Addendum for the Soil and Water Assessment Tool (SWAT) Watershed Models: Model Extensions Through Calendar Year 2018

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Background

The Highland Lakes, six reservoirs along the Colorado River (Texas) (Figure 1), supply water for over 1 million people, help manage floods, generate hydroelectric power, and provide recreational opportunities (Lower Colorado River Authority, 2021a). Established with the construction of six different dams between 1938 and 1951, the Highland Lakes have a total surface area of over 20,600 hectares (80 sq. miles) and a storage capacity of over two million acre-feet when at capacity (Lower Colorado River Authority, 2021a). Given the importance of the Highland Lakes for central Texas and the Austin, Texas metropolitan area, the Lower Colorado River Authority (LCRA) places a high value on collecting extensive datasets to better understand water quality and creating management tools to preserve the high-quality water resources of the Highland Lakes.

As part of the effort to preserve the water resources of the Highland Lakes, multiple water-quality models also have been created to characterize and simulate water quality of the reservoirs and the watersheds surrounding the Highland Lakes. These models include a series of independent Soil and Water Assessment Tool (SWAT) and CE-QUAL-W2 models that characterize the watersheds and reservoirs, respectively, of the following five Highland Lakes: Lake Buchanan, Inks Lake, Lake Lyndon B. Johnson (LBJ), Lake Marble Falls, and Lake Travis (Lower Colorado River Authority, 2021b). The SWAT watershed model is capable of simulating the constituent loads arising from the watershed and accounting for the various land uses and associated activities (Neitsch and others, 2005; Neitsch and others, 2011), whereas CE-QUAL-W2 is a two-dimensional, laterally averaged hydrodynamic and water-quality model originally developed by the U.S. Army Corps of Engineers and currently supported by Portland State University (Cole and Wells, 2008; Wells, 2021). Collectively, these models are part of the Colorado River Environmental Models (CREMs) project to predict the consequences of various management decisions on water resources, habitat conservation, ecological health and associated actions on water quality. These models leverage historical data and current monitoring efforts to inform predictions and assess the impacts of different management scenarios.

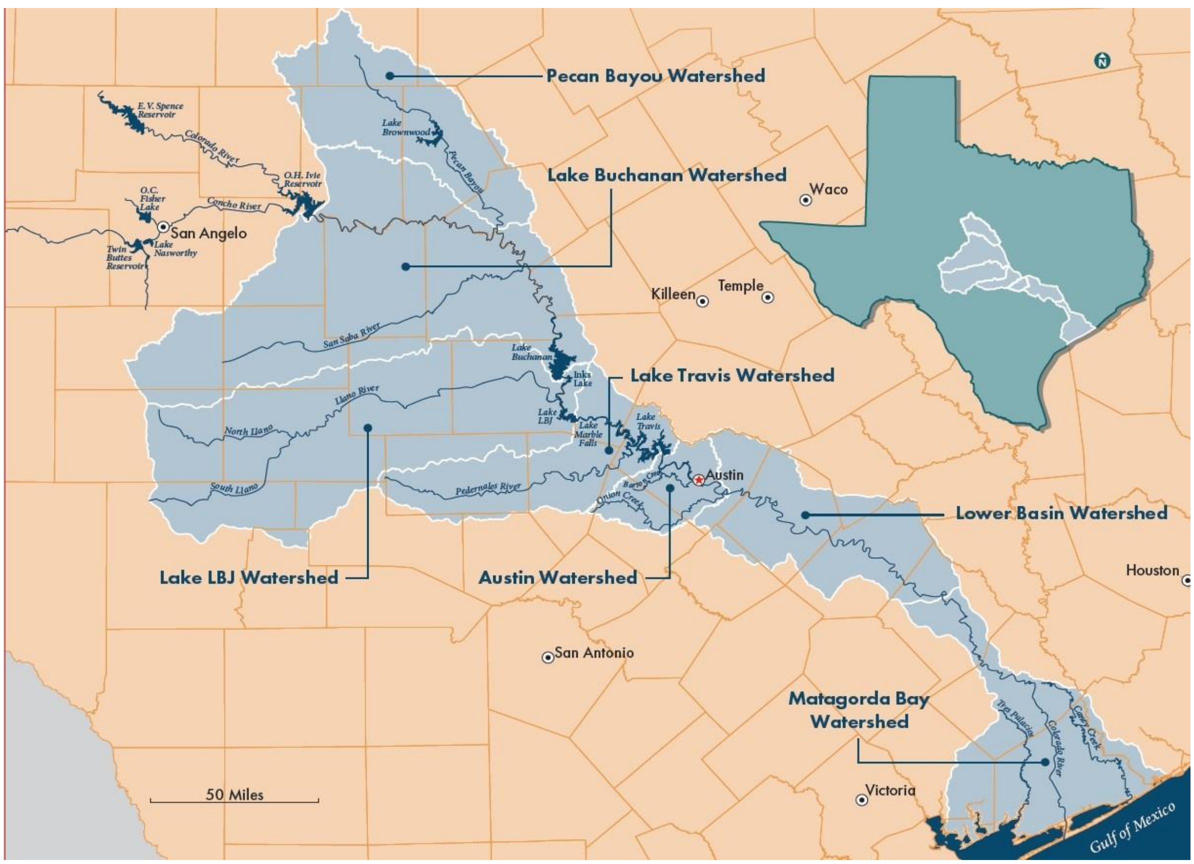

Figure 1: Lower Colorado River and associated watersheds, including the Highland Lakes (Lake Buchanan, Inks Lake, Lake LBJ, Lake Marble Falls, Lake Travis, and Lake Austin).

As part of the effort to continuously improve the water-quality models that make up CREMs, LCRA partnered with the U.S. Geological Survey (USGS) to merge the five existing CE-QUAL-W2 models into a single, merged framework, in addition to extending the time frame for all five models through 2018. This time frame captures the recent introduction of zebra mussels (2017) and the high rainfall events that led to extremely high turbidity levels (2018). As part of the effort, LCRA updated the SWAT models through 2018 in order to provide new inputs into the CE-QUAL-W2 models.

Objectives

The primary goal of this addendum report documents the extension of the Highland Lakes (Buchanan, Inks, LBJ, Marble Falls, and Travis) watershed water quality models, in particular the SWAT watershed models. A separate USGS model release includes the updated CE-QUAL-W2 models (Smith and Yesildirek, 2025). The SWAT models were originally developed as part of the phased development of CREMs project, with the length of the model time frames differing for the individual models depending on the different phases (Table 1).

Reservoir	Model Time Frame	Model Reference and Completion Date
Buchanan	1984-2011	Anchor QEA and Parsons Water (March 2013)
Inks	1984-2008	Parsons and Anchor QEA (March 2011)
LBJ	1984-2008	Parsons and Anchor QEA (March 2011)
Marble Falls	1984-2008	Parsons and Anchor QEA (March 2011)
Travis	1984-2012	Anchor QEA and Parsons Water (May 2009); Anchor QEA (February 2013)

Table 1: Available Highland Lakes CE-QUAL-W2 models, with the existing model time frame and final LCRA partner reports published and shared with LCRA (month and date in parentheses).

The extension of the SWAT watershed water quality models was completed to provide input data to the existing CE-QUAL-W2 models to:

1. Merge the five existing CE-QUAL-W2 models (Buchanan, Inks, LBJ, Marble Falls, Travis) into a single framework using CE-QUAL-W2 (version 4.5);
2. Lengthen the model time frame through calendar year 2018.

No new calibration efforts were completed as part of this effort, as the main driver of this work was to connect the models and extend the model time frame.

Model Extension – Additions to Forcing Functions

The SWAT models for the Highland Lakes (Buchanan, Inks, LBJ, Marble Falls, and Travis) were originally developed to simulate time spans as shown in Table 1. For example, Lake Buchanan was originally developed to simulate 1984 through 2011. Each of the five Highland Lakes in Table 1 are documented in the model references (Anchor QEA and Parsons Water, 2013; Parsons and Anchor QEA, 2011; Anchor QEA and Parsons Water, 2009; Anchor QEA, 2013). With the SWAT model extensions in this addendum report, the models were all extended through Dec. 31, 2018. In order to include the additional years for simulation, only the model climate forcing functions (precipitation, temperature) were changed, with the exception of Lake Travis that also had additional external loads [i.e., point sources] for the extensions. All other inputs remained unchanged from the original SWAT models. Furthermore, no model parameters were change from the final parameter sets established during the original calibrations.

Lake Buchanan

Climatic inputs used in SWAT include measured and generated records of precipitation, maximum and minimum temperature, solar radiation, relative humidity, and wind speed. Precipitation, relative humidity, and temperature data were available for the watershed model from proximal weather stations from LCRA’s Hydromet network and the National Weather Service (NWS) cooperative observer network (Table 2). Precipitation data from up to 32 meteorological stations (17 NWS cooperative stations and 15 LCRA Hydromet stations) were added as input to the Lake Buchanan SWAT model for the model extension. Temperature data were derived from up to nine NWS stations. For days or periods when precipitation or temperature data were not available at a meteorological station, observations from a nearby meteorological station were substituted. Relative humidity data were available for up to 10 LCRA Hydromet stations. The time-series of precipitation, relative humidity, and temperature data were imported into the SWAT model along with the station coordinates, and SWAT subsequently spatially distributed them to model sub-basins throughout the modeled watershed (Neitsch and others, 2005). Solar radiation and wind speed records were created using the SWAT U.S. database weather generator as needed (Neitsch and others, 2011).

Station ID	Station Name	Source	Data Types
411017	Brady	NWS	P, T
411138	Brownwood	NWS	P, T
1993	Buchanan Dam 2 miles west-northwest	LCRA	P, RH
411250	Burnet	NWS	T
1984	Burnet 5 miles north-northwest	LCRA	P
1927	Cherokee 4 miles east	LCRA	P, RH
1929	Cherokee Creek at Bend	LCRA	RH
411875	Coleman	NWS	P, T
411934	Concho Peak/Ivie Reservoir	NWS	P
412809	Eldorado	NWS	P
413257	Fort McKavett	NWS	P
413614	Goldthwaite 1 mile west-southwest	NWS	P, T
1964	Lampasas 10 miles west-southwest	LCRA	P
1940	Lampasas 13 miles west-northwest	LCRA	P
415272	Llano	NWS	P, T
415650	Mason	NWS	P, T
1540	Mason 13 miles west-northwest	LCRA	P
1578	Mason 15 miles north-northeast	LCRA	P, RH
415822	Menard	NWS	P, T
2348	Menard 12 miles south-southeast	LCRA	P
416140	Mullin	NWS	P
416747	Paint Rock	NWS	T
1390	Pecan Bayou near Mullin	LCRA	RH
417480	Red Bluff Crossing	NWS	P
417593	Richland Springs	NWS	P
417992	San Saba	NWS	P
1936	San Saba 15 miles east-southeast	LCRA	P, RH
1707	San Saba 15 miles southwest	LCRA	P
1777	San Saba 6 miles south	LCRA	P
417994	San Saba 7 miles northwest	NWS	P
1742	San Saba 8 miles west	LCRA	P
1563	San Saba River near Brady	LCRA	RH
1499	San Saba River near Menard	LCRA	RH
1769	San Saba River near San Saba	LCRA	RH
418863	Taylor Ranch	NWS	P
1983	Tow 10 miles east-southeast	LCRA	P
1966	Tow 10 miles north-northwest	LCRA	P
419099	Tow 3 miles southeast	NWS	P
1199	Winchell	LCRA	P, RH

Table 2: Meteorological stations used for the Lake Buchanan SWAT model extension. [LCRA: Lower Colorado River Authority; NWS: National Weather Service; P: precipitation; RH: relative humidity; T: temperature]

Inks Lake

Climatic inputs used in the Inks Lake SWAT model include measured and generated records of precipitation, maximum and minimum temperature, solar radiation, relative humidity, and wind speed. Precipitation from two weather stations were available for the watershed model from Texas A&M (TAMU) AgriLIFE Research Center and the National Climatic Data Center (NCDC) (Table 3). Temperature data was available from the same TAMU station as the precipitation data (Table 3). The time-series of precipitation and temperature data were imported into the SWAT model along with the station coordinates, and SWAT subsequently spatially distributed them to model sub-basins throughout the modeled watershed (Neitsch and others, 2005). Solar radiation, relative humidity and wind speed records were created using the SWAT U.S. database weather generator as needed (Neitsch and others, 2011).

Station ID	Station Name	Source	Data Types
419099	Tow	NCDC	P
411250	Burnet	TAMU	P, T

Table 3: Meteorological stations used for the Inks Lake SWAT model extension. [NCDC: National Climatic Data Center; TAMU: Texas A&M (TAMU) AgriLIFE Research Center; P: precipitation; T: temperature]

Lake LBJ

Climatic inputs used in the Lake LBJ SWAT model include measured and generated records of precipitation, maximum and minimum temperature, solar radiation, relative humidity, and wind speed. Precipitation and temperature data were available from either TAMU or NCDC stations (Table 4). Precipitation data from up to 22 meteorological stations (nine NCDC stations and 13 TAMU stations) were added as input to the Lake LBJ SWAT model for the model extension. Temperature data were derived from up to 10 meteorological stations (three NCDC stations and seven TAMU stations). For days or periods when precipitation or temperature data were not available at a meteorological station, observations from a nearby meteorological station were substituted. The time-series of precipitation and temperature data were imported into the SWAT model along with the station coordinates, and SWAT subsequently spatially distributed them to model sub-basins throughout the modeled watershed (Neitsch and others, 2005). Solar radiation and wind speed records were created using the SWAT U.S. database weather generator as needed (Neitsch and others, 2011).

Station ID	Station Name	Source	Data Types
413954 06	Harper 1W	NCDC	P
417787	Round MTN 4WNW	NCDC	P
418531	Spicewood	NCDC	P
418863 06	Taylor Ranch	NCDC	P
418877 06	Teague Ranch	NCDC	P
419099	Tow	NCDC	P
414670 06	Junction 4SSW	NCDC	P, T
417232 05	Prade Ranch	NCDC	P, T
417706 06	Rocksprings	NCDC	P, T
410738	Bertram 3 ENE	TAMU	P
412040 06	Cottonwood	TAMU	P
413605 05	Gold	TAMU	P
414363 06	Humble Pump	TAMU	P
414402	Hye	TAMU	P
418897 05	Telegraph	TAMU	P
411250	Burnet	TAMU	P, T
413329 07	Fredericksburg	TAMU	P, T
414605	Johnson City	TAMU	P, T
415272	Llano	TAMU	P, T
415650 06	Mason	TAMU	P, T
415822 06	Menard	TAMU	P, T
418449 05	Sonora	TAMU	P, T

Table 4: Meteorological stations used for the Lake LBJ SWAT model extension. [NCDC: National Climatic Data Center; TAMU: Texas A&M (TAMU) AgriLIFE Research Center; P: precipitation; T: temperature]

Lake Marble Falls

Climatic inputs used in the Lake Marble Falls SWAT model include measured and generated records of precipitation, maximum and minimum temperature, solar radiation, relative humidity, and wind speed. Precipitation and temperature data were available from either TAMU or NCDC stations (Table 5). Precipitation data from up to three meteorological stations (two NCDC stations and one TAMU station) were added as input to the Lake Marble Falls SWAT model for the model extension. Temperature data were derived from up to two TAMU meteorological stations. The time-series of precipitation and temperature data were imported into the SWAT model along with the station coordinates, and SWAT subsequently spatially distributed them to model sub-basins throughout the modeled watershed (Neitsch and others, 2005). Solar radiation and wind speed records were created using the SWAT U.S. database weather generator as needed (Neitsch and others, 2011).

Station ID	Station Name	Source	Data Types
414605	Johnson City	TAMU	T
417787	Round MTN 4WNW	NCDC	P
418531	Spicewood	NCDC	P
411250	Burnet	TAMU	P, T

Table 5: Meteorological stations used for the Lake Marble Falls SWAT model extension. [NCDC: National Climatic Data Center; TAMU: Texas A&M (TAMU) AgriLIFE Research Center; P: precipitation; T: temperature]

Lake Travis

Climatic inputs used in the Lake Travis SWAT model include measured and generated records of precipitation, maximum and minimum temperature, solar radiation, relative humidity, and wind speed. Precipitation and temperature data were available from either TAMU or NCDC stations (Table 4). Precipitation data from up to 12 meteorological stations (seven NCDC stations and five TAMU stations) were added as input to the Lake Travis SWAT model for the model extension. Temperature data were derived from up to four TAMU meteorological stations. For days or periods when precipitation or temperature data were not available at a meteorological station, observations from a nearby meteorological station were substituted. The time-series of precipitation and temperature data were imported into the SWAT model along with the station coordinates, and SWAT subsequently spatially distributed them to model sub-basins throughout the modeled watershed (Neitsch and others, 2005). Solar radiation and wind speed records were created using the SWAT U.S. database weather generator as needed (Neitsch and others, 2011).

Station ID	Station Name	Source	Data Types
410832	Blanco	NCDC	P
412040 06	Cottonwood	TAMU	P
413329 07	Fredericksburg	TAMU	P, T
413605 05	Gold	TAMU	P, T
413954 06	Harper 1W	NCDC	P
418877 06	Teague Ranch	NCDC	P
414605	Johnson City	TAMU	P, T
417787	Round MTN 4WNW	NCDC	P
411250	Burnet	TAMU	P, T
418531	Spicewood	NCDC	P
410246	Andice 2 SW	NCDC	P
410428	Austin Mueller Municipal Airport	NCDC	P

Table 6: Meteorological stations used for the Lake Travis SWAT model extension. [NCDC: National Climatic Data Center; TAMU: Texas A&M (TAMU) AgriLIFE Research Center; P: precipitation; T: temperature]

In addition to meteorological data, the other time series input required by the Lake Travis SWAT model is point source data. Point source inputs were developed for the model extension from Texas Commission on Environmental Quality (TCEQ) Discharge Monitoring Report (DMR) records for three TCEQ permitted dischargers within the Lake Travis watershed (Table 7). No changes were applied to the point source concentrations or flows for the model extension process; constant concentrations and flows were either computed from the DMR data or assumed. These constant concentrations and flows were applied to the extension period in the same way as during the original calibration and validation periods (Anchor QEA and Parsons, 2009; Anchor QEA, 2013).

Permit Number	Permittee	County
10171-001	City of Fredicksburg	Gillespie
10198-001	City of Johnson City	Blanco
11531-001	Travis Vista	Travis

Table 7: Texas Commission on Environmental Quality (TCEQ)-permitted dischargers within the Lake Travis watershed, applied to the Lake Travis SWAT model as point source inputs.

Summary

The Highland Lakes SWAT watershed models have been extended through Dec. 31, 2018. These models were developed during a series of four phases of the CREMs project to assist LCRA to support policy decisions that proactively and effectively protect the integrity of water resources in the lower Colorado River basin (Anchor QEA and Parsons Water, 2013; Parsons and Anchor QEA, 2011; Anchor QEA and Parsons Water, 2009; Anchor QEA, 2013). The SWAT model extensions were completed to support the model extensions of the CREMs project CE-QUAL-W2 models; the CE-QUAL-W2 model extensions were documented as part of a joint USGS and LCRA project (Smith and Yesildirek, 2025). The extension process for these SWAT models included extending several forcing input files over time; however, no further calibration or validation was completed as part of this effort. Notably, no model calibration parameters were changed in any of the SWAT model extensions.

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