A nested-scale experimental watershed study design approach was used in an urban watershed of the central U.S. to investigate stream water temperature ($T_w$) variability during water year’s 2011, 2012, and 2013. Drought conditions were observed during water year 2012 when total annual precipitation was approximately 340 mm less than the 30 year record. Sudden increases of $>1$ °C within a 15 minute time interval in $T_w$ ($T_w$ surges) following summer thunderstorms were observed at urban sites. Differences in mean $T_w$ between gauging sites were significantly ($p=0.02$) correlated to urban land use and downstream distance as discharge increased. Linear and nonlinear regression analyses were performed between $T_w$ and air temperature ($T_a$) data at time scales ranging from 15 minute to seasonal time steps. Additionally, the linear $T_w$ model used in the Soil and Water Assessment Tool (SWAT), and a new processed based $T_w$ model that accounts for hydrology were evaluated. Significant ($p>0.05$) differences in model efficiency were not found between the linear $T_w$ model used in SWAT and the new process based $T_w$ model. Results from this study will provide land managers with quantitative information and $T_w$ models needed to make informed management decisions and improve water quality in urban watersheds.