jocassee**	**Keowee**	**Hartwell**	**Russell**	**Thurmond**	**System Total**
A2	**CHEOPS (MWh)**	**2,145,854**	**952,533**	**64,845**	**446,263**	**679,541**	**681,892**	**4,970,929**
	ResSim (MWh)	**2,187,920**	**842,418**	**69,084**	**433,662**	**695,856**	**665,861**	**4,894,801**
	Difference (MWh) (ResSim - CHEOPS)	*42,066*	*(110,116)*	*4,239*	*(12,601)*	*16,315*	*(16,030)*	*(76,128)*
	Percent Difference (Difference/ CHEOPS)	*2%*	*-12%*	*7%*	*-3%*	*2%*	*-2%*	*-2%*
A3	**CHEOPS (MWh)**	**2,167,165**	**1,127,071**	**63,736**	**445,360**	**679,182**	**680,941**	**5,163,455**
	ResSim (MWh)	**2,189,453**	**861,946**	**69,151**	**434,665**	**696,182**	**665,912**	**4,917,310**
	Difference (MWh) (ResSim - CHEOPS)	*22,289*	*(265,125)*	*5,415*	*(10,695)*	*17,001*	*(15,030)*	*(246,145)*
	Percent Difference (Difference/ CHEOPS)	*1%*	*-24%*	*8%*	*-2%*	*3%*	*-2%*	*-5%*

Table J-2

Hydrologic Year	Projection Year	Hydrologic Year	Projection Year	Hydrologic Year	Projection Year	Hydrologic Year	Projection Year
1939	2010	1957	2028	1975	2046	1993	2064
1940	2011	1958	2029	1976	2047	1994	2065
1941	2012	1959	2030	1977	2048	1995	2066
1942	2013	1960	2031	1978	2049	1996	2066
1943	2014	1961	2032	1979	2050	1997	2066
1944	2015	1962	2033	1980	2051	1998	2066
1945	2016	1963	2034	1981	2052	1999	2066
1946	2017	1964	2035	1982	2053	2000	2066
1947	2018	1965	2036	1983	2054	2001	2066
1948	2019	1966	2037	1984	2055	2002	2066
1949	2020	1967	2038	1985	2056	2003	2066
1950	2021	1968	2039	1986	2057	2004	2066
1951	2022	1969	2040	1987	2058	2005	2066
1952	2023	1970	2041	1988	2059	2006	2066
1953	2024	1971	2042	1989	2060	2007	2066
1954	2025	1972	2043	1990	2061	2008	2066
1955	2026	1973	2044	1991	2062		
1956	2027	1974	2045	1992	2063		

Note: Water use Projection Year corresponds to Appendix C of the Keowee Toxaway Savannah River Basin Water Supply Study Report, April 2014.

It should be noted that the ResSim model tends to operate all reservoirs lower in elevation than CHEOPS, see Figures J-3 through J-8. Model testing and review indicates that differences in daily reservoir elevations are partially due to the handling of the storage balance. The CHEOPS model remains the primary tool for evaluation of water quantity and operations for Keowee-Toxaway Relicensing.

The ResSim model handles the operational rules of the 1968 Operating Agreement (1968 Agreement) between Duke Energy Carolinas, LLC (Duke Energy) and the USACE differently than the CHEOPS model. The CHEOPS model incorporates the terms of the 1968 Agreement through a series of programming rules and follows the language of the 1968 Agreement. The ResSim model incorporates the terms of the 1968 Agreement through the storage balance logic (tandem operation) specifically available in the 3.1 RC3 build 3.1.7.157R June 2011 of the ResSim model. It should be noted that other versions of the ResSim model may produce different results and may not run with configuration defined in the Savannah River model. HDR Engineering, Inc. of the Carolinas (HDR) has not tested other versions of ResSim, therefore, no insights about other versions can be offered. The 3.1 RC3 build 3.1.7.157R version of the

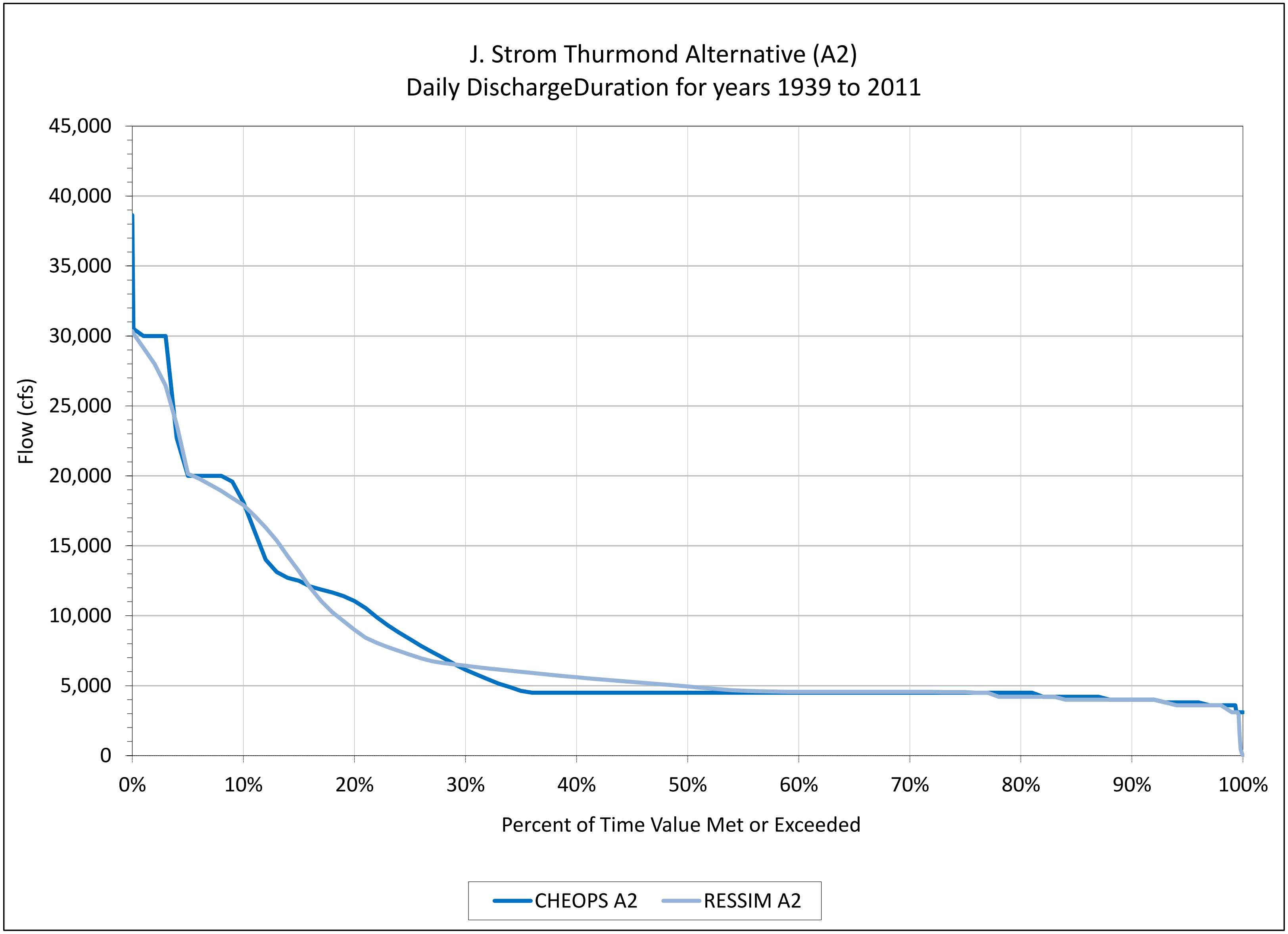
ResSim model provides for tandem operation to manage storage distribution between upstream and downstream reservoirs.

When a tandem or parallel reservoir system is defined, the model determines the priority and the amount of release to make from each reservoir in order to operate towards a storage balance. For every decision interval, an end-of-period storage is first estimated for each reservoir based on the sum of beginning-of-period storage and period average inflow volume, minus all potential outflow volumes. The estimated end-of-period storage for each reservoir is compared to a desired storage that is determined by using a system storage balance scheme. The priority for release is then given to the reservoir that is furthest above the desired storage. When a final release decision is made, the end-of-period storages are recomputed. Depending on other constraints or higher priority rules, system operation strives for a storage balance such that the reservoirs have either reached their guide curves or they are operating at the desired storage (percent of the active storage zone) (HEC-ResSim Reservoir System Simulation User's Manual, Version 3.0 April 2007).

Two key differences between the ResSim balancing logic and the 1968 Agreement (and CHEOPS logic) are the timestep and balance inputs. The ResSim tandem operation is carried out for every timestep whereas the 1968 Agreement only requires weekly balance checks; CHEOPS follows the 1968 Agreement. ResSim also only allows for the input of a single storage relationship between the reservoirs. A single storage relationship for the USACE facilities was entered using the highest seasonal reservoir elevations which occur between April 1 to October 15. Since the USACE facilities are operated with winter drawdowns (not a single storage relationship), the storage percentages referenced in the ResSim model during the seasonal drawdown (October 16 to March 31) do not use the adjusted storage percentages reflective of the change in the guide curve. The ResSim manual also notes the "release decision made for a particular time period may not necessarily achieve the desired balance."

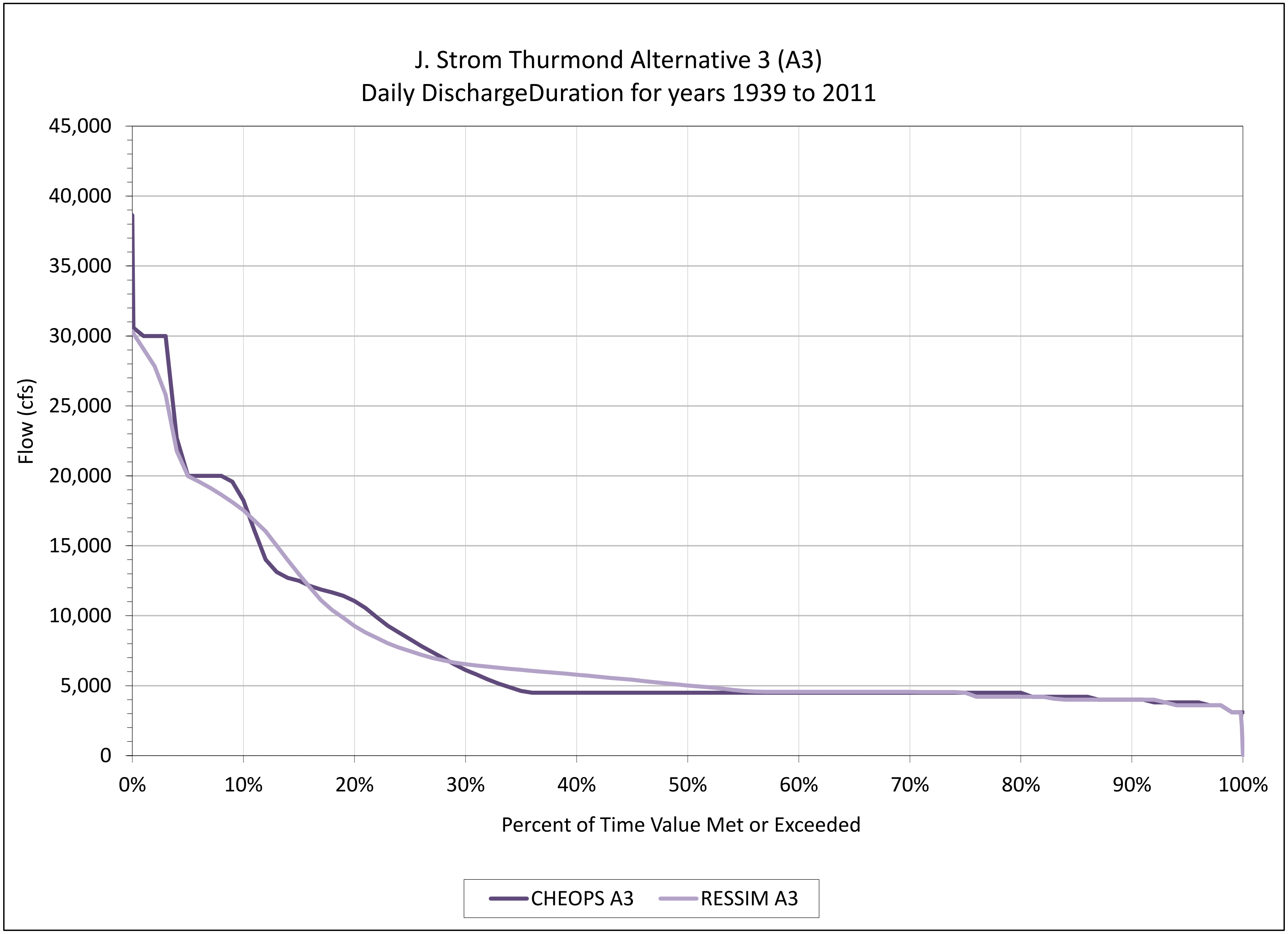
It should also be noted that the ResSim model handles the pumping within Richard B. Russell (RBR) differently than the CHEOPS model. ResSim tends to fluctuate the elevation to which it fills the reservoir on a daily basis much more than the CHEOPS model. This is shown in Figures J-9 and J-10. However over time the gross generation and, therefore, the unit operations compare favorably (within approximately 3 percent) between the two models, as shown in Table J-1.

Figure J-1



J. Strom Thurmond Alternative (A2)
Daily DischargeDuration for years 1939 to 2011
Flow (cfs)
45,000
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percent of Time Value Met or Exceeded
CHEOPS A2
RESSIM A2

Figure J-2


J. Strom Thurmond Alternative 3 (A3)
Daily DischargeDuration for years 1939 to 2011
Flow (cfs)
45,000
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percent of Time Value Met or Exceeded
CHEOPS A3
RESSIM A3

The following figures display a comparison of end of day reservoir elevations for the A2 and A3 from CHEOPS and ResSim with the historical hydrology and projected withdrawals.

Figure J-3

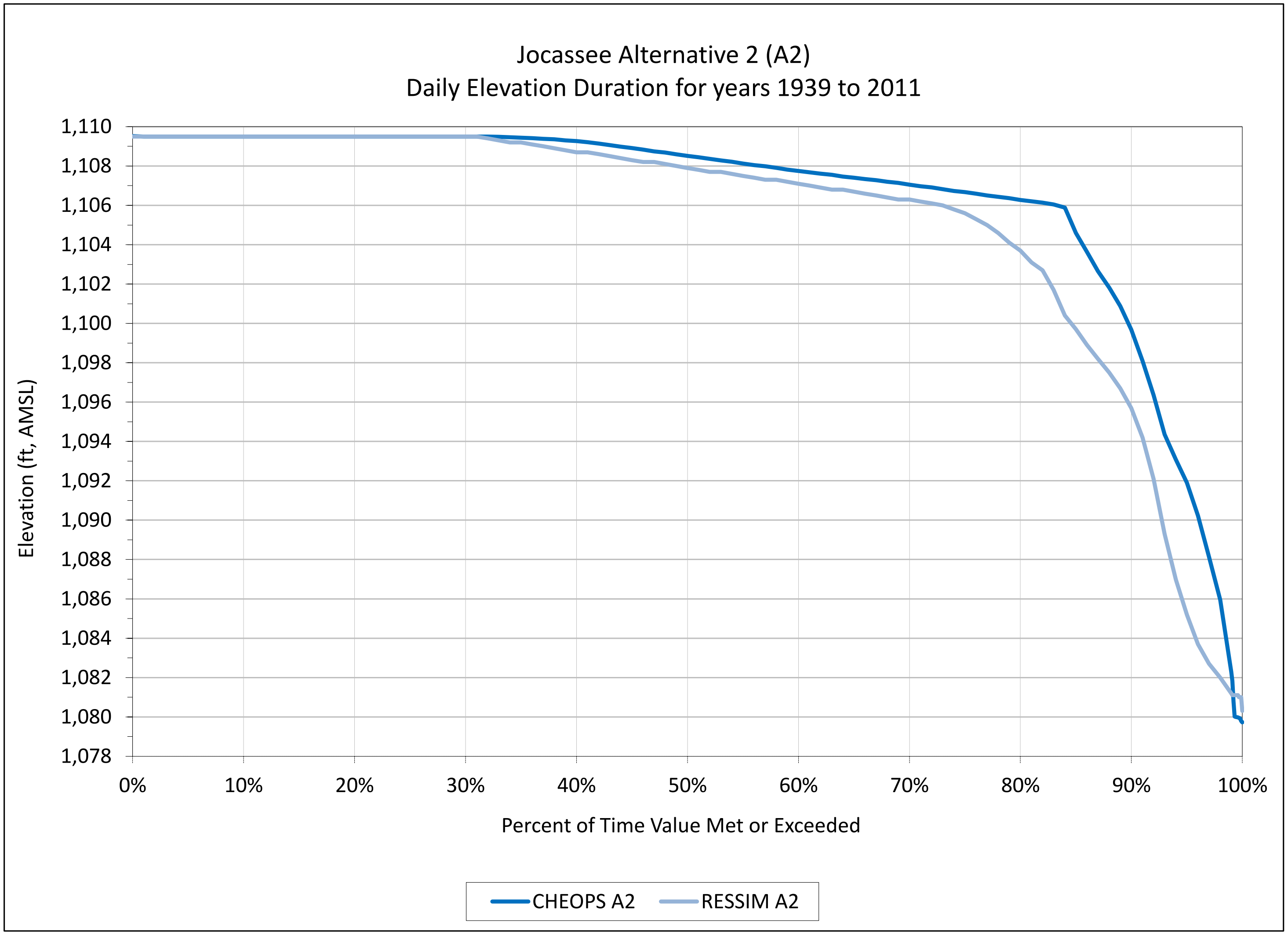


Figure J-4

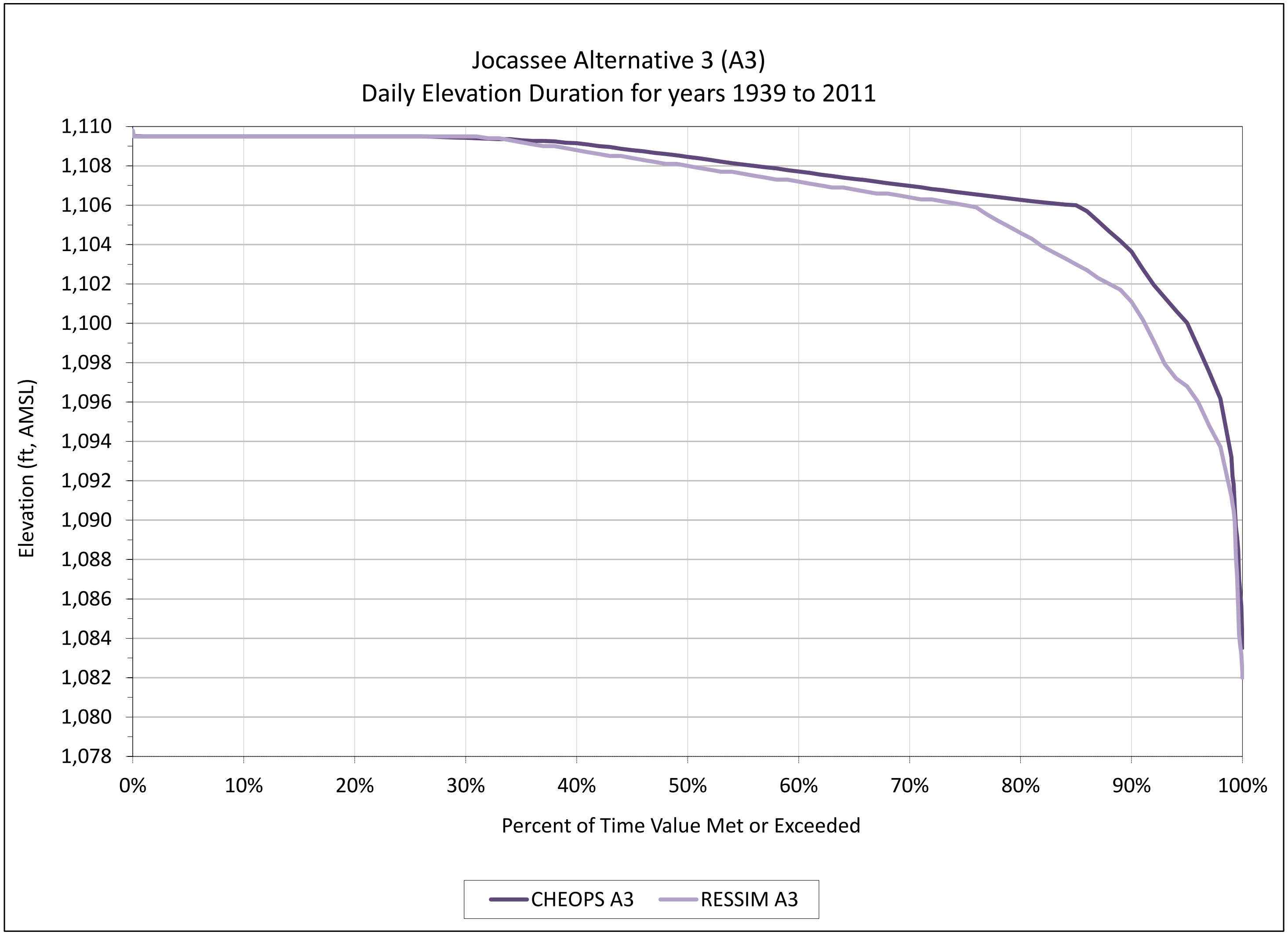
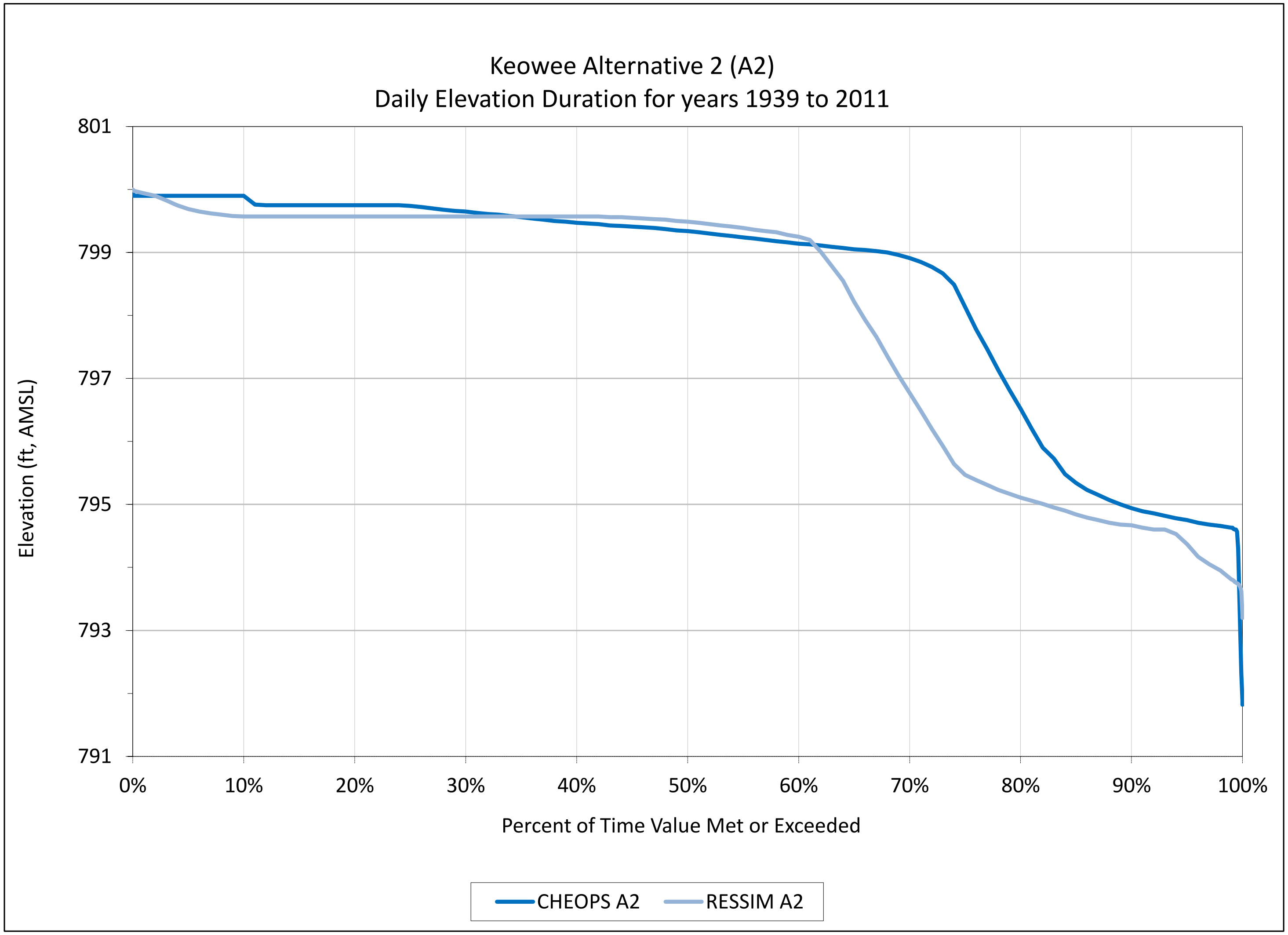

Jocassee Alternative 3 (A3)
Daily Elevation Duration for years 1939 to 2011
Elevation (ft, AMSL)
1,110
1,108
1,106
1,104
1,102
1,100
1,098
1,096
1,094
1,092
1,090
1,088
1,086
1,084
1,082
1,080
1,078
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percent of Time Value Met or Exceeded
CHEOPS A3
RESSIM A3

Figure J-5



Keowee Alternative 2 (A2)
Daily Elevation Duration for years 1939 to 2011
801
799
797
795
793
791
Elevation (ft, AMSL)
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percent of Time Value Met or Exceeded
CHEOPS A2
RESSIM A2

Figure J-6

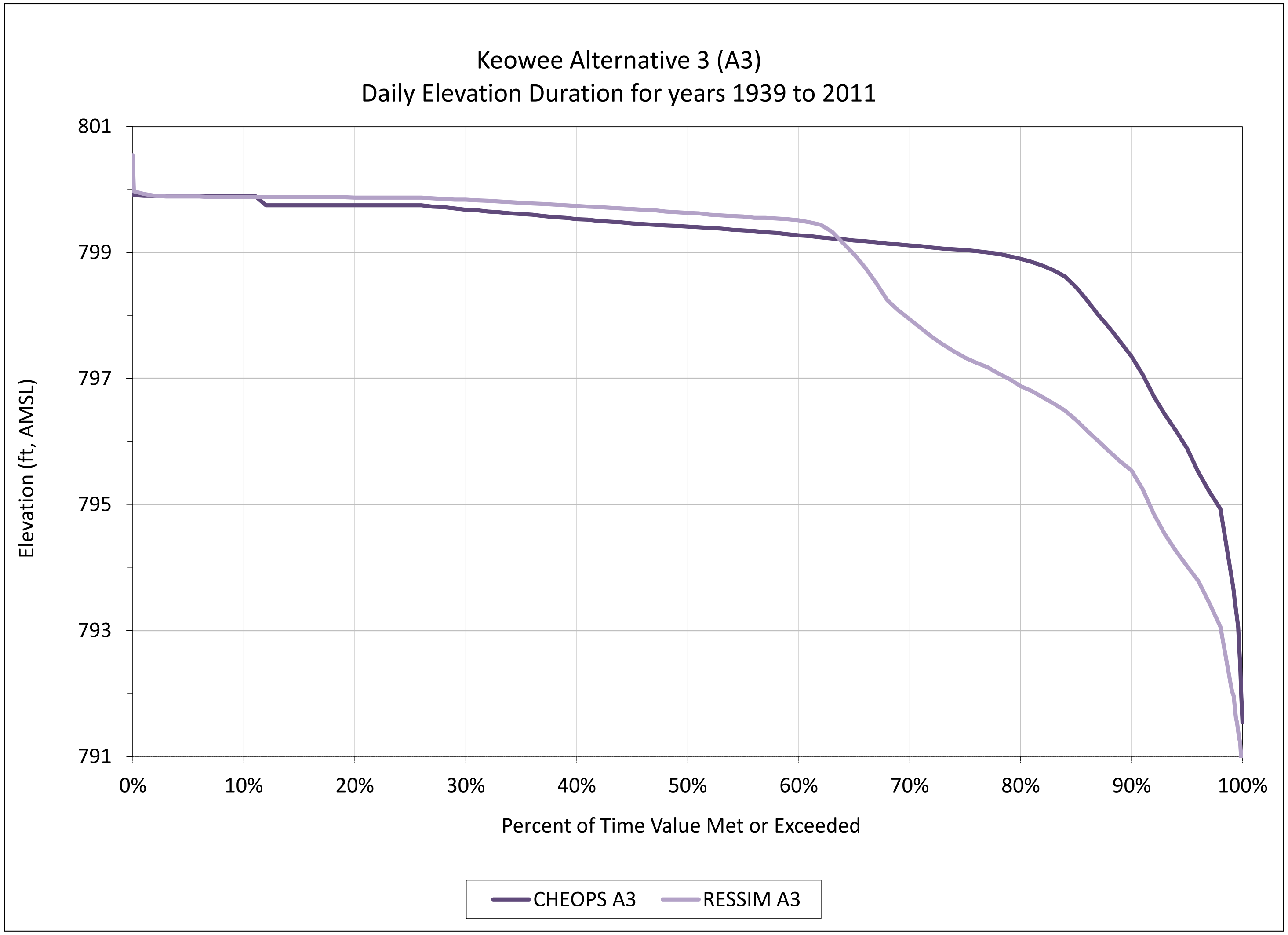

Keowee Alternative 3 (A3)
Daily Elevation Duration for years 1939 to 2011
801
799
797
795
793
791
Elevation (ft, AMSL)
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percent of Time Value Met or Exceeded
CHEOPS A3
RESSIM A3

Figure J-7

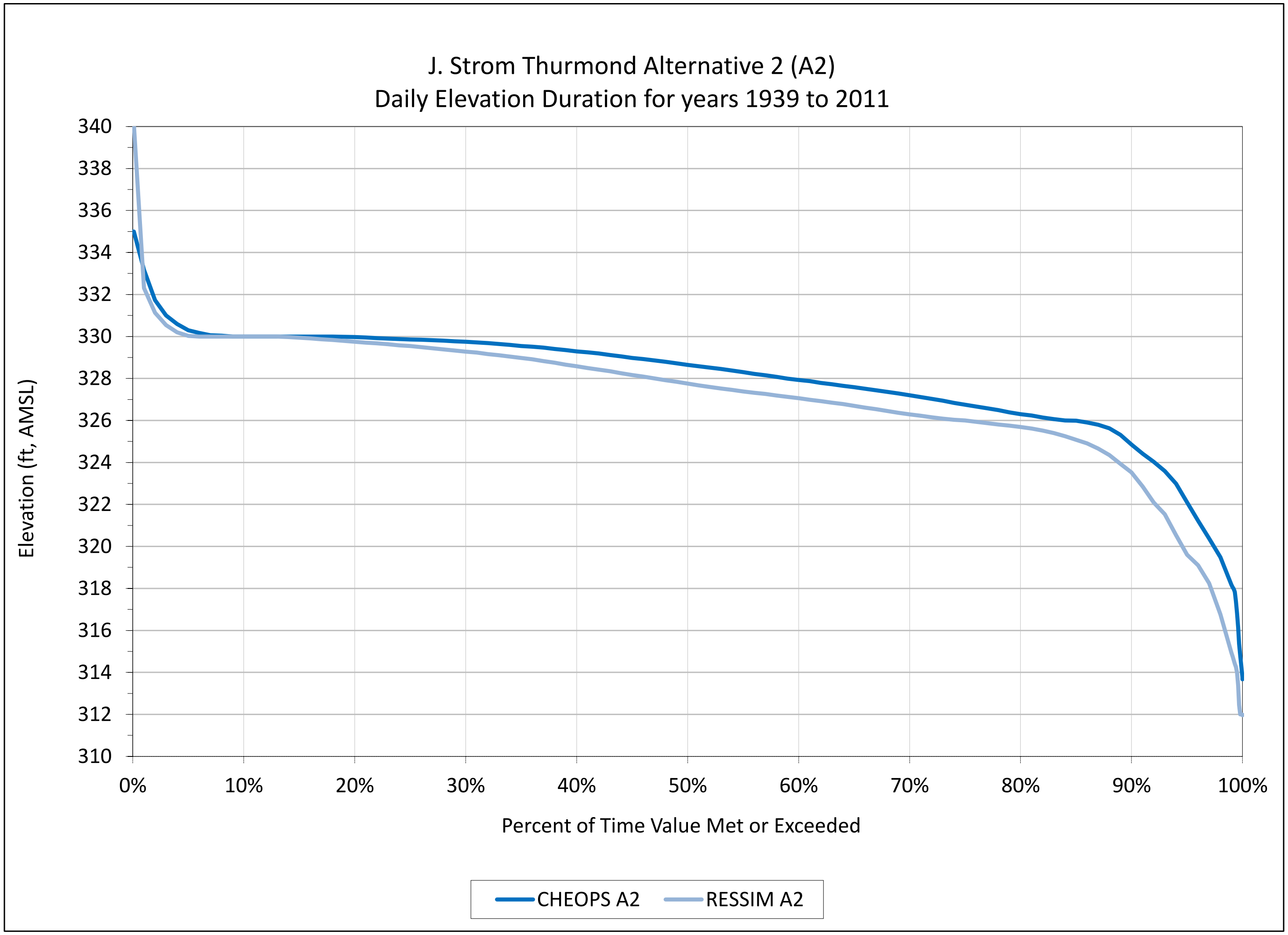

J. Strom Thurmond Alternative 2 (A2)
Daily Elevation Duration for years 1939 to 2011
Elevation (ft, AMSL)
340
338
336
334
332
330
328
326
324
322
320
318
316
314
312
310
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percent of Time Value Met or Exceeded
CHEOPS A2
RESSIM A2

Figure J-8

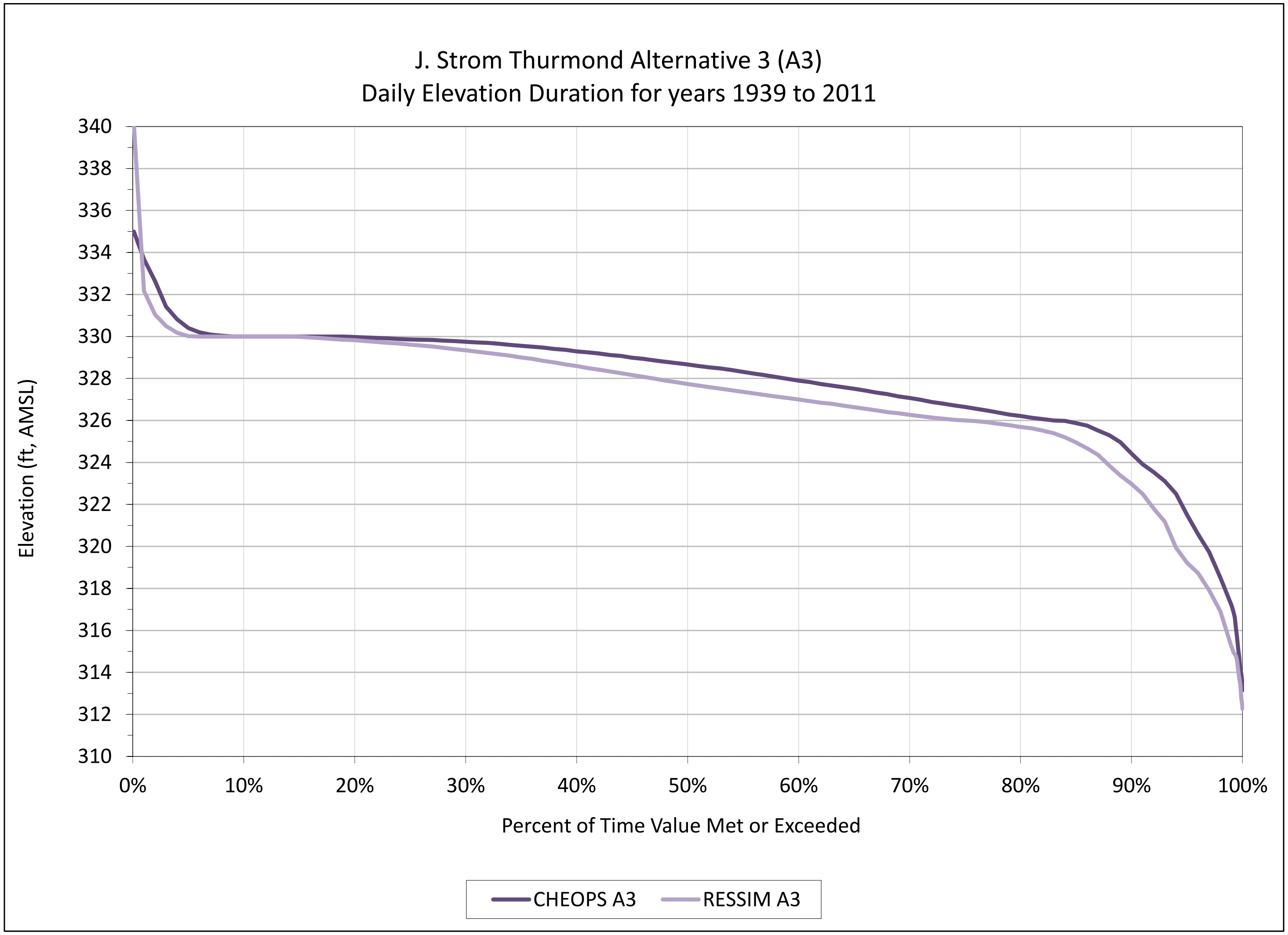

J. Strom Thurmond Alternative 3 (A3)
Daily Elevation Duration for years 1939 to 2011
340
338
336
334
332
330
328
326
324
322
320
318
316
314
312
310
Elevation (ft, AMSL)
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percent of Time Value Met or Exceeded
CHEOPS A3
RESSIM A3

Figure J-9

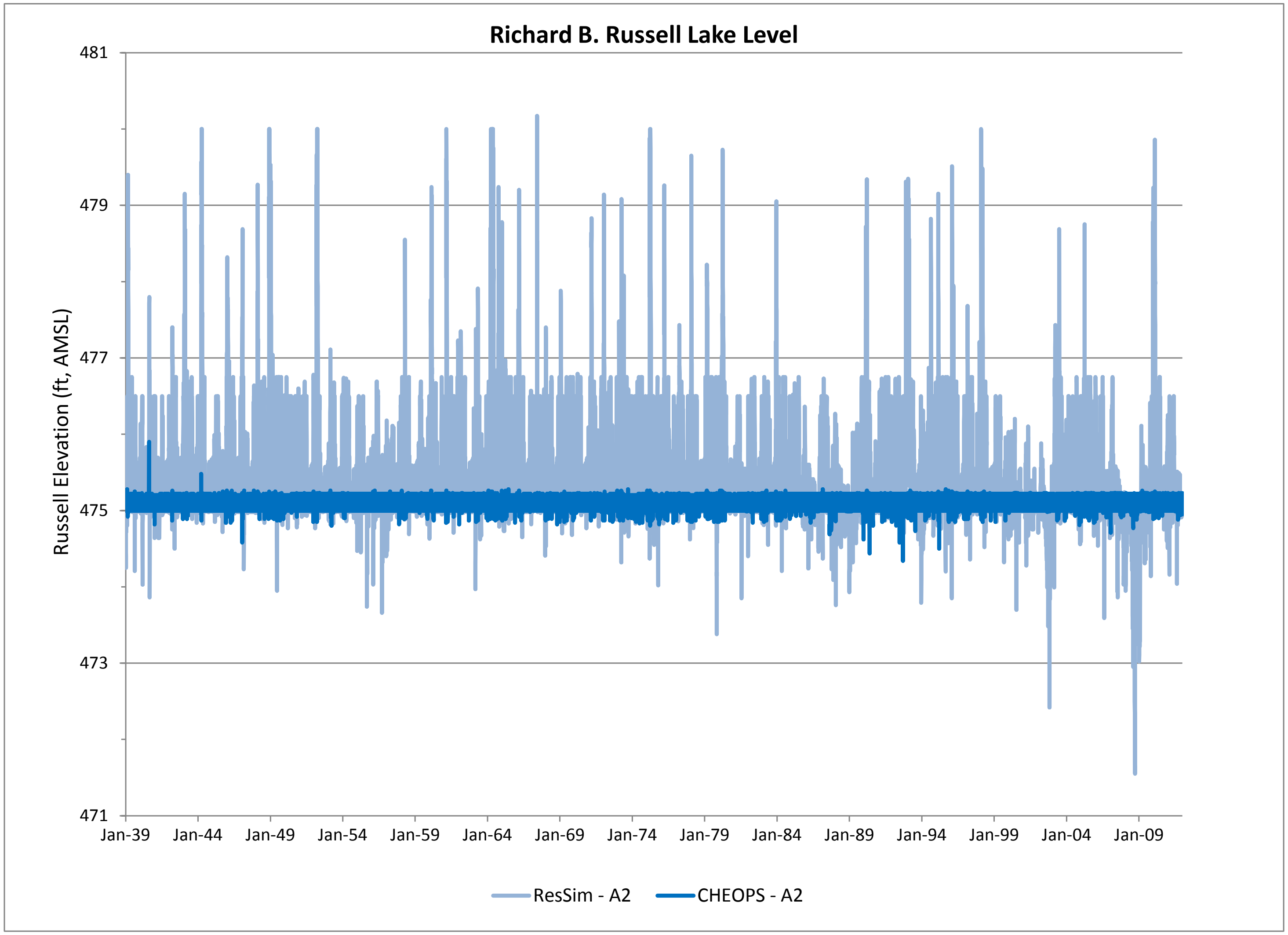
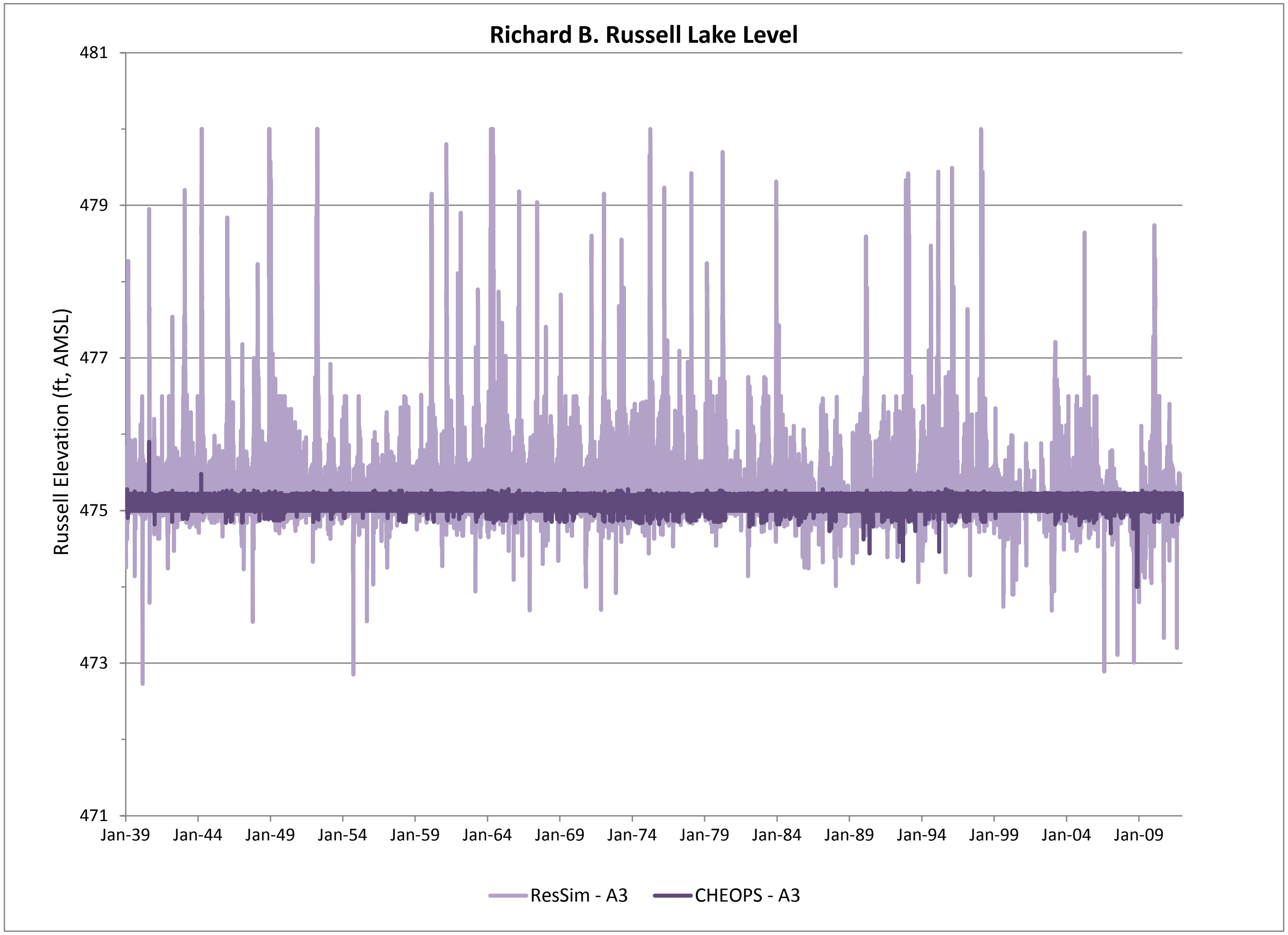
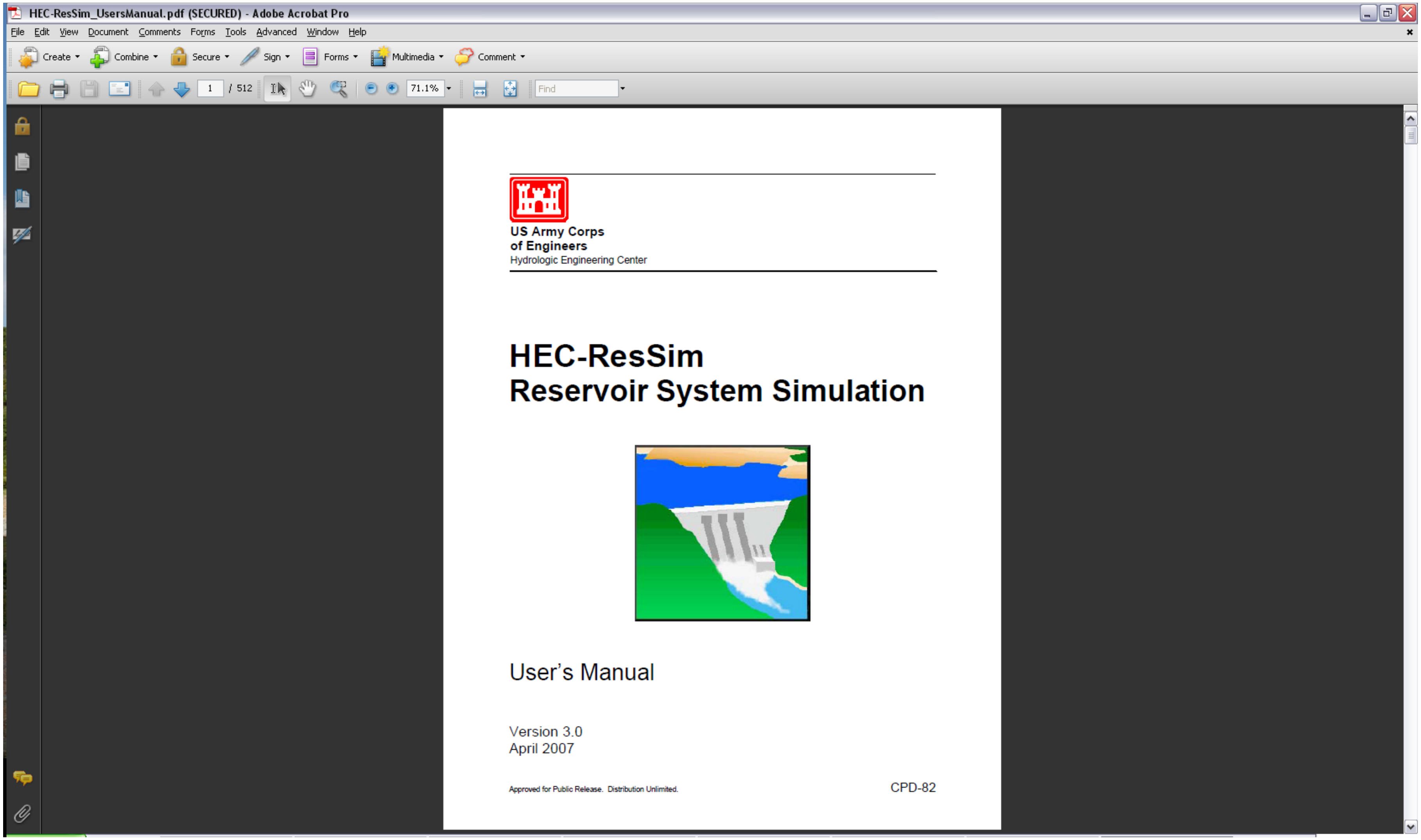

Richard B. Russell Lake Level
Russell Elevation (ft, AMSL)
481
479
477
475
473
471
Jan-39
Jan-44
Jan-49
Jan-54
Jan-59
Jan-64
Jan-69
Jan-74
Jan-79
Jan-84
Jan-89
Jan-94
Jan-99
Jan-04
Jan-09
ResSim - A2
CHEOPS - A2

Figure J-10


Richard B. Russell Lake Level
481
479
477
475
473
471
Russell Elevation (ft, AMSL)
Jan-39
Jan-44
Jan-49
Jan-54
Jan-59
Jan-64
Jan-69
Jan-74
Jan-79
Jan-84
Jan-89
Jan-94
Jan-99
Jan-04
Jan-09
ResSim - A3
CHEOPS - A3

For Reference



US Army Corps
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HEC-ResSim
Reservoir System Simulation

User's Manual

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