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Arnold Schwarzenegger
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MEMORANDUM

Date: 19 November 2010

To: File: Laguna de Santa Rosa; TMDL Development and Planning

From: Steve Butkus

Subject: Nutrient Loading Estimates for Laguna TMDL Source Analysis

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Current and pre-European settlement nutrient load estimates were developed as box plots and as load duration curves. The box plots showing the distribution of current nutrient loads are shown in Figures 3-65. Current load duration curves by land uses are shown in Figures 66-121. Current and pre-settlement load duration curves by catchment area are shown in Figures 123-185.

The conceptual model for the *Laguna TMDL Nutrient Source Analysis* was designed to compare current pollutant loads to pre-settlement historical loads. The Land Cover Loading Model (LCLM) framework was developed for this comparison. The LCLM is based on simple pollutant transport from different land covers. The LCLM allows estimates of pollutant loading from catchments based on land cover areas and representative loading rates (i.e., load per area of land).

Distribution of Current Nutrient Loads

The Regional Water Board staff estimated the distributional quality of current nutrient concentrations in runoff in the Laguna watershed in part by sampling runoff from selected land covers from 2009-2010.

Wet & Dry Period Sampling Protocols

Samples were collected during both wet and dry periods as identified by federal guidance (USEPA, 1992) and federal regulations (40 CFR 122.21(g)(7)(ii)). Statistical hypothesis test results showed significant differences between wet period and dry period concentrations and between the land covers assessed.

Dry periods were defined as days with less than 0.1 inches of precipitation within the preceding 72 hour period. Dry period loads were derived from the measured pollutant concentration data and estimate of the base flow at the sampling location. Sampling location base flows were estimated using flows collected at the USGS gaging location near the base of the Laguna watershed at Trenton-Healdsburg Road. Base flows at the gaging station were assumed to be represented by the mean 3-day antecedent flow. Flows at each sampling location were scaled proportionately based on the drainage areas of the site and the USGS gage.

Wet period samples were collected during storm events, which are defined as days with more than 0.1 inches of precipitation with no 72-hour antecedent precipitation preceding the event. Wet period loads were derived from measured pollutant concentration data and estimated sampling location flows. Sampling location flows were estimated as the combined base flow plus the storm event runoff flow. Base flow was estimated using the same approach described above for dry periods. Storm event runoff flow was estimated by applying the Rational Method with precipitation data (Burien et al., 1999). Land use specific runoff coefficients were selected from McCuen (1998). Storm intensity was derived from daily precipitation measurements collected since 1931 at a weather station near the center of the watershed (National Climatic Data Center Cooperative Weather Station 47965). Seven years of precipitation data were excluded due to greater than 10 percent of missing daily values resulting in a 72-year period of record. The 24-hr storm duration was assumed to be much greater than the time of concentration when applied to the small catchments sampled as required for application of the Rational Method.

Wet & Dry Period Sampling Bias

The monitoring design for the land cover loading assessment stratified sampling between wet and dry periods. The logistics of planning to collect samples based on weather forecasts can create sampling bias in the loading results distribution. Many of the days that are near the threshold between wet and dry periods do not tend to become selected for sampling. There is a tendency to select sampling days with larger storms to ensure that runoff flow is available to collect. Using only the runoff flows from those sampling dates to estimate load introduces the wet weather bias due to the larger estimated flows (Figure 1). A similar bias is also observed for dry weather period samples (Figure 2).

Monte-Carlo simulation was used to address the potential bias from using only flows observed during sampling events. Monte Carlo simulation is a stochastic method that accounts for the inherent variability of data sets. The probability distributions from the flow, precipitation, and concentration records were applied to the loading models repeatedly until descriptive statistics converged in the resulting loading distribution.

Results

The distributions of the nutrient unit area loads by land cover are shown as box plots in Figures 3 – 51. Box plots comparing the distributions between land cover pollutant unit area loads are presented in Figures 52 – 65. Box plots provide a concise graphical display summarizing the distribution of a data set (Helsel and Hirsch, 2002). The top and bottom of the box represent the lower and upper quartiles with the band near the middle of the box showing the median. The error bars (i.e., whiskers) represent the 10th and 90th percentiles. The mean is shown with a 'X' on the box plot. Some of the box ploys are scaled to no show the 90th percentile whiskers and means so that the main interquartile ranges can be more easily viewed.

Loads from all land covers show non-normal, left-skewed distributions. Mean loads are often higher than the 75th percentile. Higher unit areas loads are observed for all wet period loads as compared to dry period loads. In general, higher dry period nutrient loads were observed from agricultural areas, However, wet period nutrient loads from agricultural areas were lower than other land covers, including rangeland and sewered residential.

Nutrient Load Duration Curves By Land Cover

Load duration curves are a useful tool identifying pollutant loading over the entire flow regime of a river (USEPA, 2007). A load duration curve provides a visual display of the relationship between flow and pollutants. The load duration curve presents the frequency and magnitude of pollutant measurements along during different annual climatic years.

Load duration curves were derived from the distributional metrics of the 2009 -2010 measurements for forest, rangeland, crop and pasture, orchards and vineyards, nonsewered residential, sewered residential, and commercial land covers (Figures 66-114). Load duration curves are presented for each land cover to represent estimated changes in annual loads due to climatic conditions. The hydrologic year was defined as April 1 through March 31 of the following year (Haith et al., 1992). The return period was based on the frequency of annual wet period days to dry period days from the 72-year precipitation record.

Load duration curves for the oak savanna land cover are displayed in Figures 114-121. The oak savanna land cover was not sampled by Regional Water Board staff in 2009. Instead, loading rates measured in a nearby watershed with similar characteristics were used to develop the oak savanna land cover load duration curves. Mean flow-weighted pollutant concentrations were measured from the runoff from an un-grazed watershed near the town of Hopland in 1999-2000 (Dahlgren et al., 2001). This watershed is about 40 miles north of the Laguna watershed in the same Russian River Hydrologic Unit with a similar climate. Native vegetation in this watershed was mixed oak woodland and annual grasslands with a similar tree density as identified for the oak savanna land cover. Concentrations of total phosphorus (TP) and total nitrogen (TN) were not measured by Dahlgren et al. (2001) in the runoff. Therefore, the TP oak savanna loading rates were derived by applying the median TP to dissolved phosphorus ratio from forest and rangeland measurements collected by the Regional Water Board (NCRWQCB, 2010) to the dissolved phosphorus load reported by Dahlgren et al. (2001). The TN oak savanna loading rates were derived by the summation of the measured ammonia-N, measured nitrate+nitrite-N, plus an estimated of organic-N concentration from measurements collected by the Regional Water Board from forest and rangeland land covered areas. Dissolved organic carbon concentrations draining from Non-flooded oak savanna watershed was measured by Shilling and Jacobsen (2009) in Iowa. The concentrations values used to develop the oak savanna land cover load duration curves are shown in Table 1.

Table 1. Oak Savanna Land Cover Pollutant Runoff Concentrations

Pollutant	**Concentration (mg/L)**
Total Phosphorus	0.021
Dissolved Phosphorus	0.01
Total Nitrogen	0.10
Ammonia-N	0.08
Nitrate+Nitrite-N	0.01
Total Suspended Solids	64.8
Total Organic Carbon	7.1

Current and Pre-Settlement Load Duration Curves By Catchment Areas

Load duration curves representing the current and pre-settlement nutrient loads were developed for each of the historical open water catchments. Sub-basins in the Laguna watershed were combined into catchment areas that drained to the historical open water areas for comparison between current and pre-settlement loads (Table 2). Four catchment areas were delineated by combining the sub-basins derived from the National Elevation Dataset (NED, 2006) 10-meter resolution topography layer (Figure 122). These catchments represent the sub-basins that would have drained to the historical open water areas.

Table 2. Catchments for Historical Open Water Areas

Historical Catchment	**Major Tributaries**	**Acres**	**Percent of Watershed**
Cunningham Lake	Copeland Creek, Blucher Creek	49,817	29%
Sebring Lake	Santa Rosa Creek	68,402	39%
Ballard Lake	Mark West Creek	36,337	21%
Lower Laguna Catchment	Windsor Creek	18,973	11%

Riverine Wetland Load Assimilation

Riverine wetlands are known to reduce pollutants from surface water runoff and groundwater (Naiman and Decamps, 1997). For the pre-European settlement period, Regional Water Board staff estimated that riverine wetlands reduce total phosphorus and total nitrogen loads by 65% and 85%, respectively. This reduction was based on the following literature.

USEPA (2005) surveyed peer-reviewed scientific literature containing data on the effect of riparian wetland buffers on nitrogen concentration in streams and groundwater. Nitrogen removal effectiveness varied widely among the different riparian zones studied. Surface removal of nitrogen was partly related to buffer width, but was only one factor controlling nitrogen removal effectiveness. Subsurface removal of nitrogen was not related to buffer width. Subsurface removal of nitrogen in riparian buffers was often high, especially where anaerobic conditions promote microbial denitrification. Buffers of various vegetation types were equally effective at removing nitrogen in the subsurface but not in surface flow. The mean nitrogen removal effectiveness of forested riparian wetlands was found to be 85 percent with a standard error of 5.2 percent (USEPA, 2005).

Riverine wetland areas can be important sinks for phosphorus and suspended sediment. USEPA (1993) compiled representative research results to document the effectiveness of riparian areas in reducing other pollutant loads. Riparian areas provided a median of 65 percent removal of phosphorus load (USEPA, 1993). The primary mechanism for phosphorus removal is the deposition of phosphorus associated with sediments (Brinson et al., 1984; Walbridge and Struthers, 1993). USEPA (1993) found that riparian areas can remove up to 50 percent of the suspended sediment loads. Dissolved phosphorus is primarily removed from runoff through adsorption by clay particles (Cooper and Gilliam, 1987).

For the current period, Regional Water Board staff estimated that riverine wetlands reduce total phosphorus and total nitrogen loads by 2.8% and 1.2%, respectively. Pollutant loading reduction from riparian wetlands was assumed to represent the maximum amount of assimilative capacity possible based on published effectiveness. Based on USEPA published estimates of pollutant load removal, pre-settlement total phosphorus and total nitrogen loads were reduced by 65 percent and 85 percent, respectively. Pollutant loading reduction from current riparian areas was reduced proportionally with the percent loss of these areas, assuming that ninety-two percent (92%) of the riparian areas have been lost in the Laguna and Santa Rosa Plain as estimated by David W. Smith Consulting (1990).

Perennial Wetland Load Assimilation

Perennial wetland microbial populations can also transform and remove nutrients from runoff from the landscape. Hydrologic conditions are extremely important to wetlands structure and function by affecting anaerobic bacterial activity and nutrient availability. Physical wetland features, such as hydroperiod, water depths, and saturation duration affect processes that support the biotic functions of the wetland system.

The conceptual model for estimating nutrient loading is based on the reduction of loading by perennial wetland areas before discharge to receiving waters. PREWet, a simple wetland model developed by the U.S. Army Corps of Engineers, was used to estimate the amount of water quality improvement provided by the perennial wetlands (Dortch and Gerald, 1995).

With basic characteristics about the wetland, pollutant removal efficiency can be computed for total suspended solids, biochemical oxygen demand, and nutrients. The removal efficiency depends on the wetland detention time and the removal rate for the constituent. The model calculates removal rate coefficients based on ambient conditions and a number of processes, such as microbial metabolism, adsorption, volatilization, denitrification, and settling. The model computes wetland outflow concentrations for each constituent.

PREWet model input variables included mean annual wetland size, flow. and temperature. Wetland sizes were varied for each catchment according to precipitation return period. The areas of perennial wetland for wet and dry periods in the Laguna pre-settlement spatial data model were assumed to represent the most extreme measured climatic years. The lowest annual dry period was measured in 1976 and was assumed to represent the dry period perennial wetland areas. Similarly, the largest annual wet period was measured in 1997 and assumed to represent the wet period perennial wetland areas.

Perennial wetland areas were linearly extrapolated between these wet and dry period areas according to precipitation return period. Perennial wetland areas were estimated for each year to be represented on the load duration curves. Perennial wetland areas in each catchment were assumed to represent a square area with a 1-meter depth, which is the median depth defined for palustrine wetlands (Cowardin et al., 1979).

Annual mean air temperatures were calculated from Laguna watershed weather station data (National Climatic Data Center Cooperative Weather Station 47965). Mean annual inflow concentrations from each catchment were derived using the median load and mean flow for each year from the load duration curves. PREWet model default values were used for all remaining model parameters.

Receiving Water Load Duration Curves

The current and pre-settlement load duration curves by catchment area are displayed in Figures 123-192. These curves include reductions in nutrient loads that are estimated to be found in the open water area after the water passes through riverine wetlands and perennial wetlands where nutrients are assimilated through natural processes.

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FIGURES

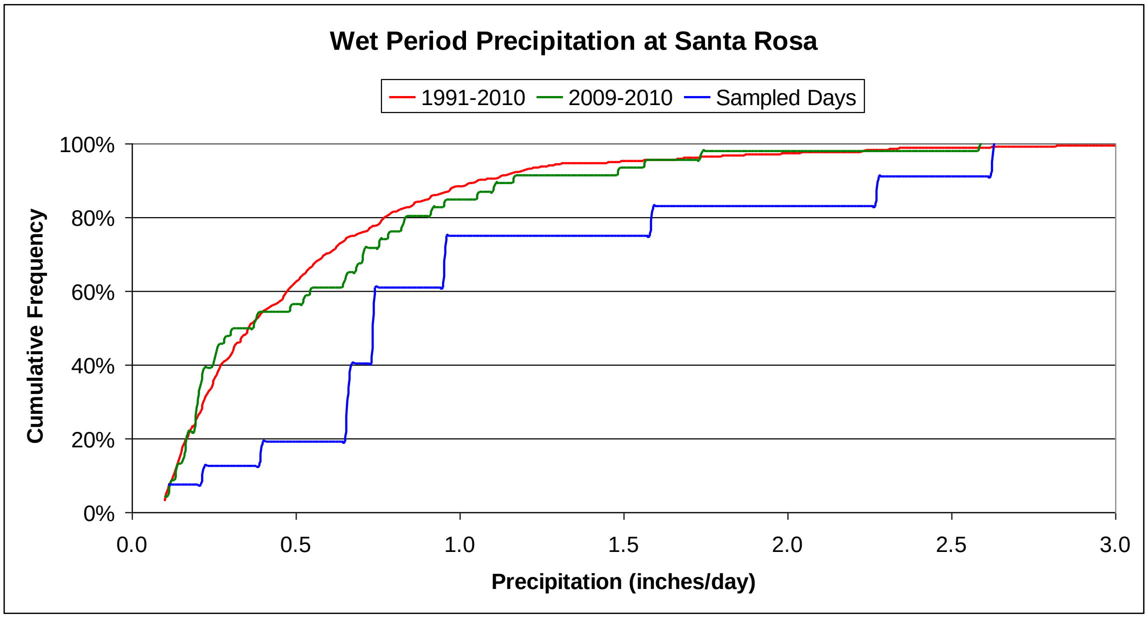

Figure 1. Distribution of Wet Period Precipitation at Santa Rosa

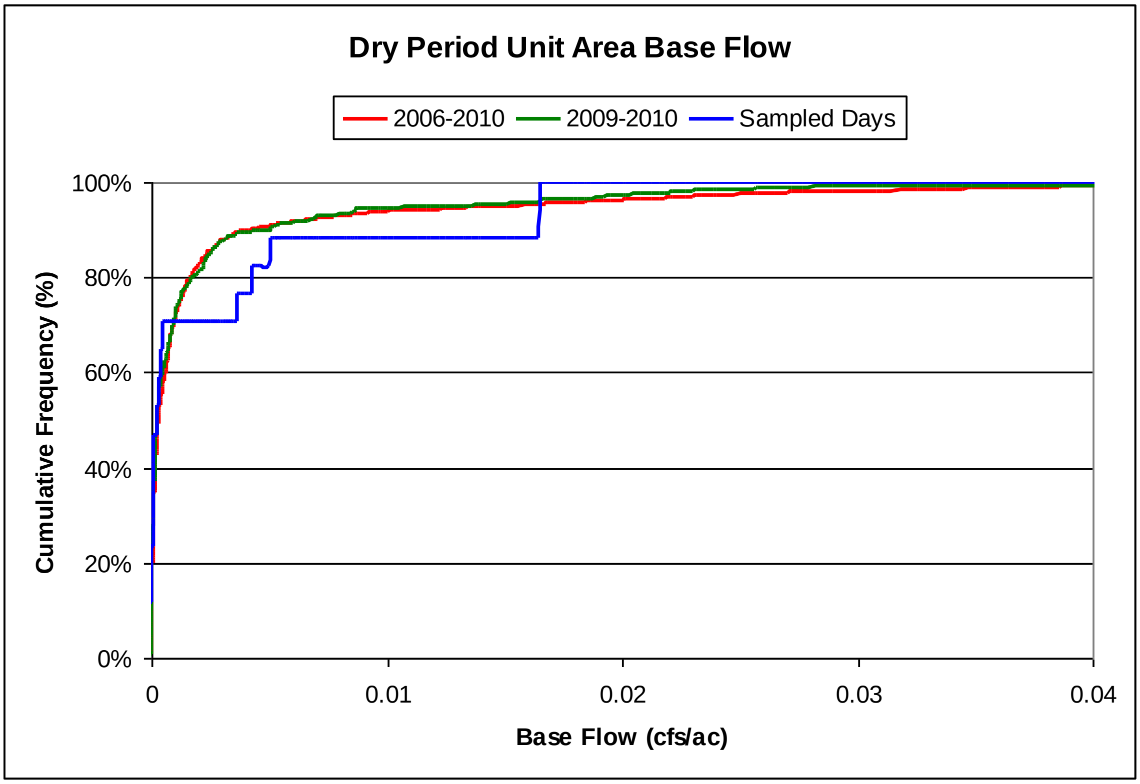

Figure 2. Distribution of Dry Period Precipitation at Santa Rosa

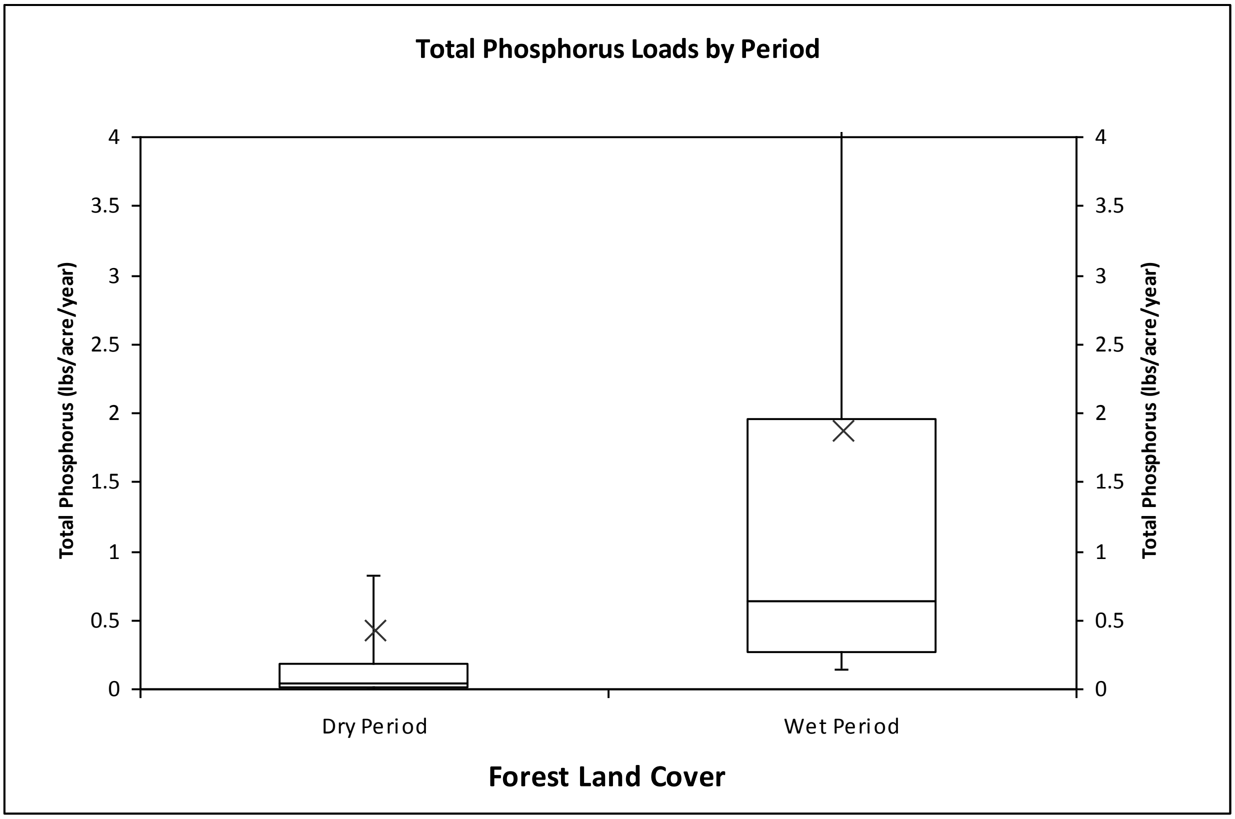

Figure 3. Distribution of Forested Land Cover Total Phosphorus Unit Area Loads

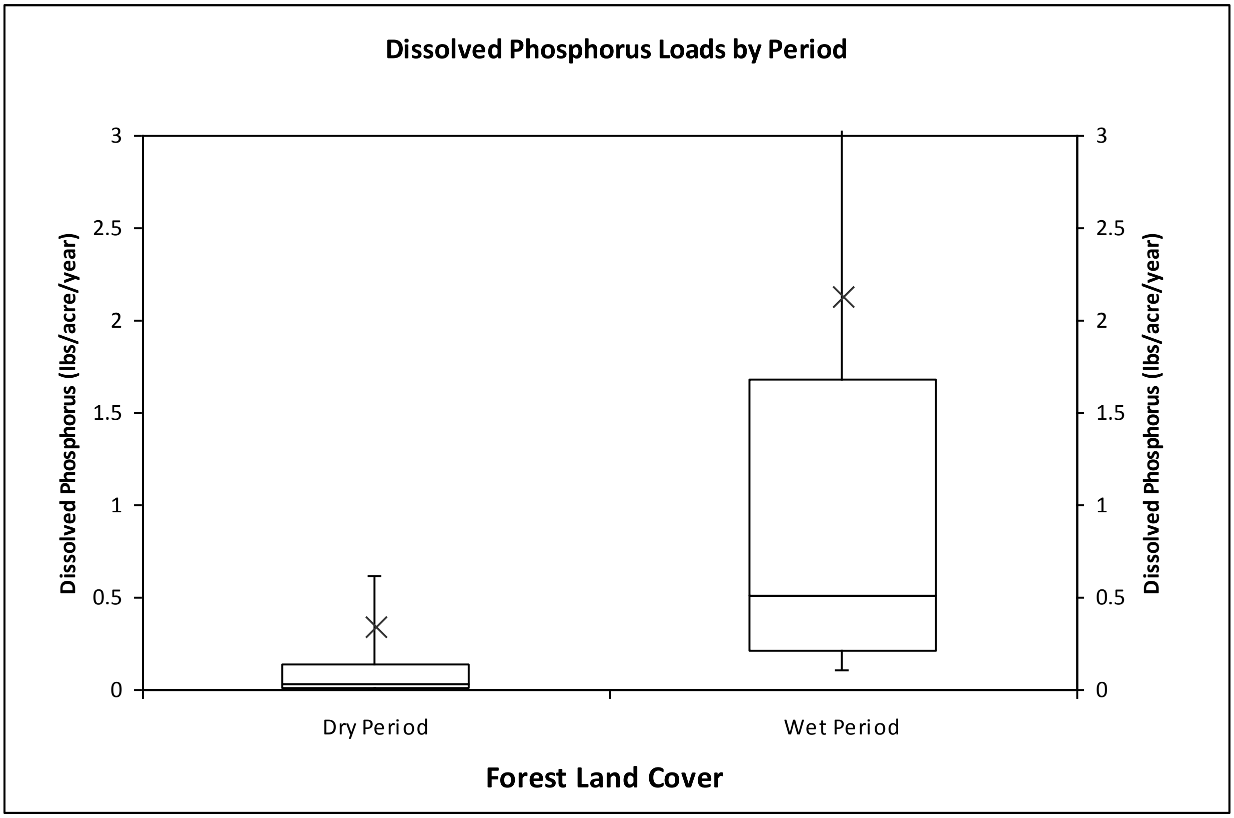

Figure 4. Distribution of Forested Land Cover Dissolved Phosphorus Unit Area Loads

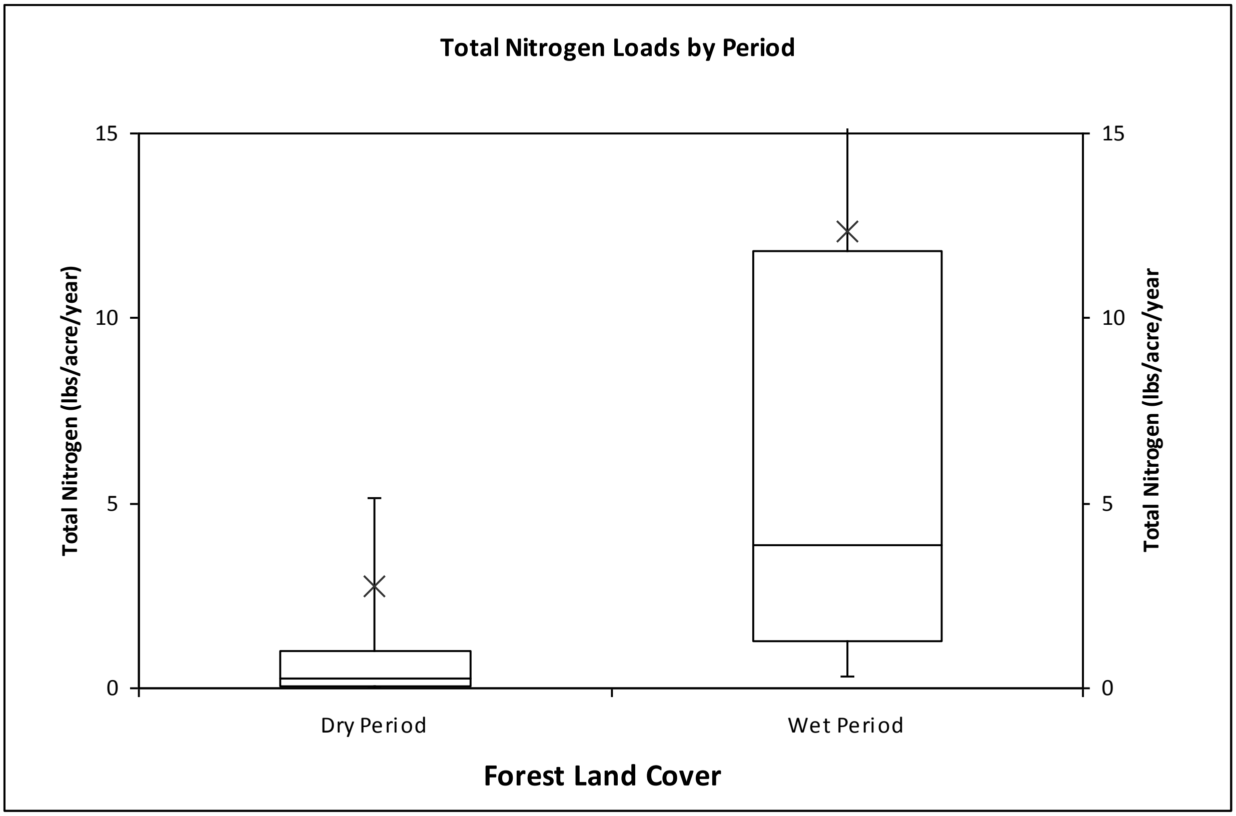

Figure 5. Distribution of Forested Land Cover Total Nitrogen Unit Area Loads

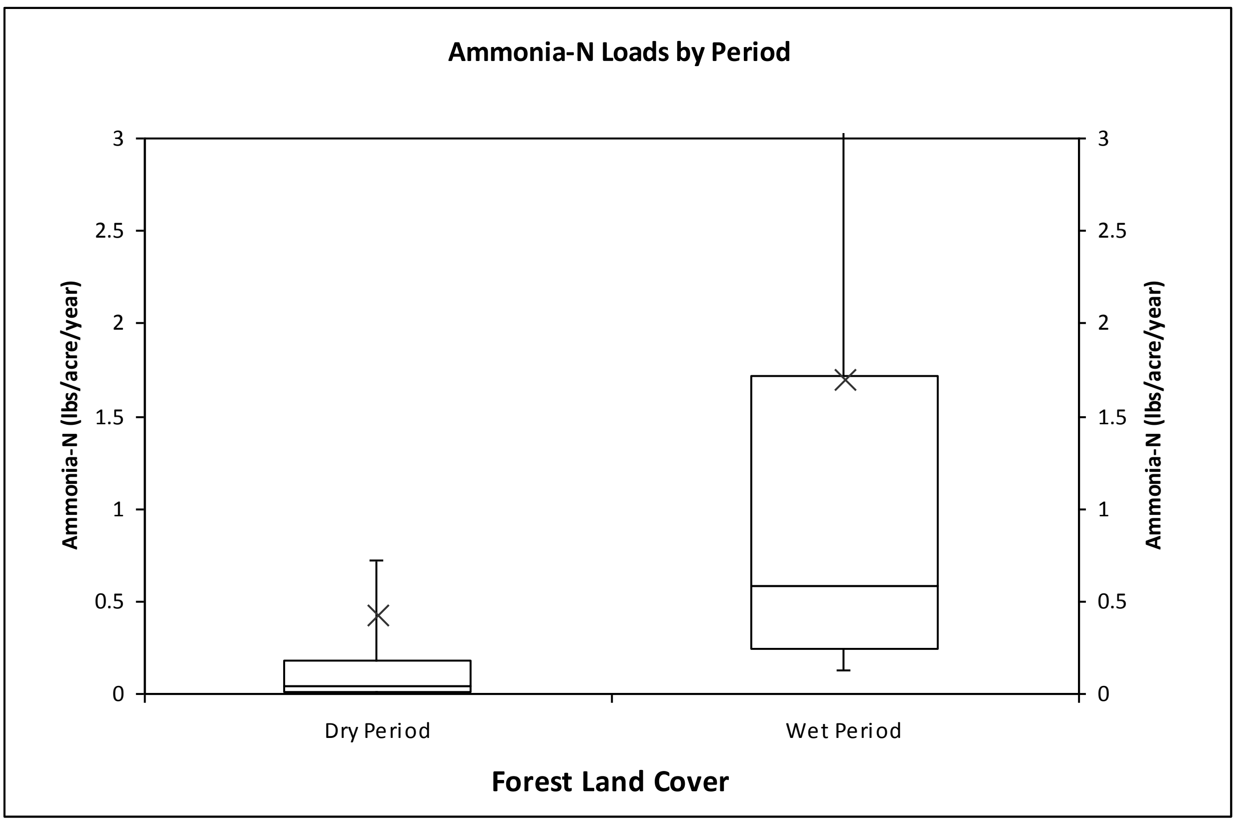

Figure 6. Distribution of Forested Land Cover Ammonia-N Unit Area Loads

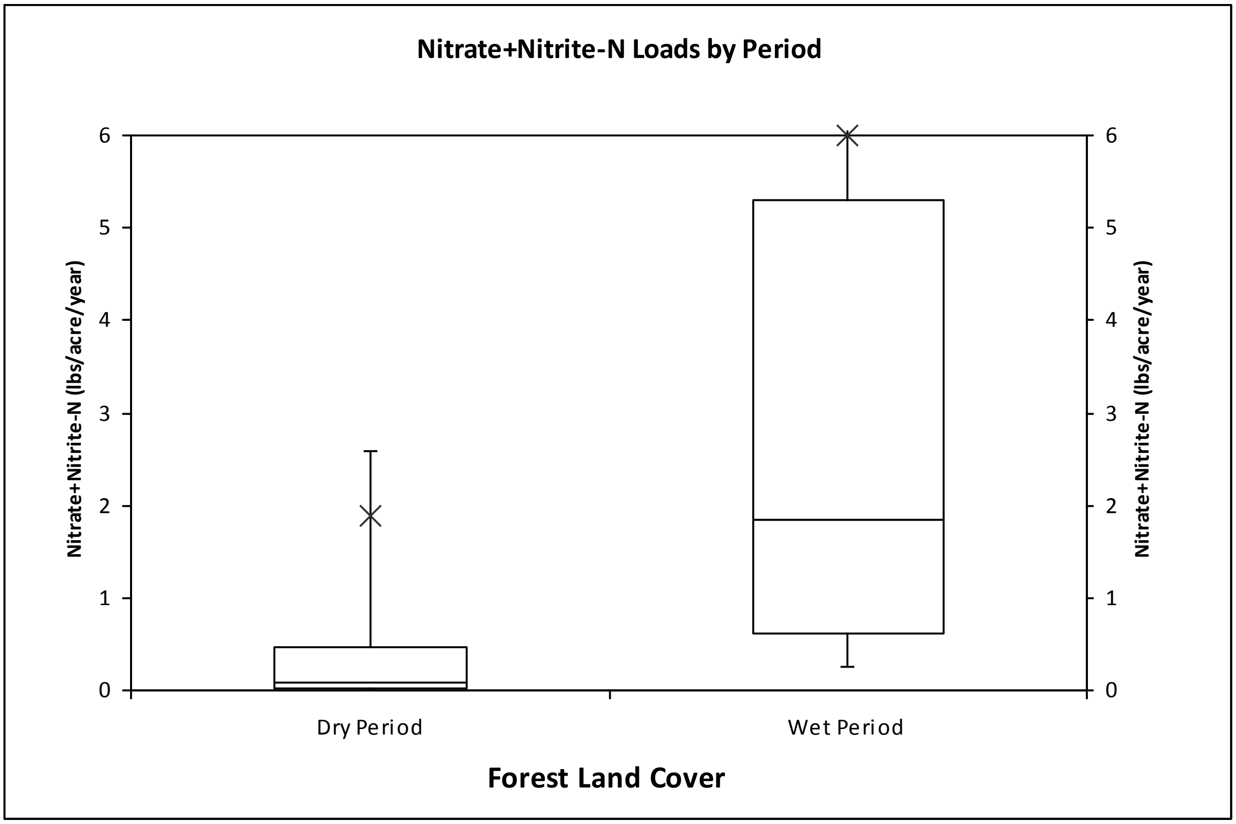

Figure 7. Distribution of Forested Land Cover Nitrate+Nitrite-N Unit Area Loads

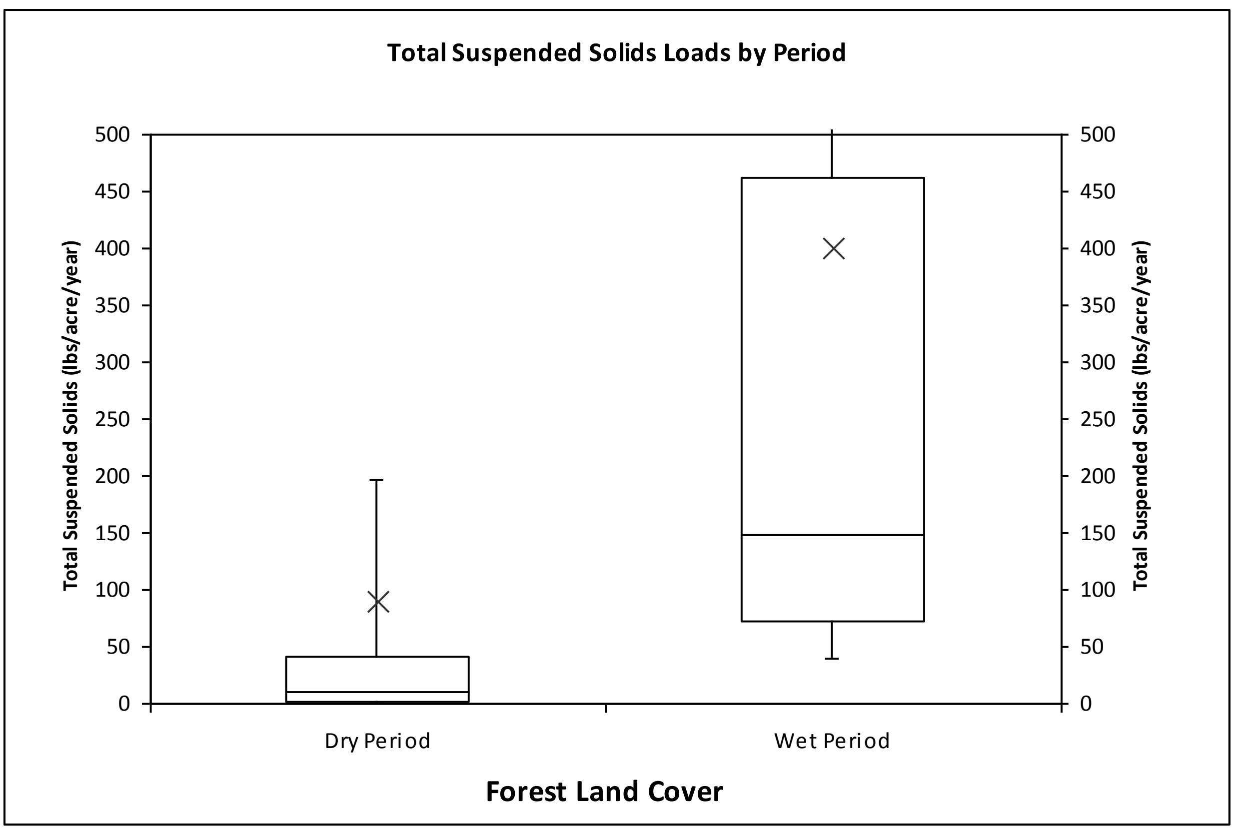

Figure 8. Distribution of Forested Land Cover Total Suspended Solids Unit Area Loads

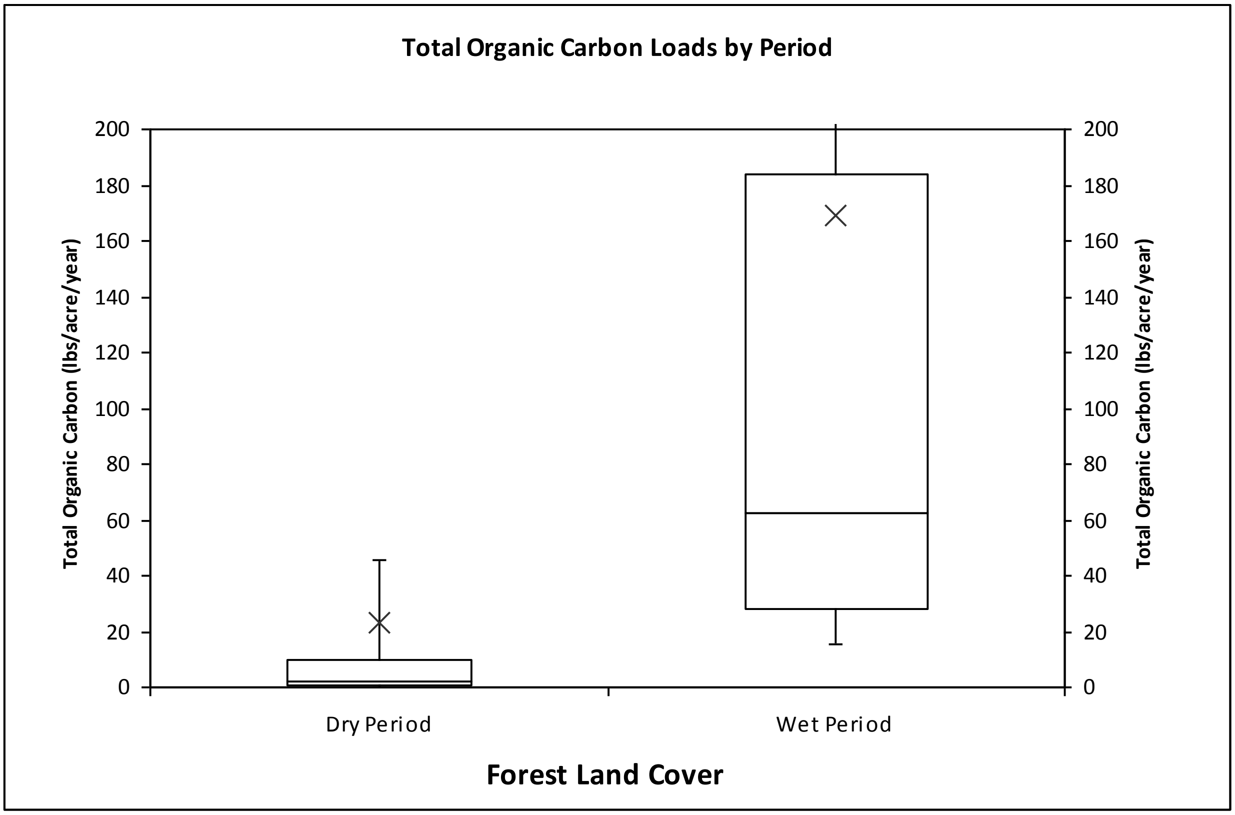

Figure 9. Distribution of Forested Land Cover Total Organic Carbon Area Loads

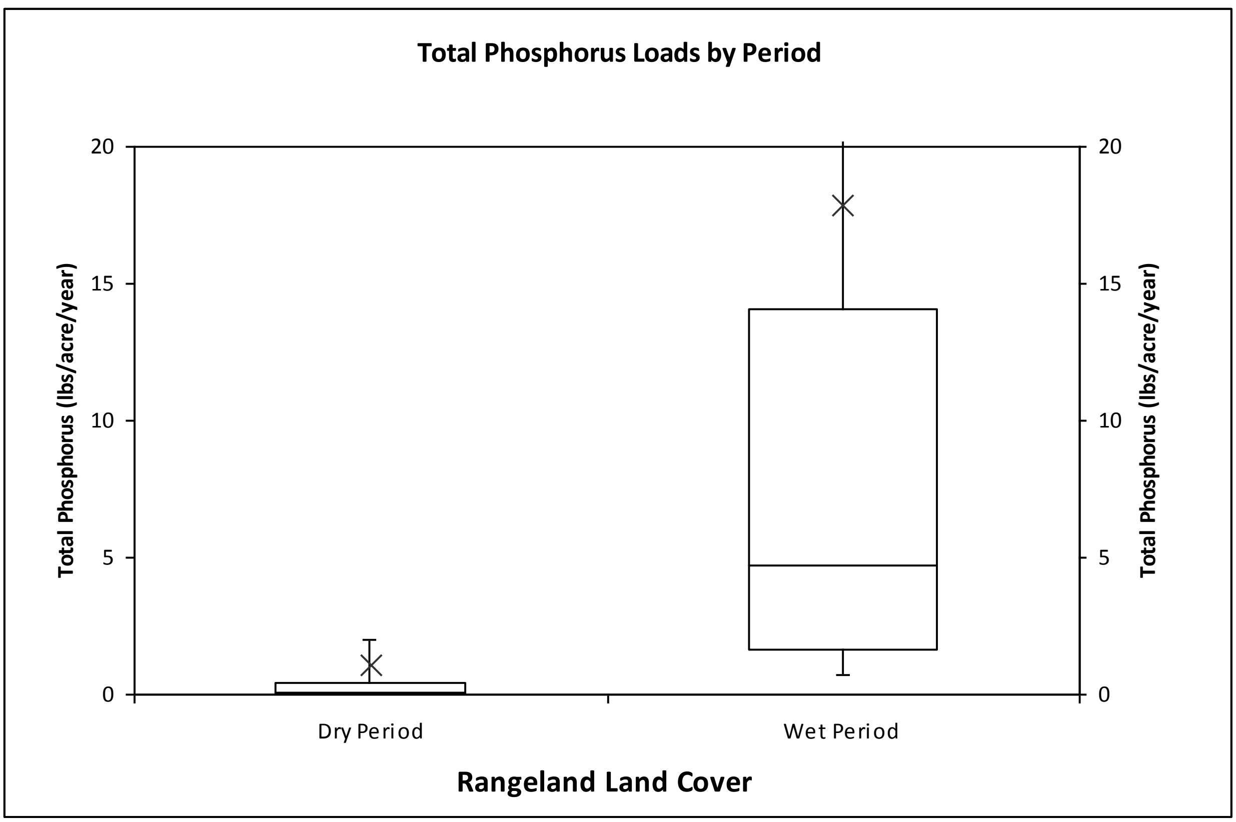

Figure 10. Distribution of Rangeland Land Cover Total Phosphorus Unit Area Loads

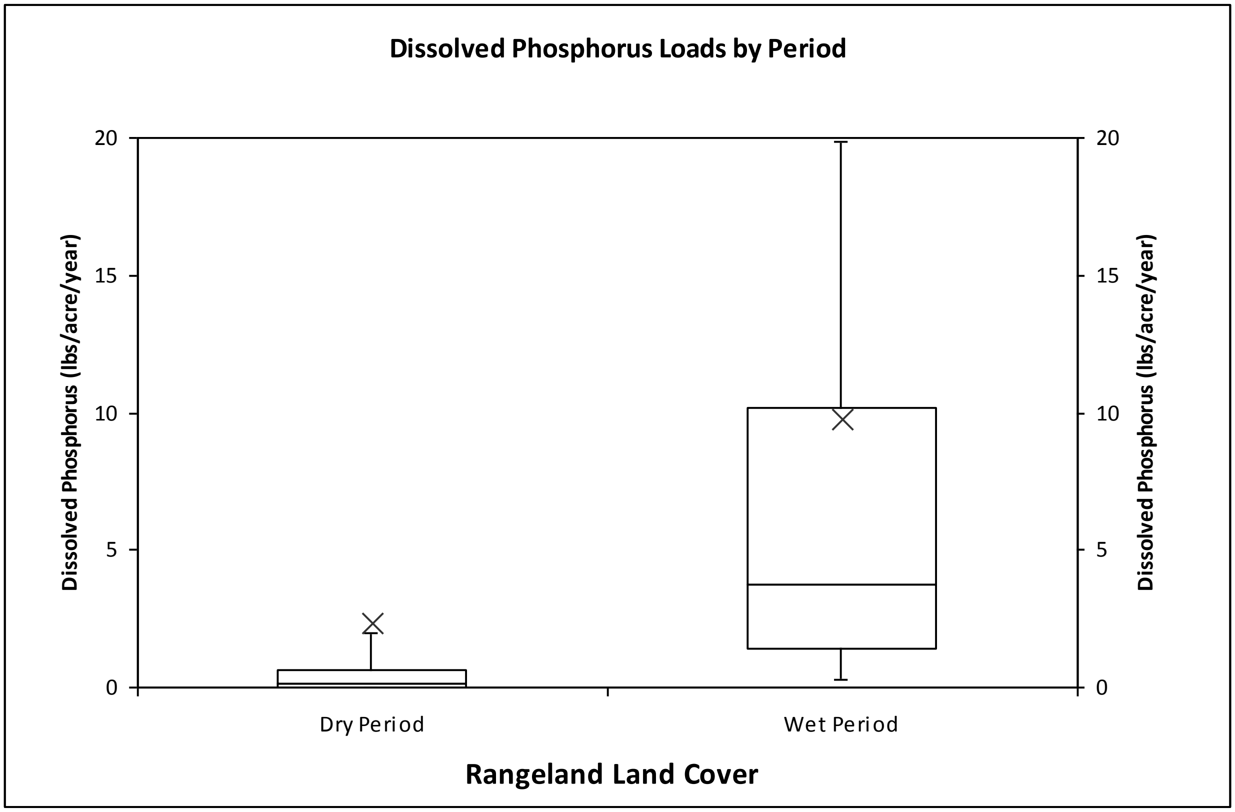

Figure 11. Distribution of Rangeland Land Cover Dissolved Phosphorus Unit Area Loads

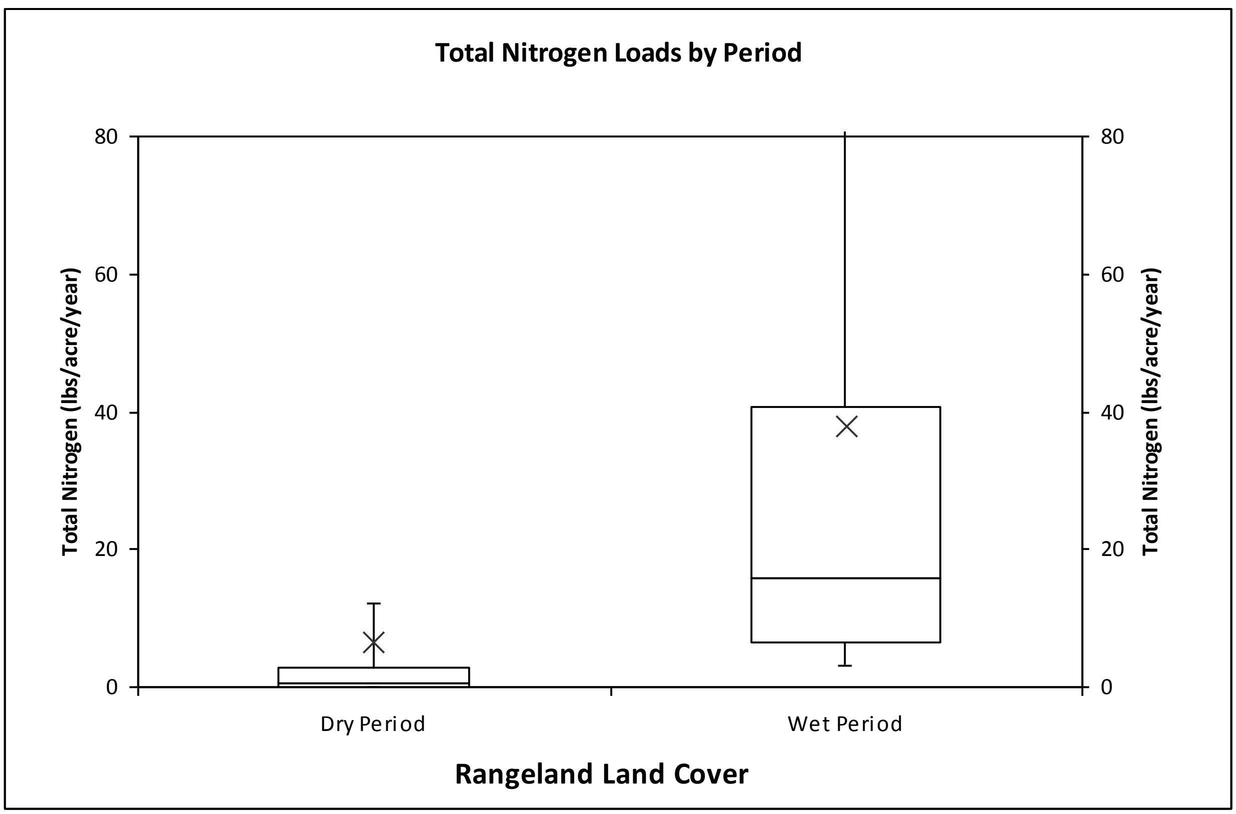

Figure 12. Distribution of Rangeland Land Cover Total Nitrogen Unit Area Loads

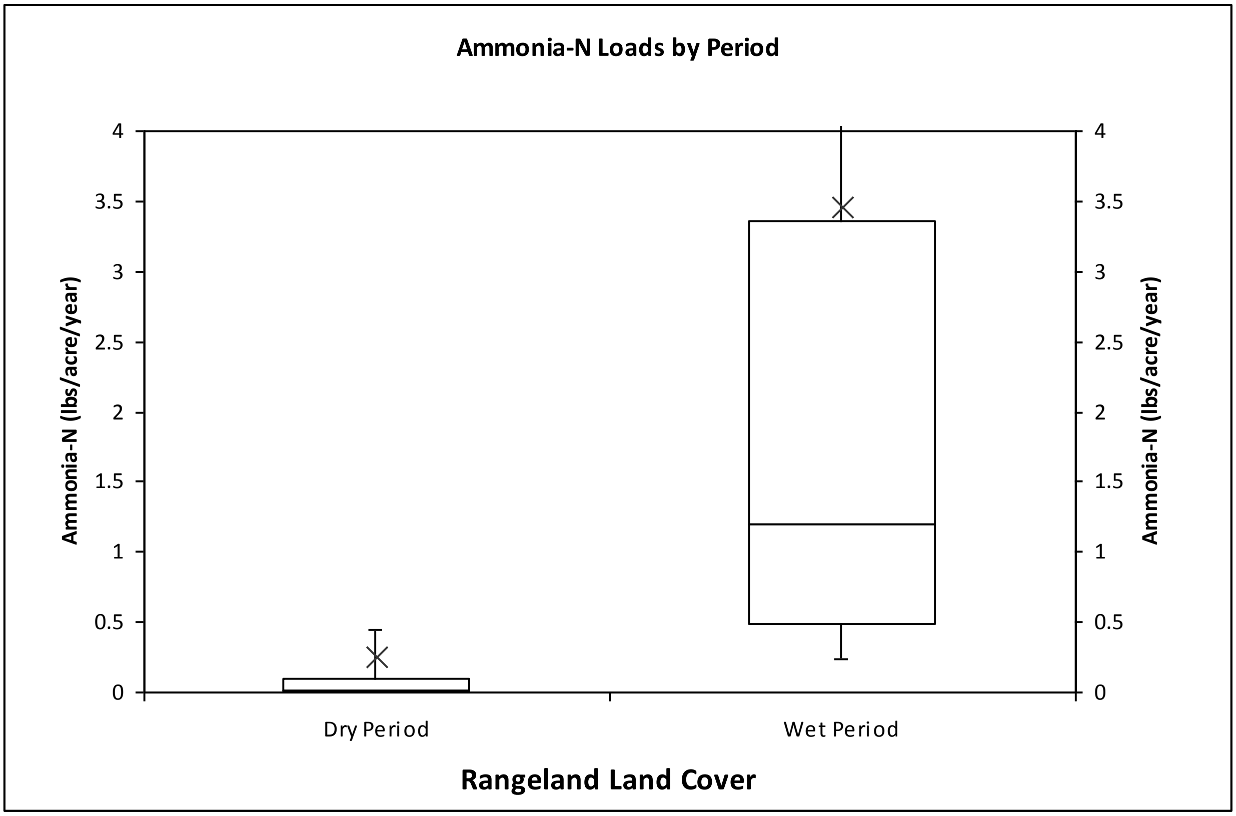

Figure 13. Distribution of Rangeland Land Cover Ammonia-N Unit Area Loads

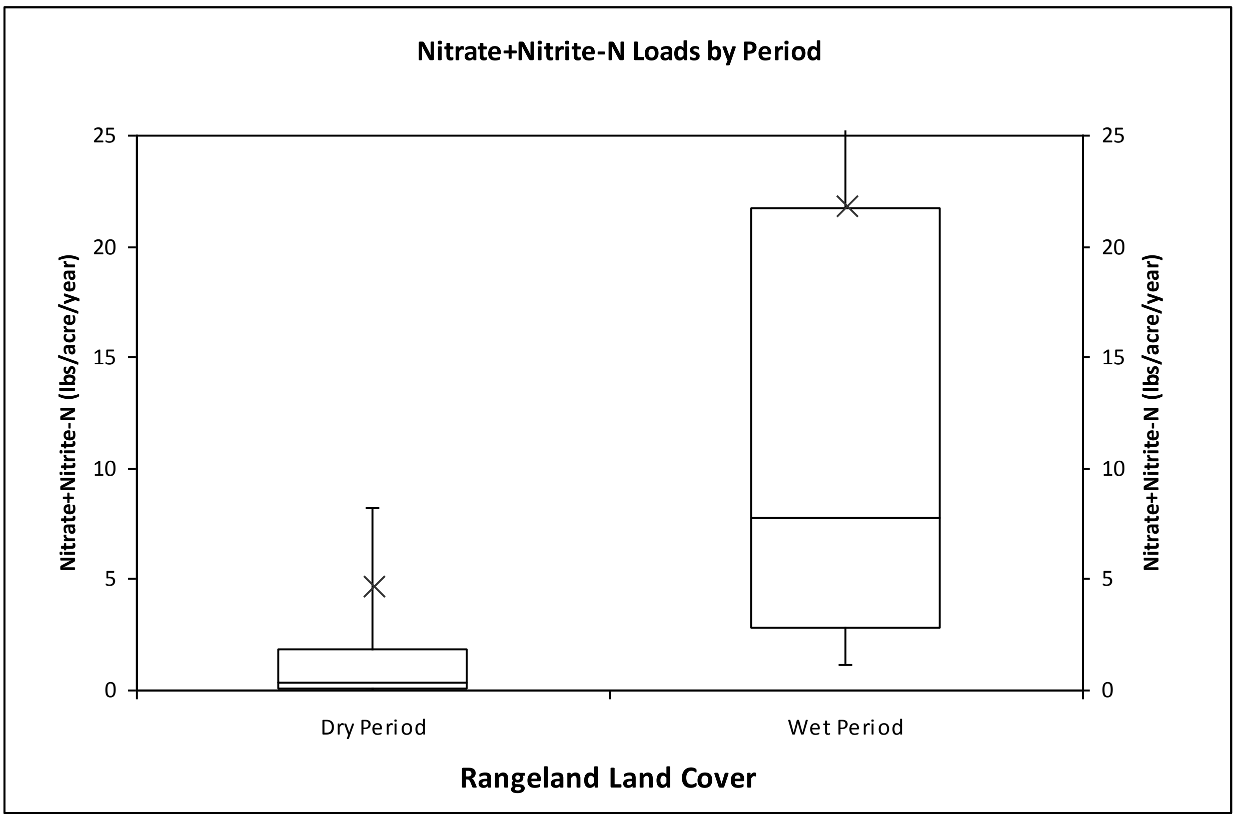

Figure 14. Distribution of Rangeland Land Cover Nitrate+Nitrite-N Unit Area Loads

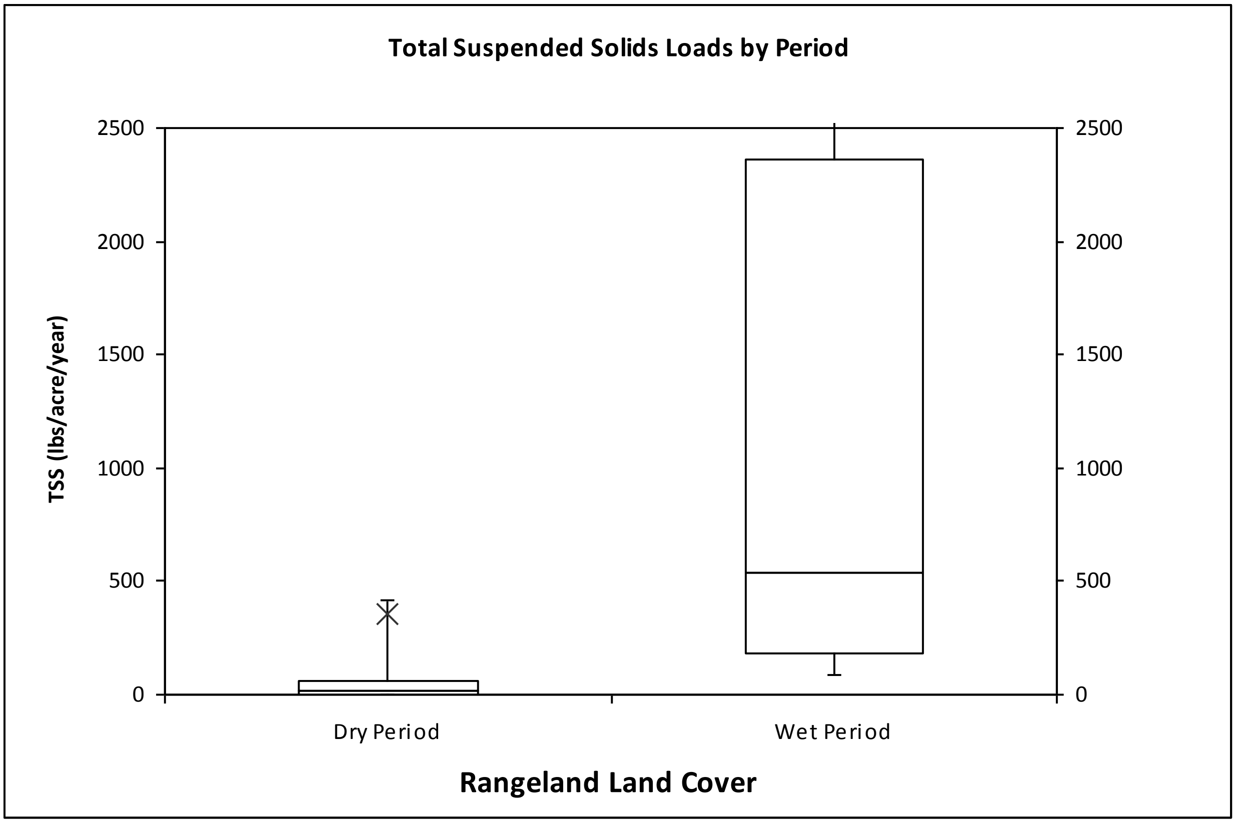

Figure 15. Distribution of Rangeland Land Cover Total Suspended Solids Unit Area Loads

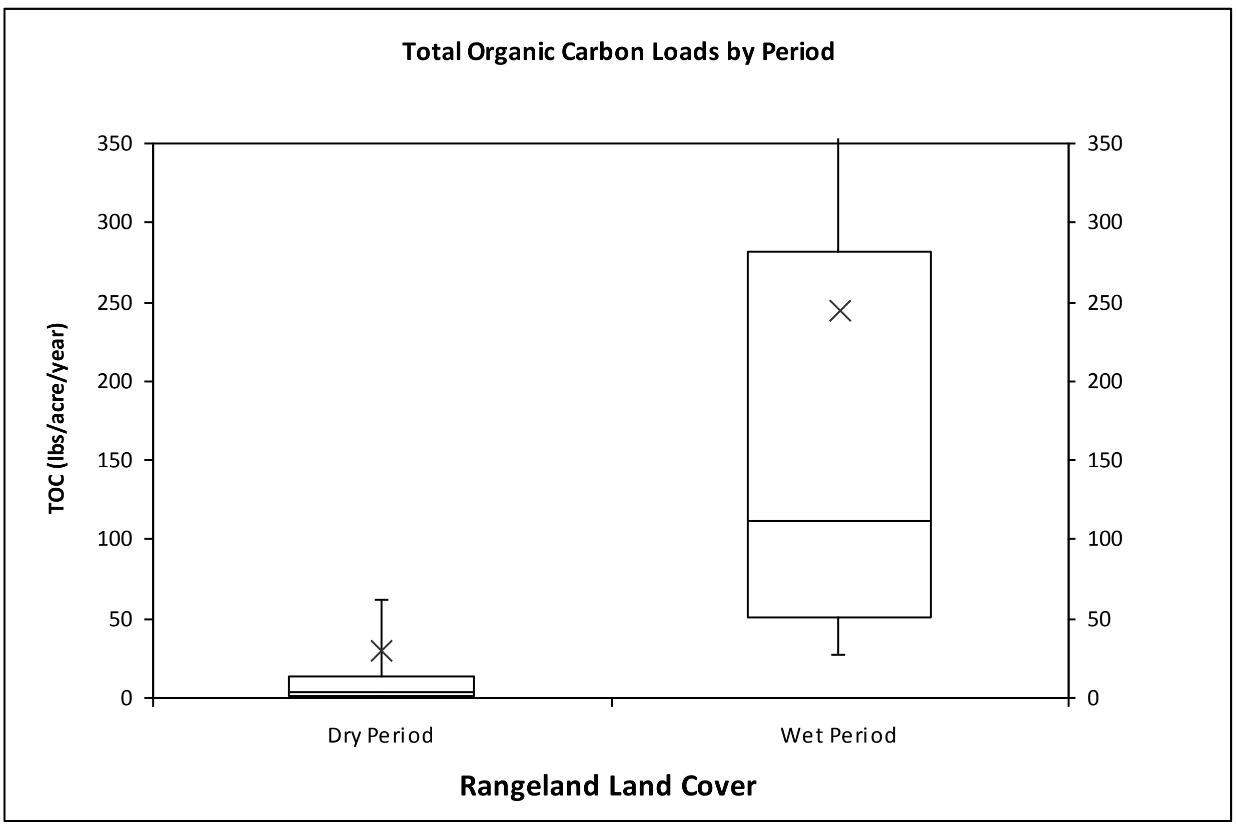

Figure 16. Distribution of Rangeland Land Cover Total Organic Carbon Area Loads

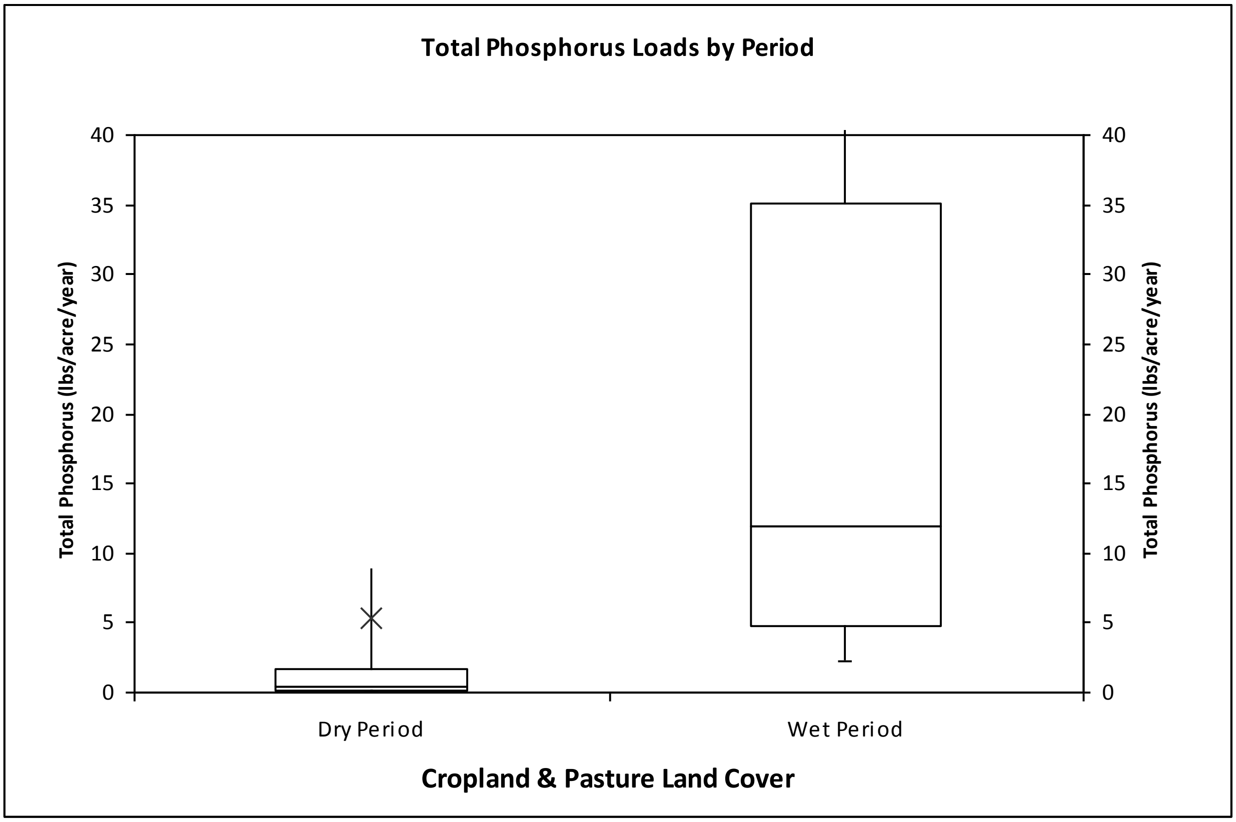

Figure 17. Distribution of Crop & Pasture Land Cover Total Phosphorus Unit Area Loads

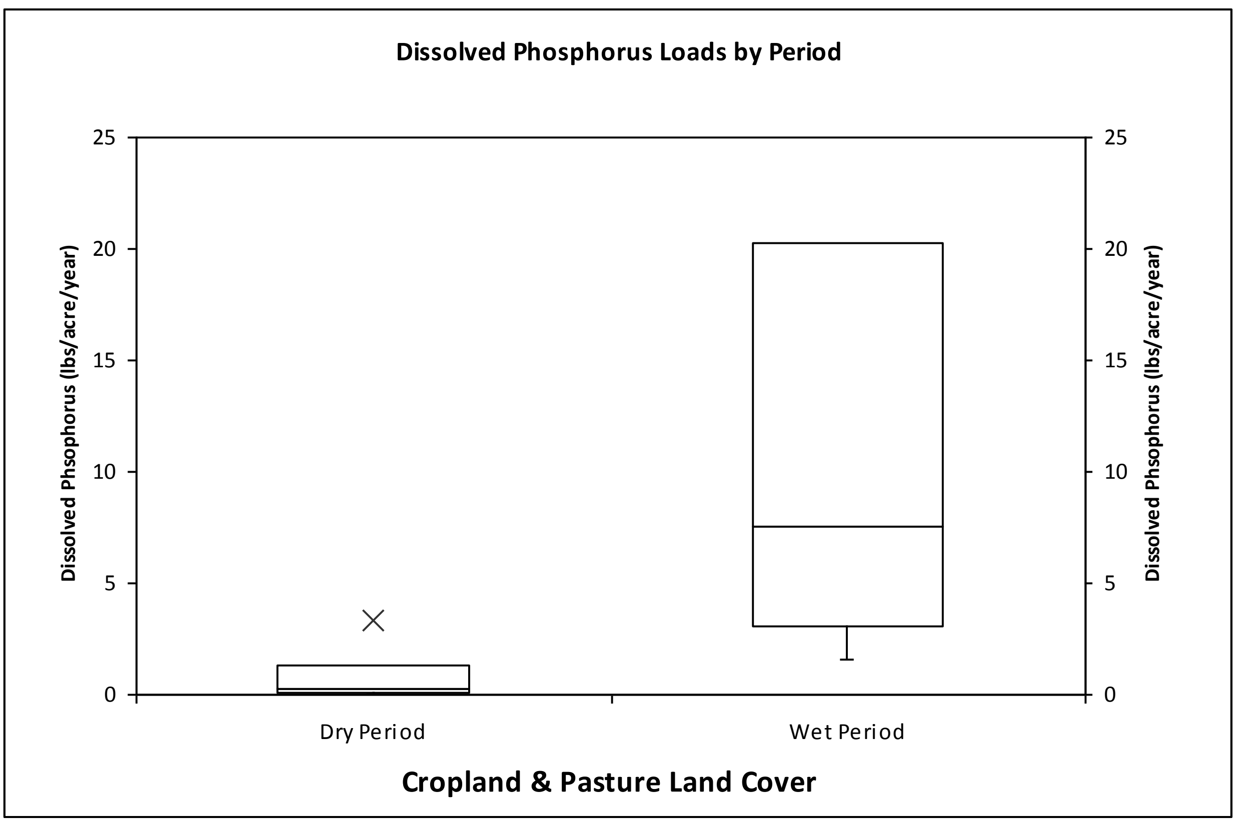

Figure 18. Distribution of Crop & Pasture Land Cover Dissolved Phosphorus Unit Area Loads

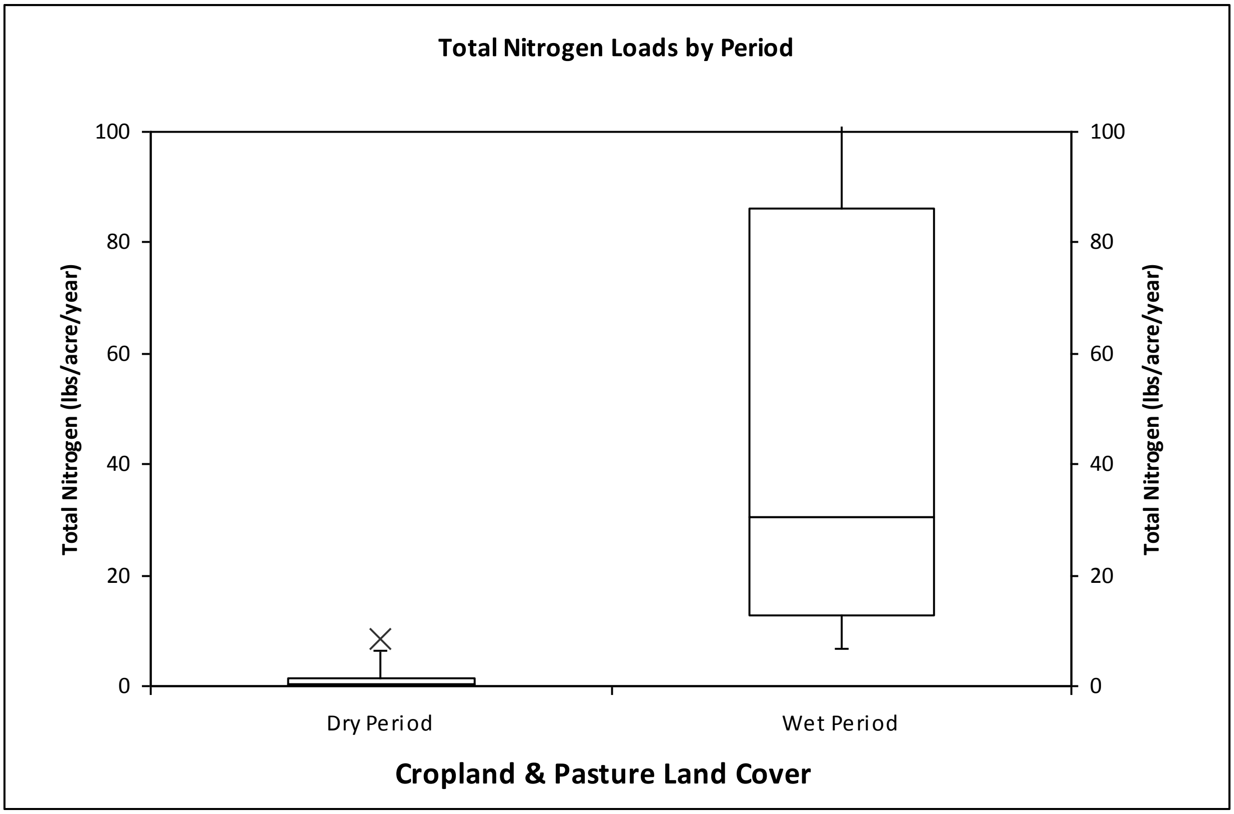

Figure 19. Distribution of Crop and Pasture Land Cover Total Nitrogen Unit Area Loads

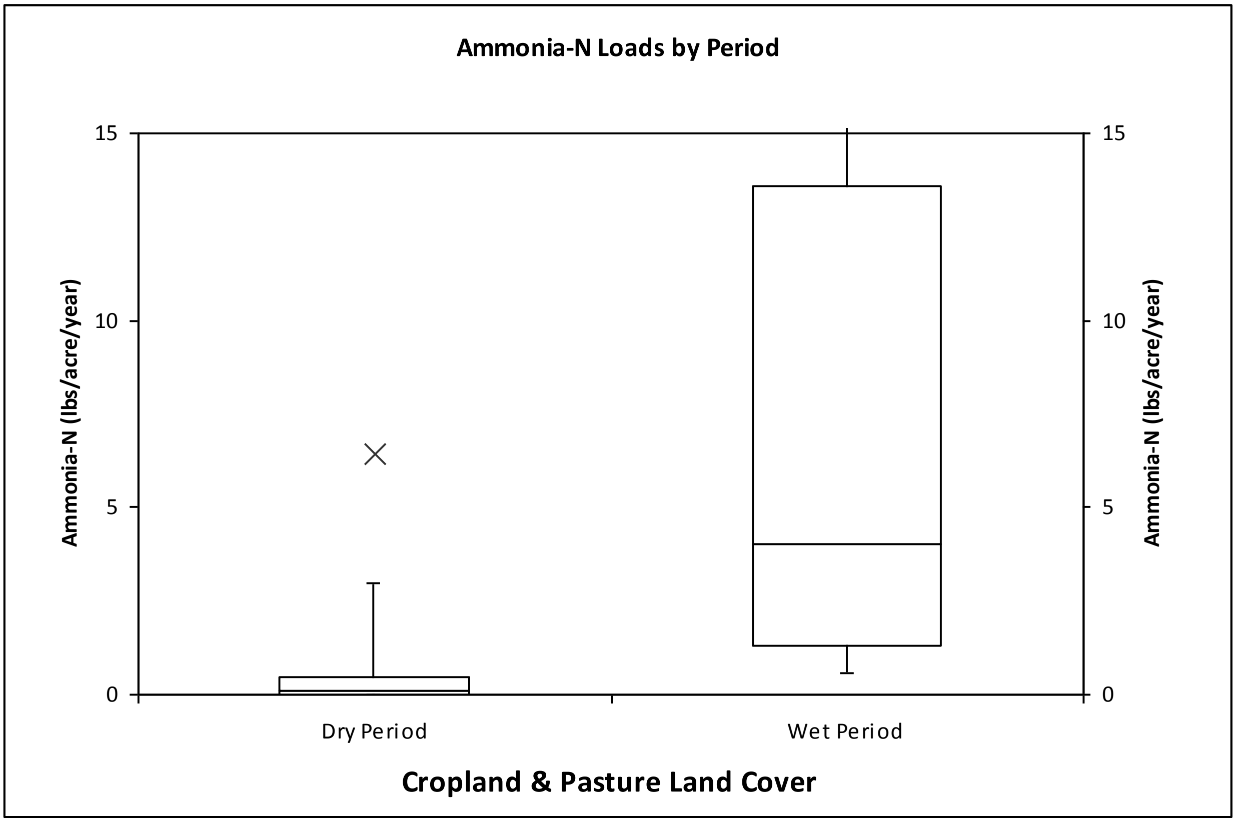

Figure 20. Distribution of Crop and Pasture Land Cover Ammonia-N Unit Area Loads

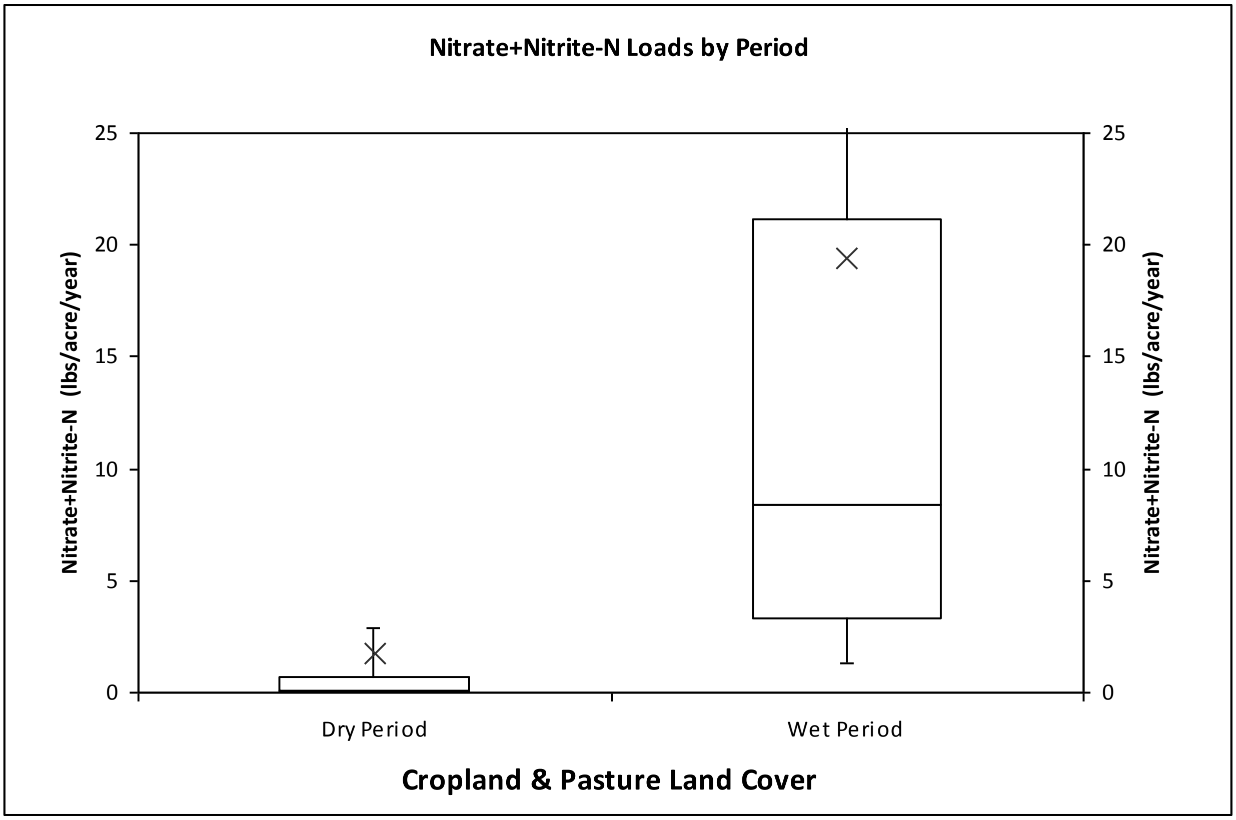

Figure 21. Distribution of Crop & Pasture Land Cover Nitrate+Nitrite-N Unit Area Loads

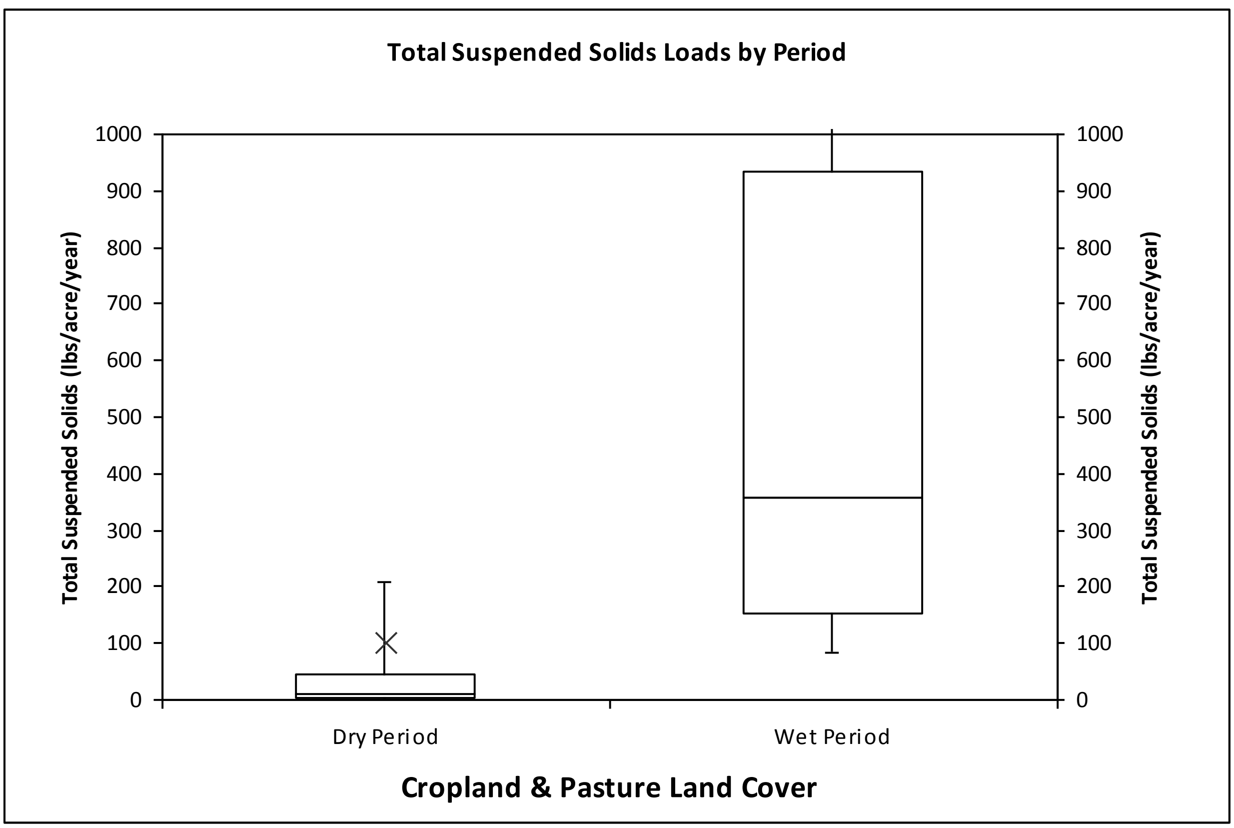

Figure 22. Distribution of Crop & Pasture Land Cover Total Suspended Solids Unit Area Loads

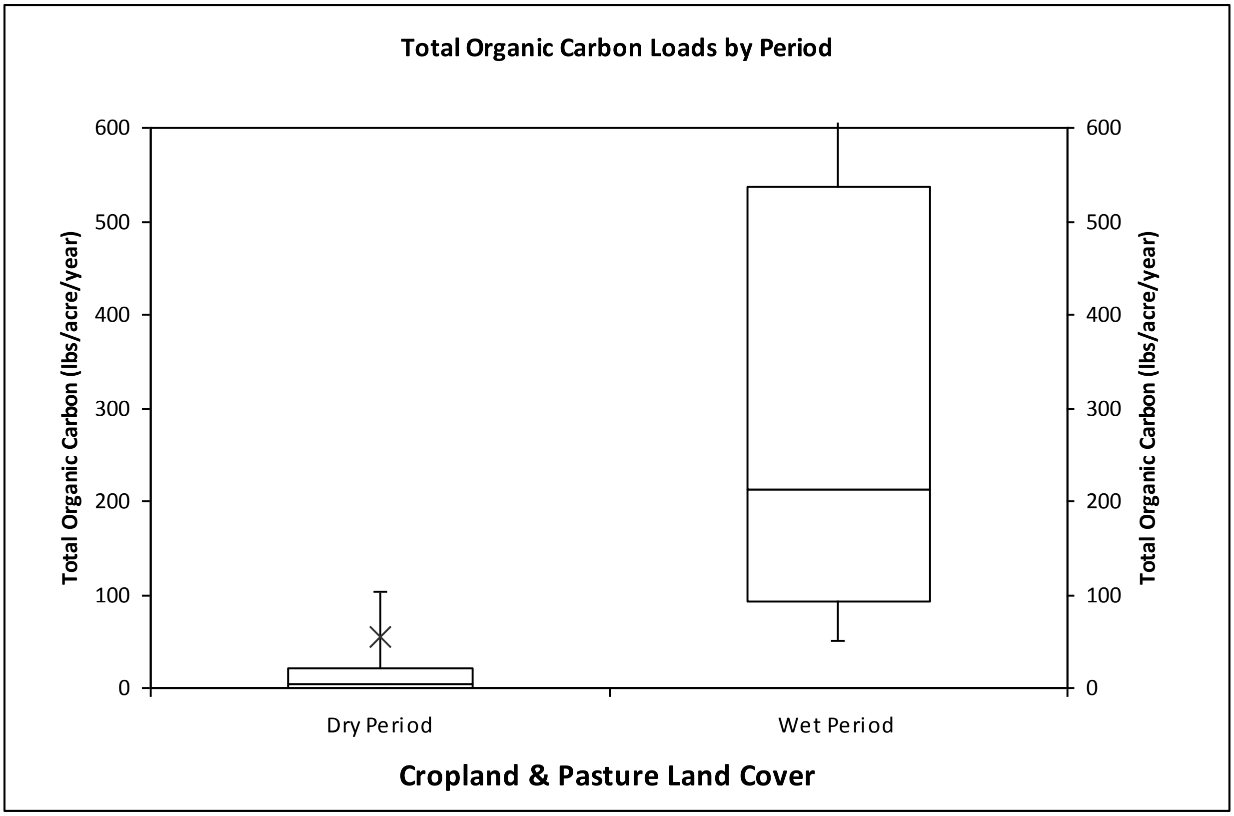

Figure 23. Distribution of Crop & Pasture Land Cover Total Organic Carbon Area Loads

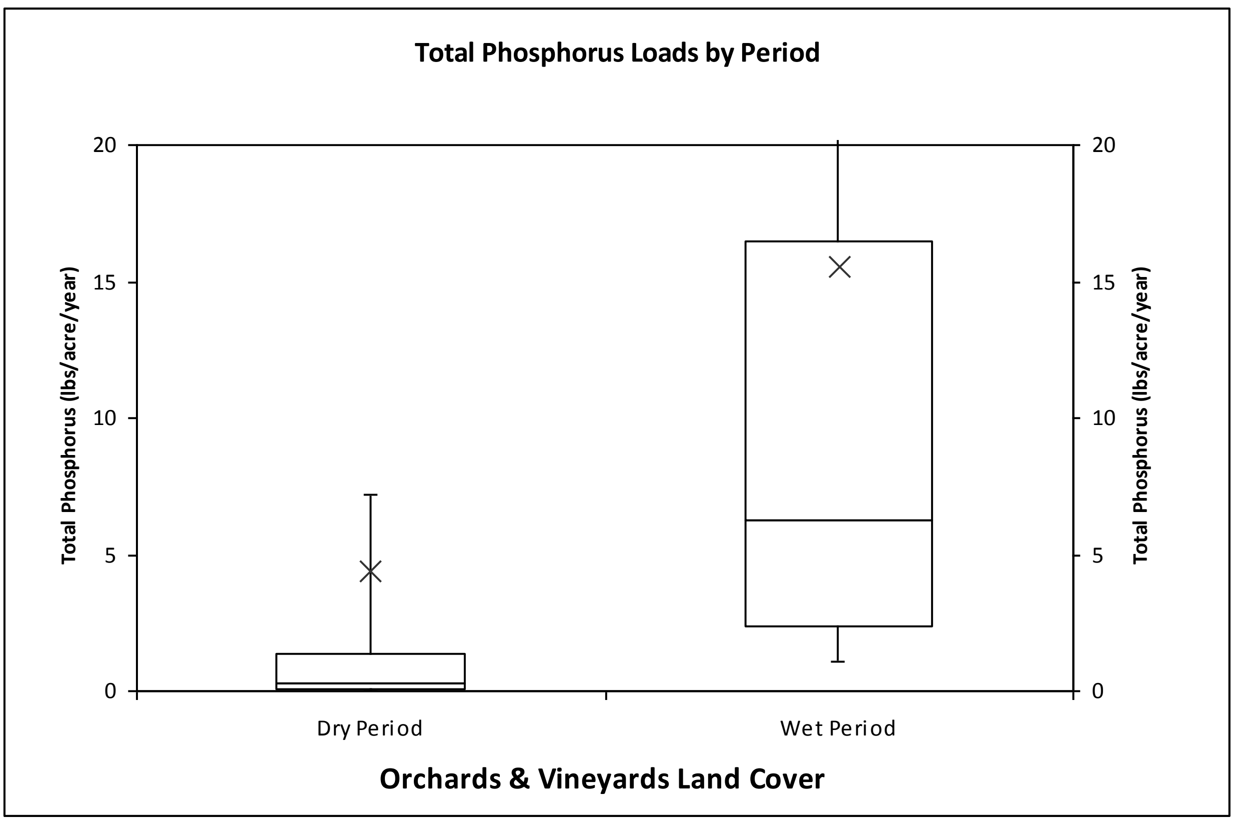

Figure 24. Distribution of Orchards & Vineyards Land Cover Total Phosphorus Unit Area Loads

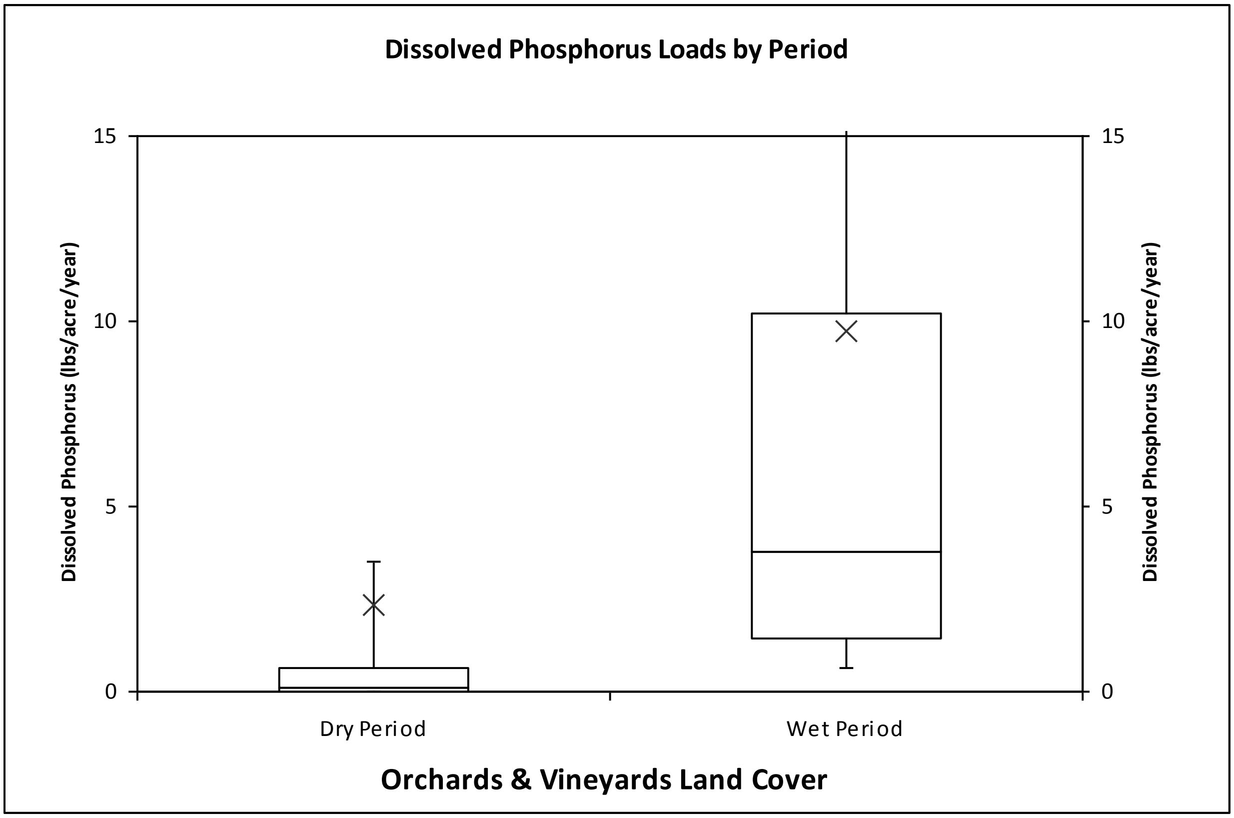

Figure 25. Distribution of Orchards & Vineyards Land Cover Dissolved Phosphorus Unit Area Loads

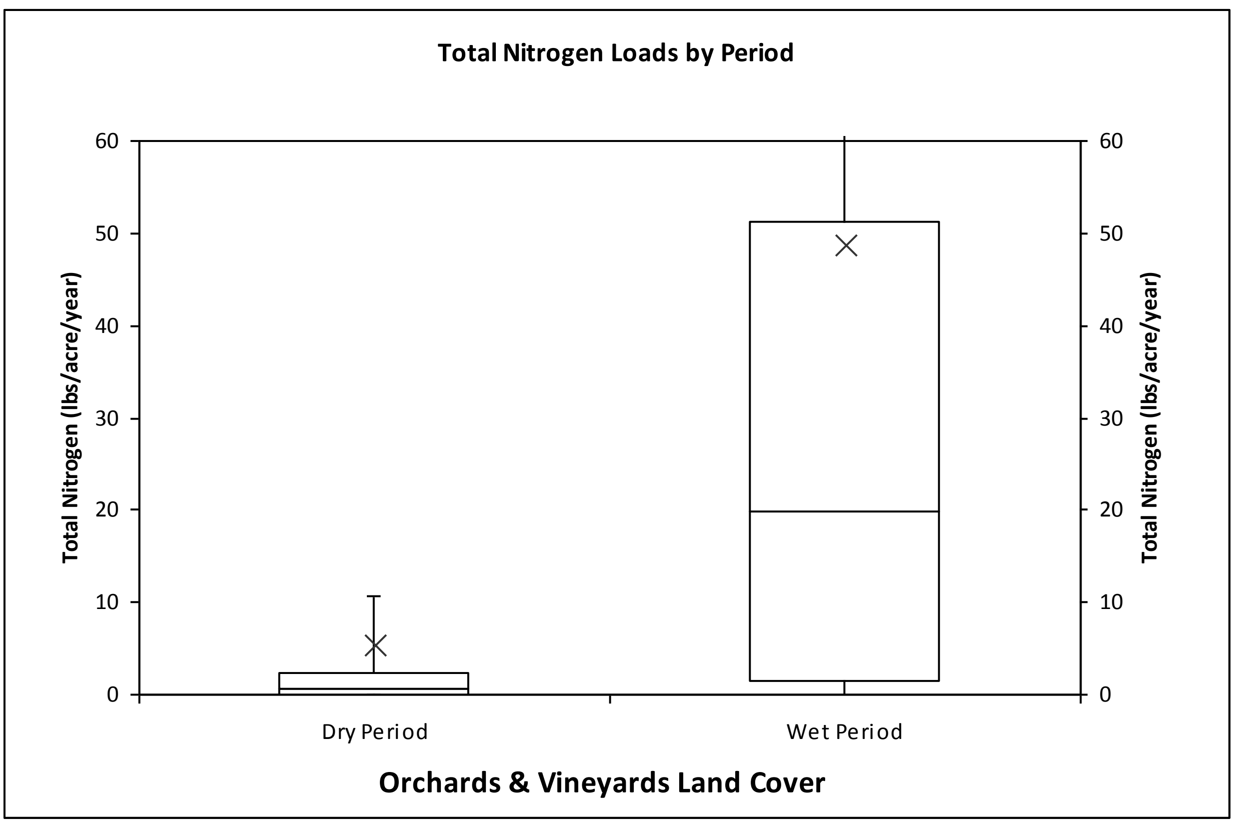

Figure 26. Distribution of Orchards & Vineyards Land Cover Total Nitrogen Unit Area Loads

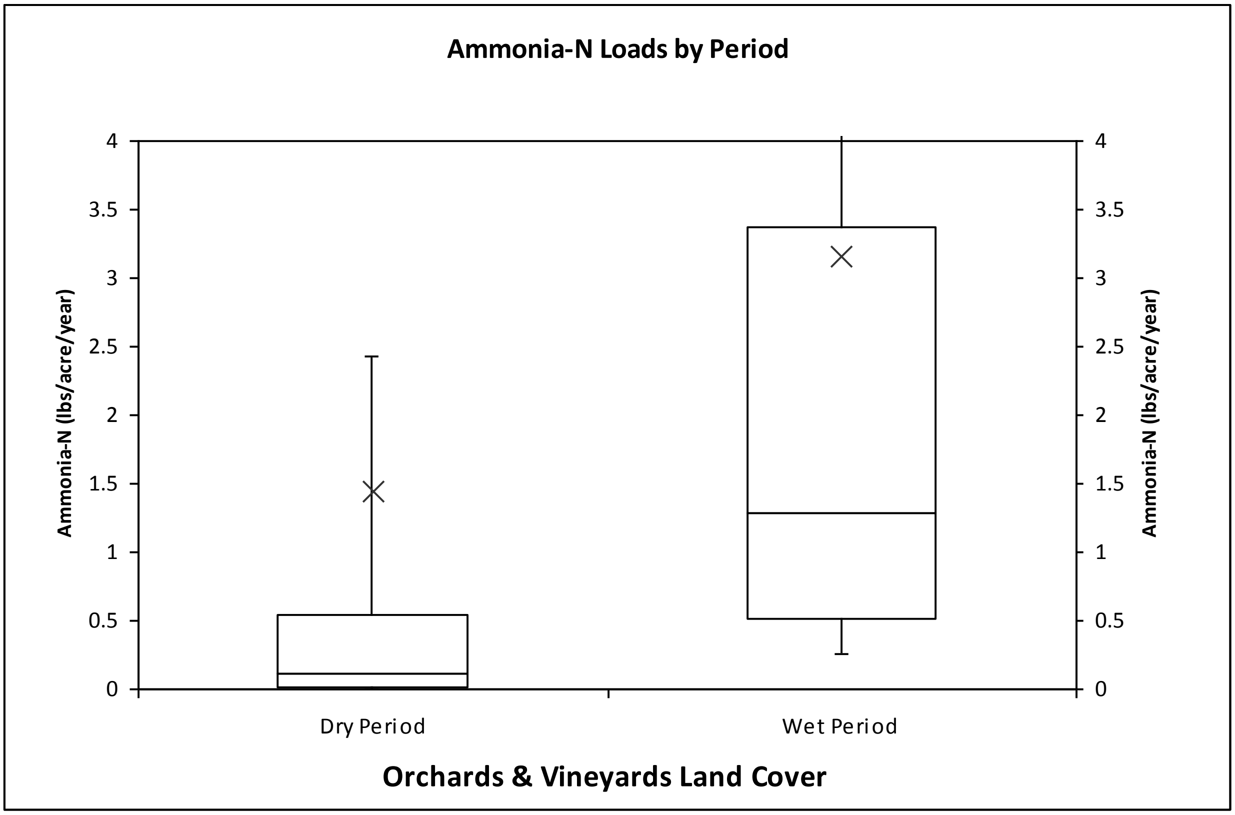

Figure 27. Distribution of Orchards & Vineyards Land Cover Ammonia-N Unit Area Loads

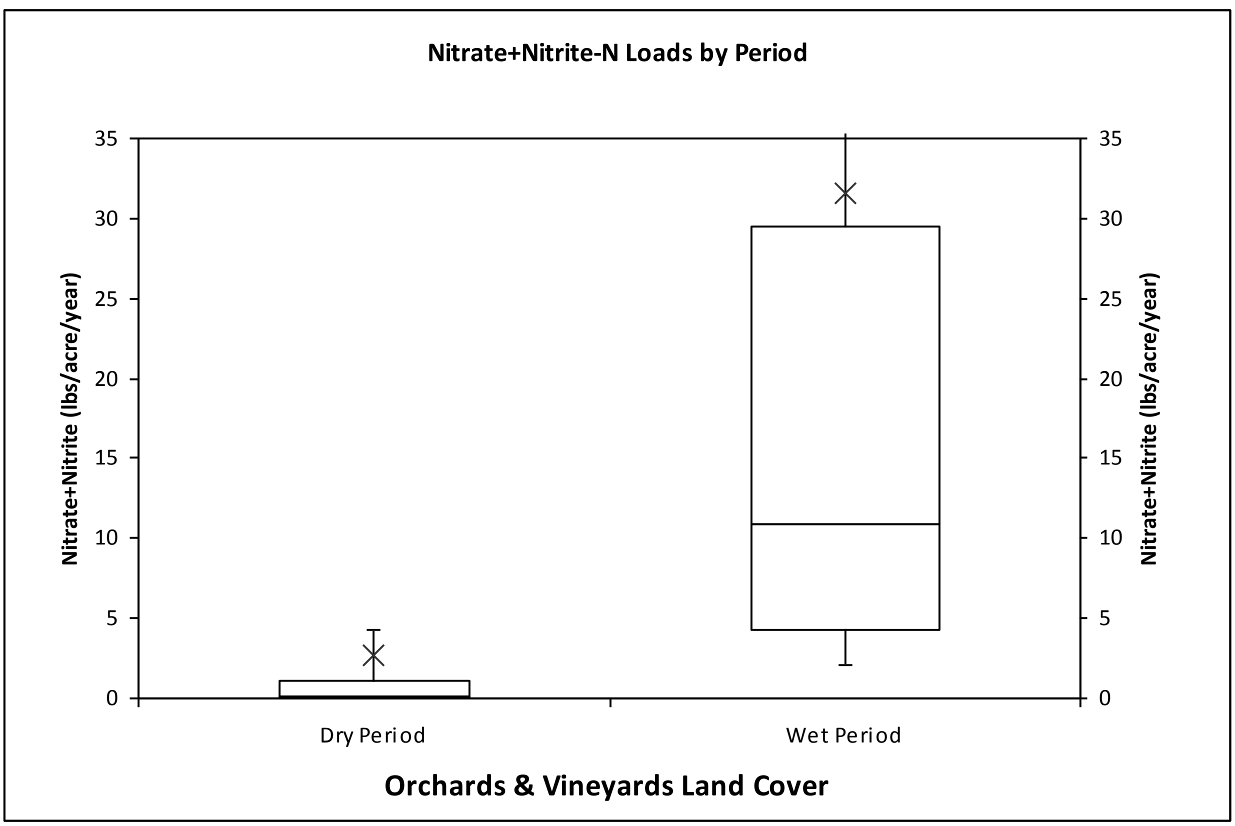

Figure 28. Distribution of Orchards & Vineyards Land Cover TNitrate+Nitrite-N Unit Area Loads

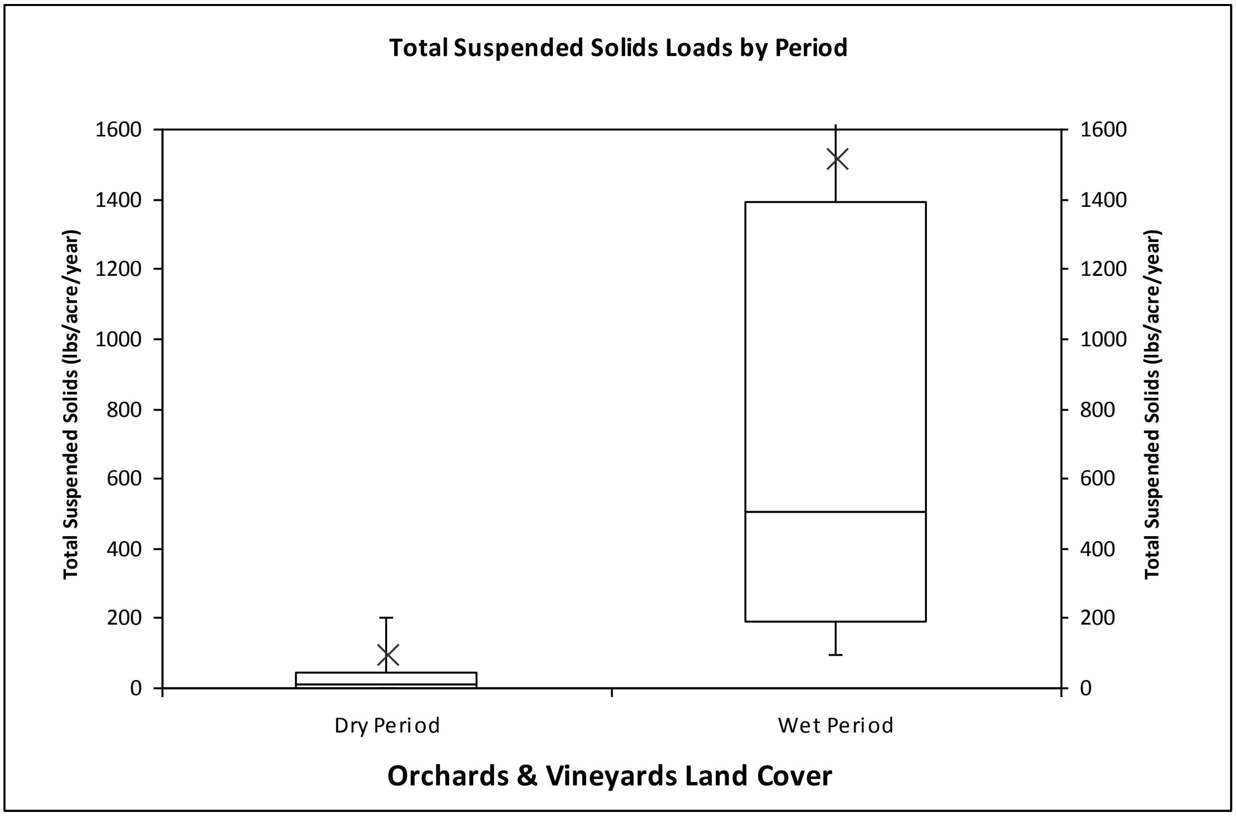

Figure 29. Distribution of Orchards & Vineyards Land Cover Total Suspended Solids Unit Area Loads

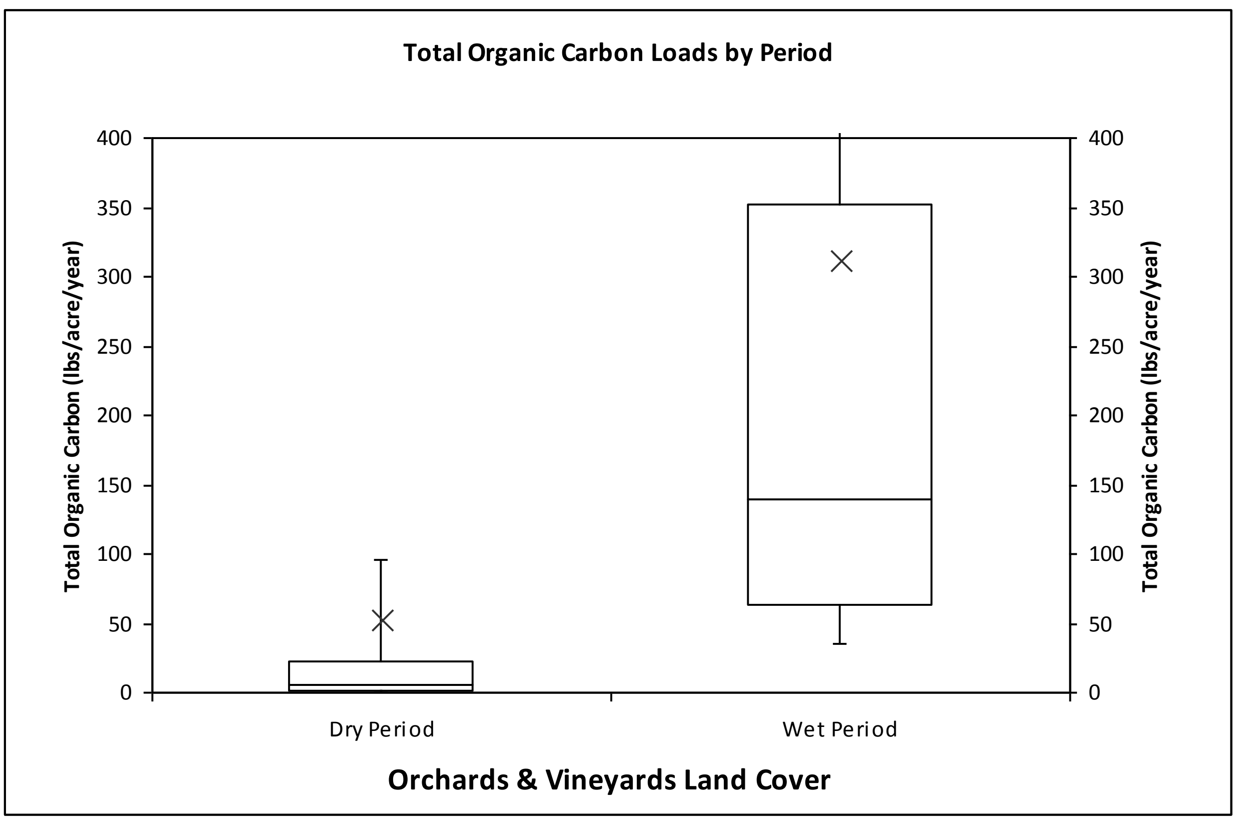

Figure 30. Distribution of Orchards & Vineyards Land Cover Total Organic Carbon Area Loads

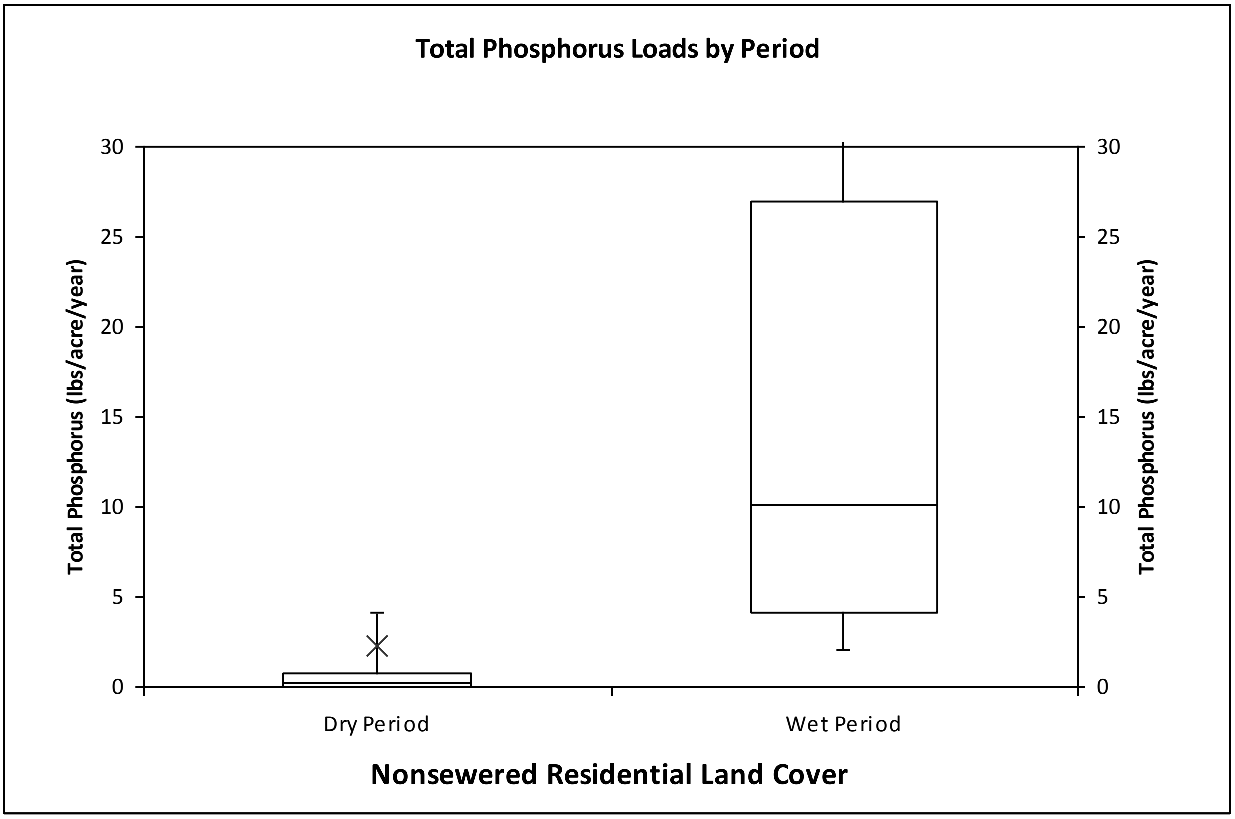

Figure 31. Distribution of Nonsewered Residential Land Cover Total Phosphorus Unit Area Loads

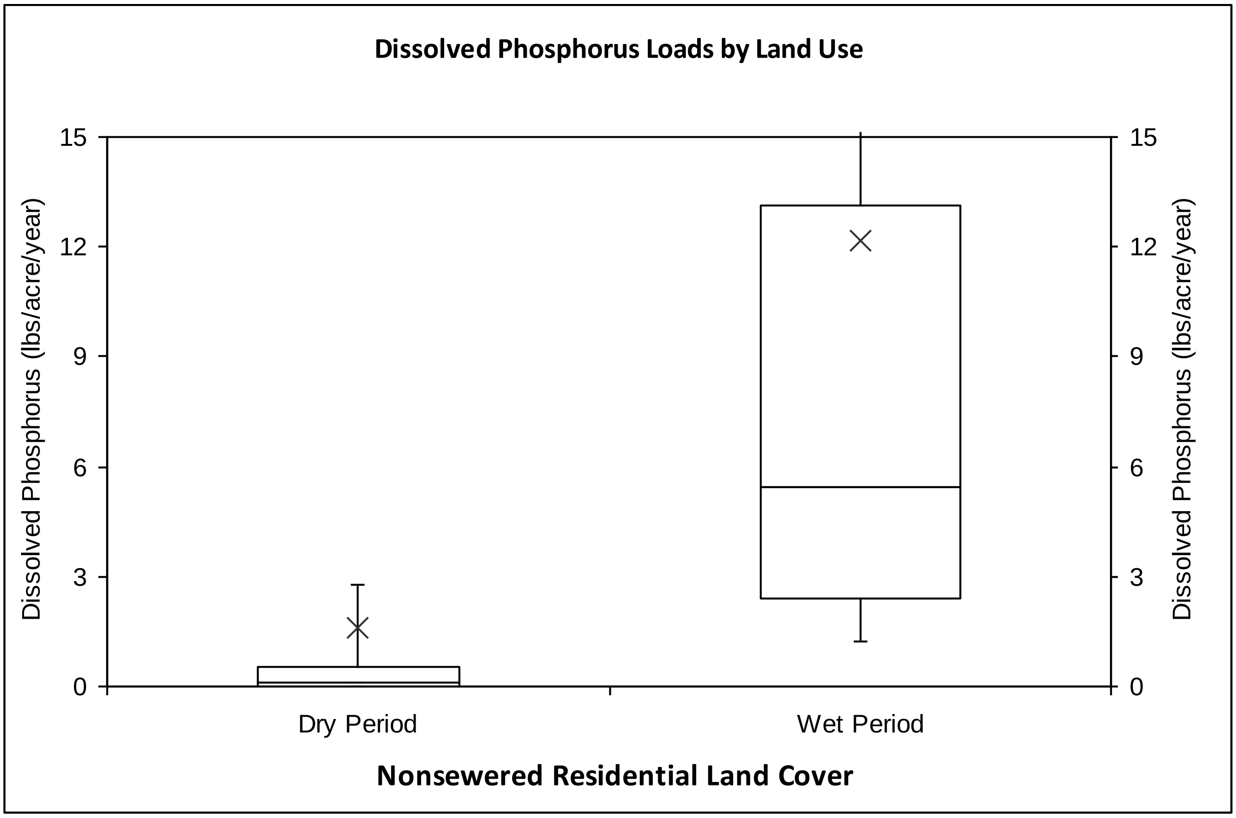

Figure 32. Distribution of Nonsewered Residential Land Cover Dissolved Phosphorus Unit Area Loads

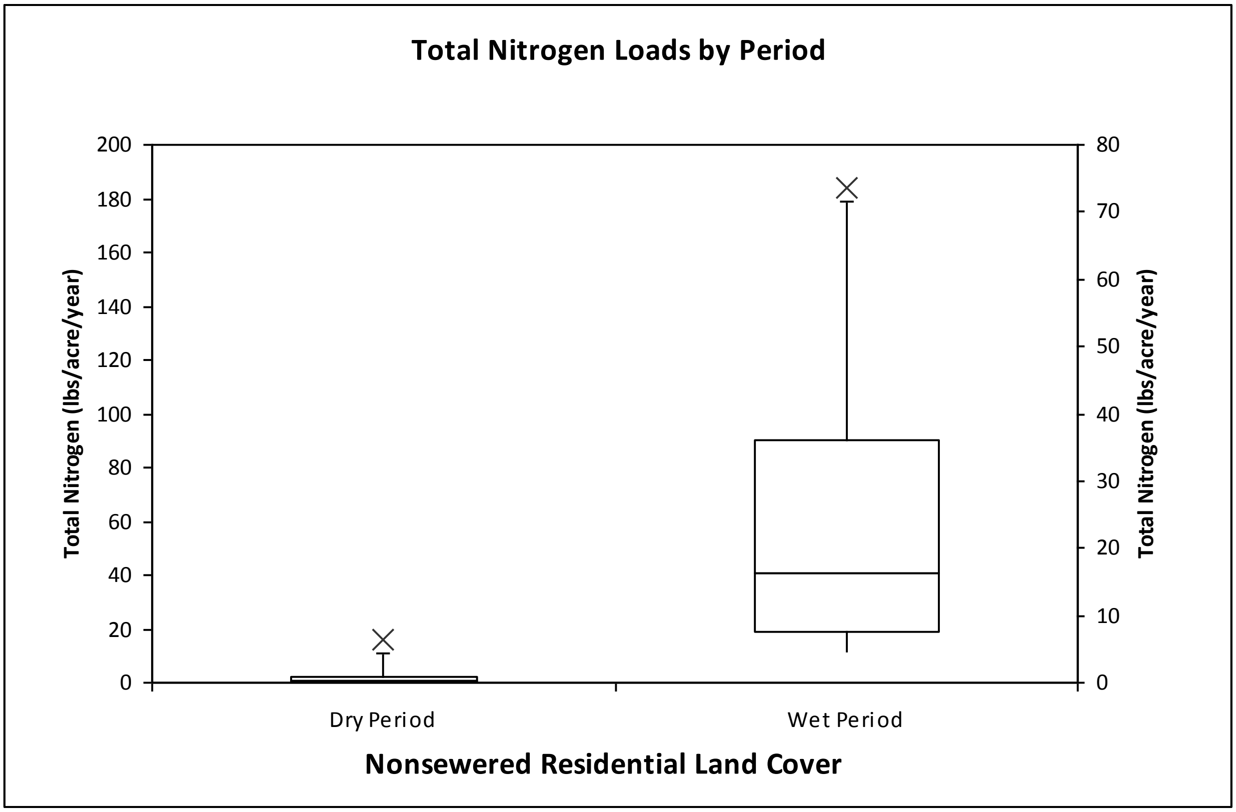

Figure 33. Distribution of Nonsewered Residential Land Cover Total Nitrogen Unit Area Loads

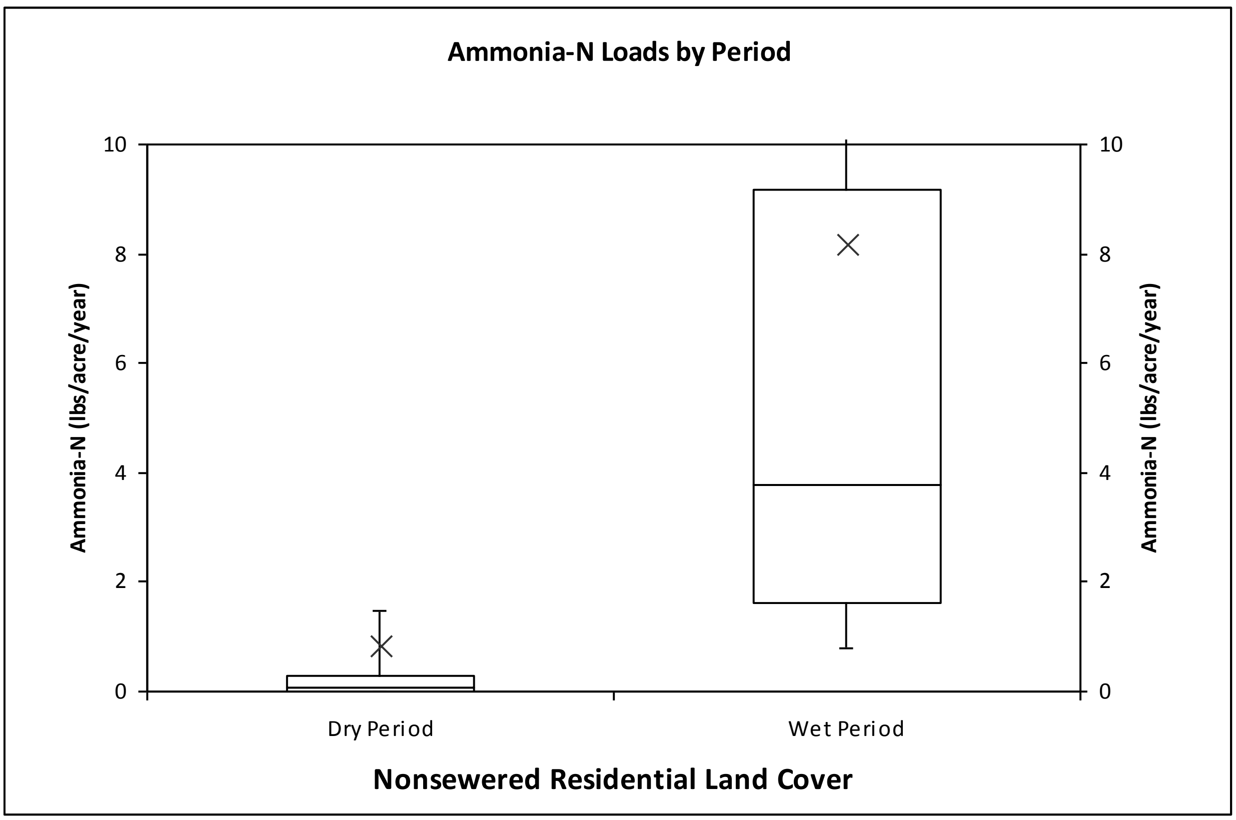

Figure 34. Distribution of Nonsewered Residential Land Cover Ammonia-N Unit Area Loads

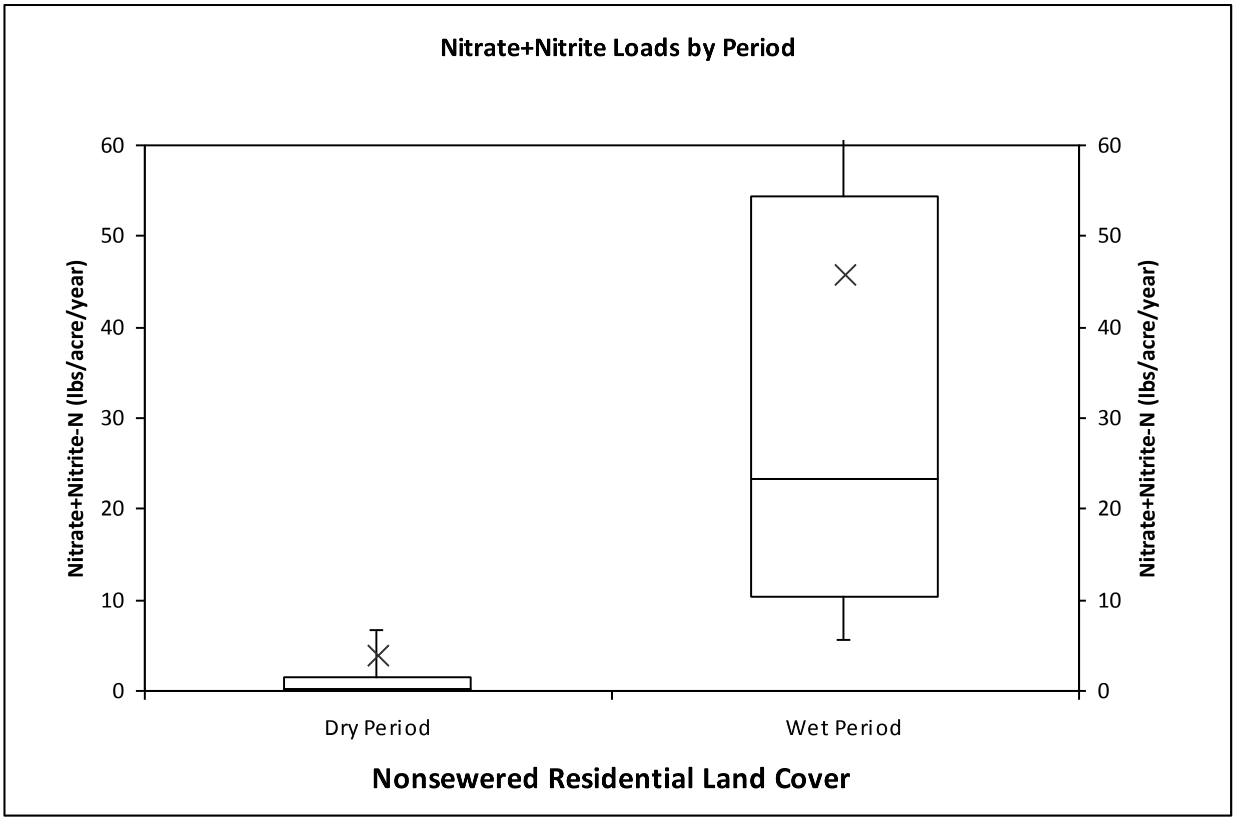

Figure 35. Distribution of Nonsewered Residential Land Cover Nitrate+Nitrite-N Unit Area Loads

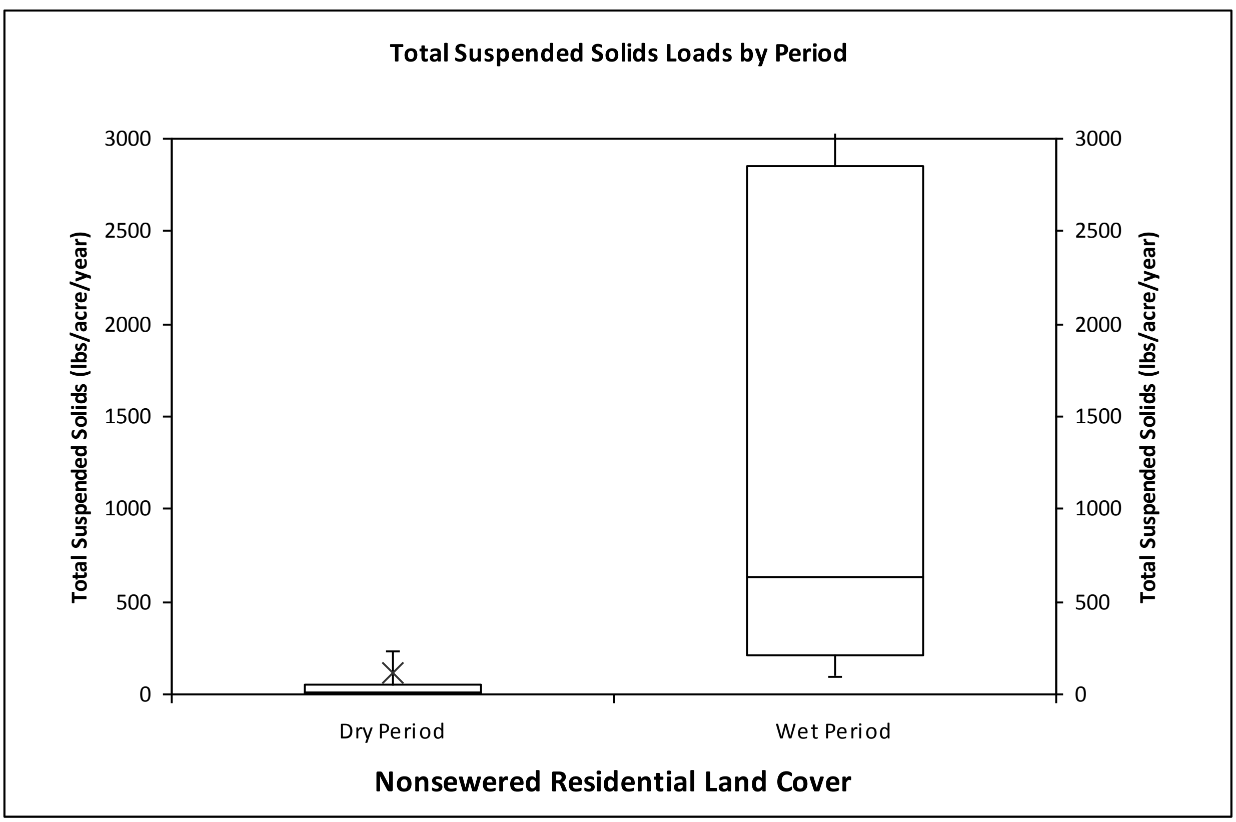

Figure 36. Distribution of Nonsewered Residential Land Cover Total Suspended Solids Unit Area Loads

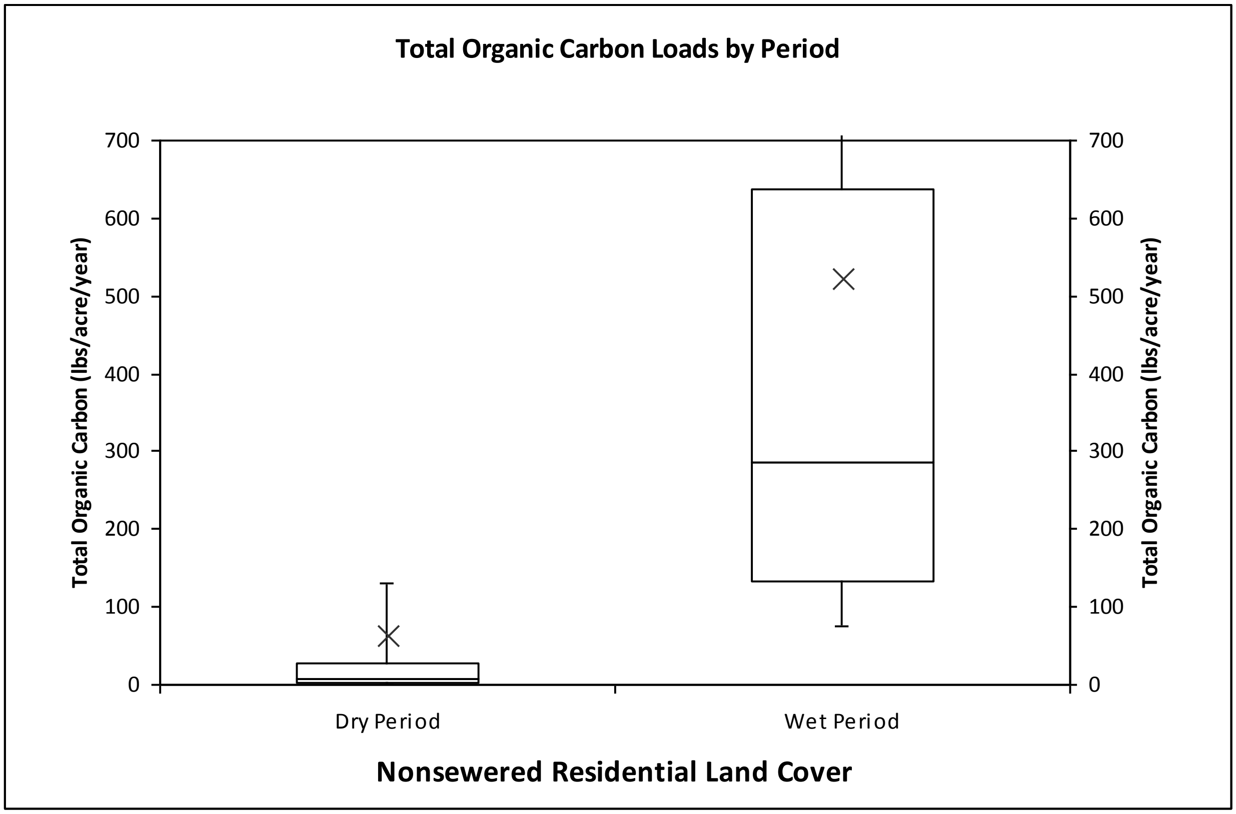

Figure 37. Distribution of Nonsewered Residential Land Cover Total Organic Carbon Area Loads

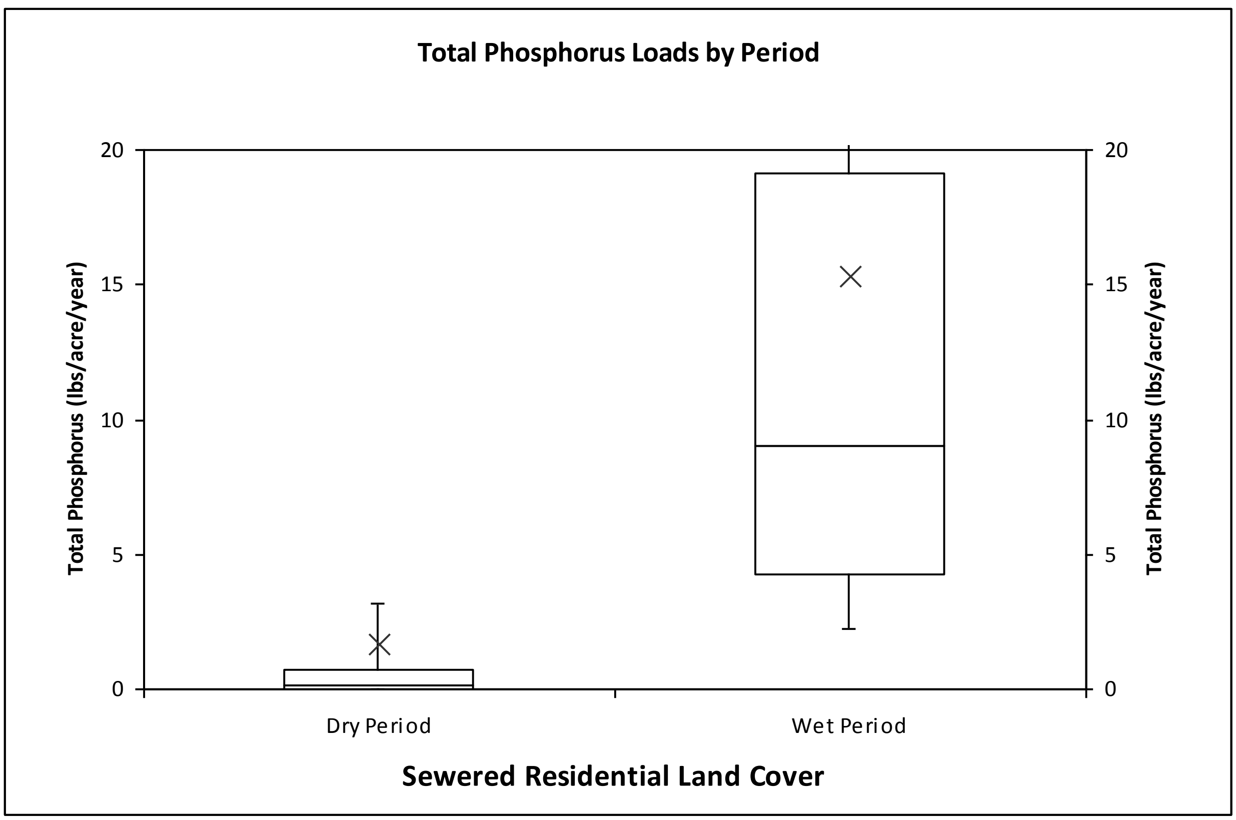

Figure 38. Distribution of Sewered Residential Land Cover Total Phosphorus Unit Area Loads

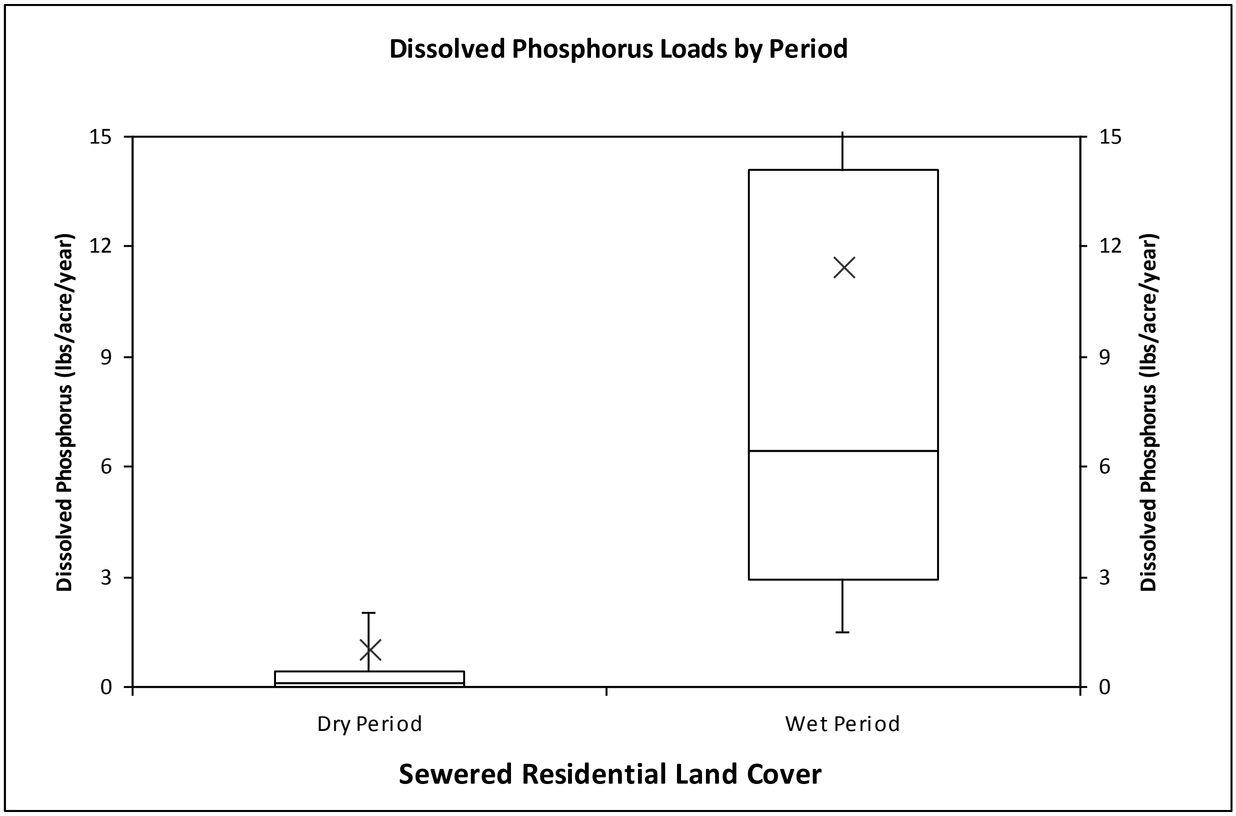

Figure 39. Distribution of Sewered Residential Land Cover Dissolved Phosphorus Unit Area Loads

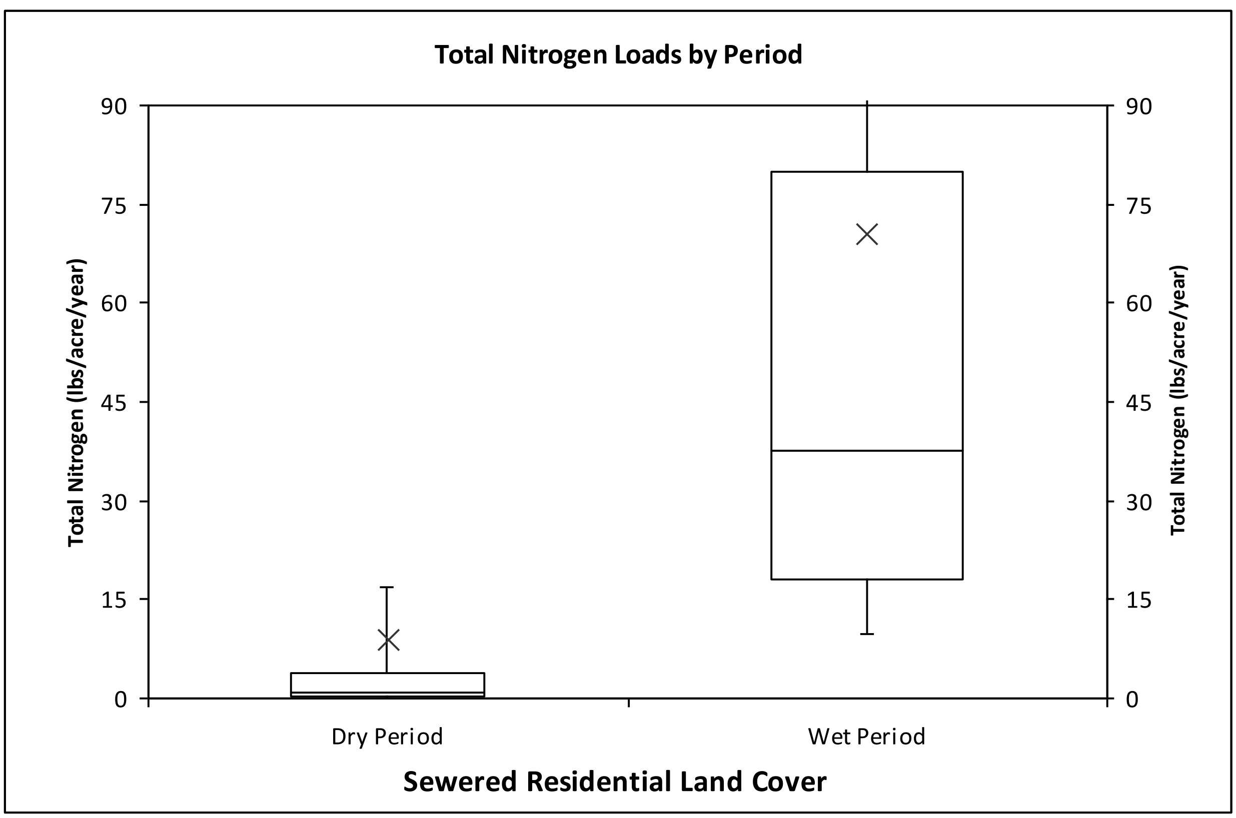

Figure 40. Distribution of Sewered Residential Land Cover Total Nitrogen Unit Area Loads

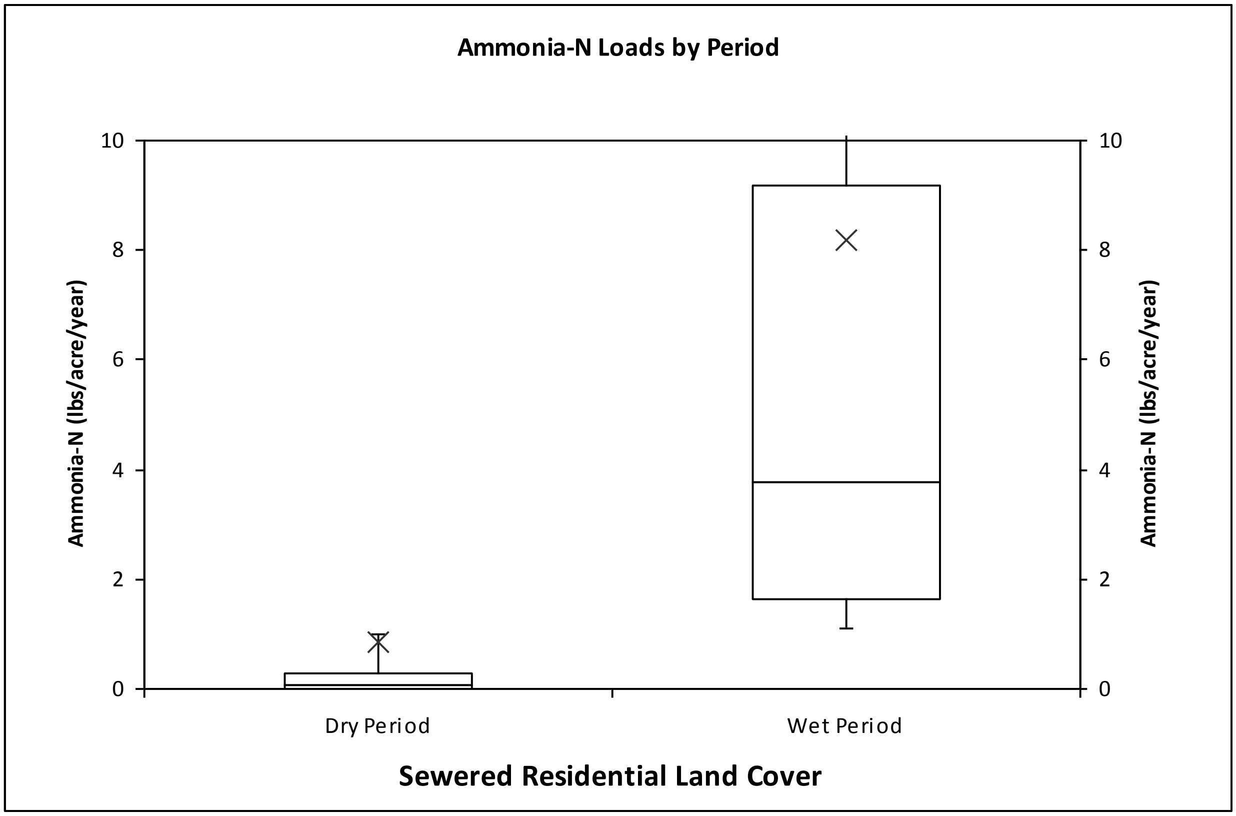

Figure 41. Distribution of Sewered Residential Land Cover Ammonia-N Unit Area Loads

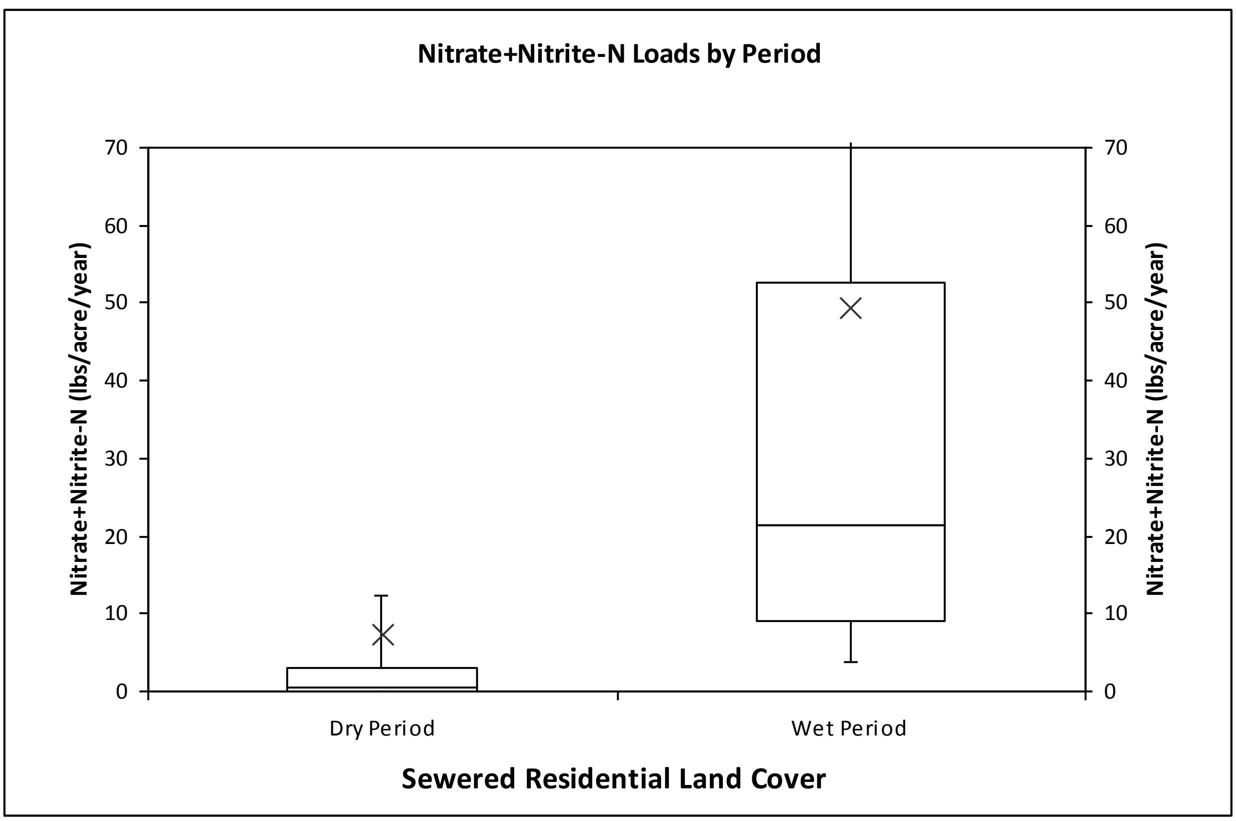

Figure 42. Distribution of Sewered Residential Land Cover Nitrate+Nitrite-N Unit Area Loads

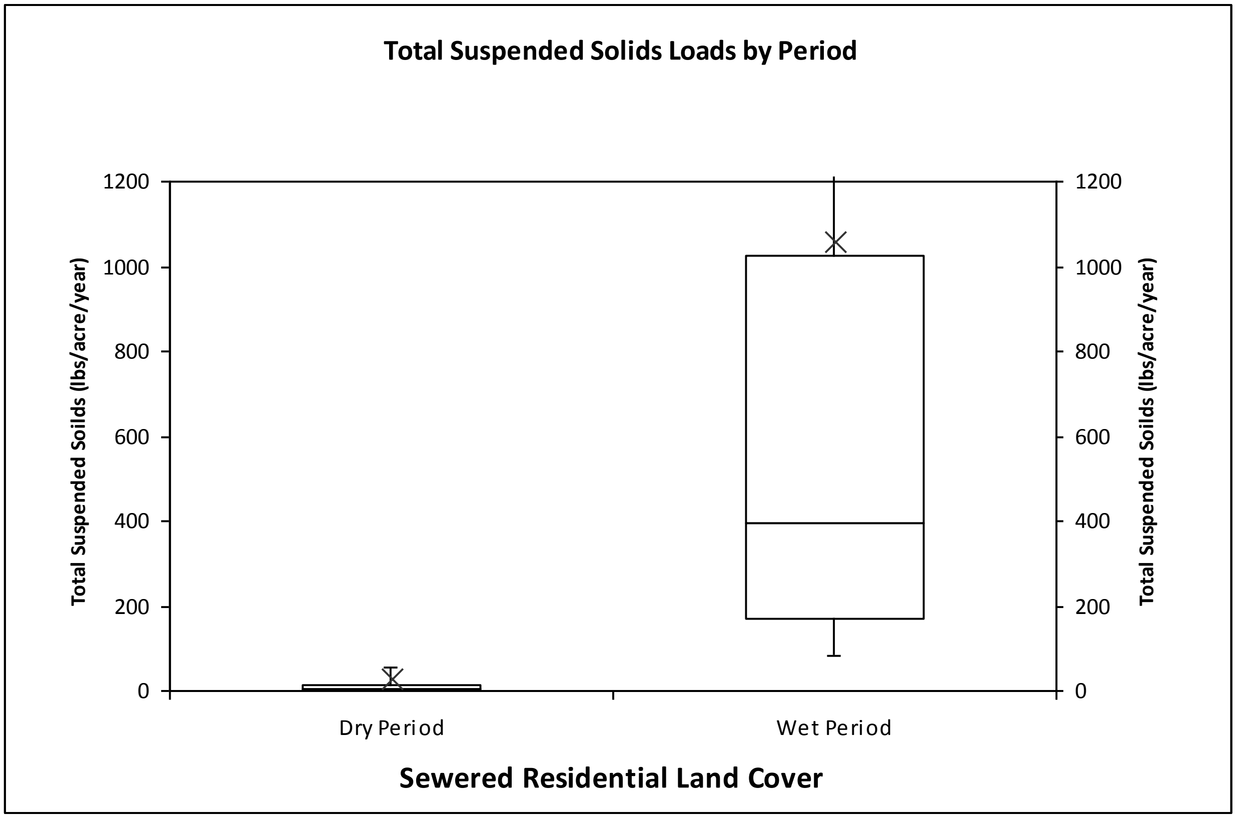

Figure 43. Distribution of Sewered Residential Land Cover Total Suspended Solids Unit Area Loads

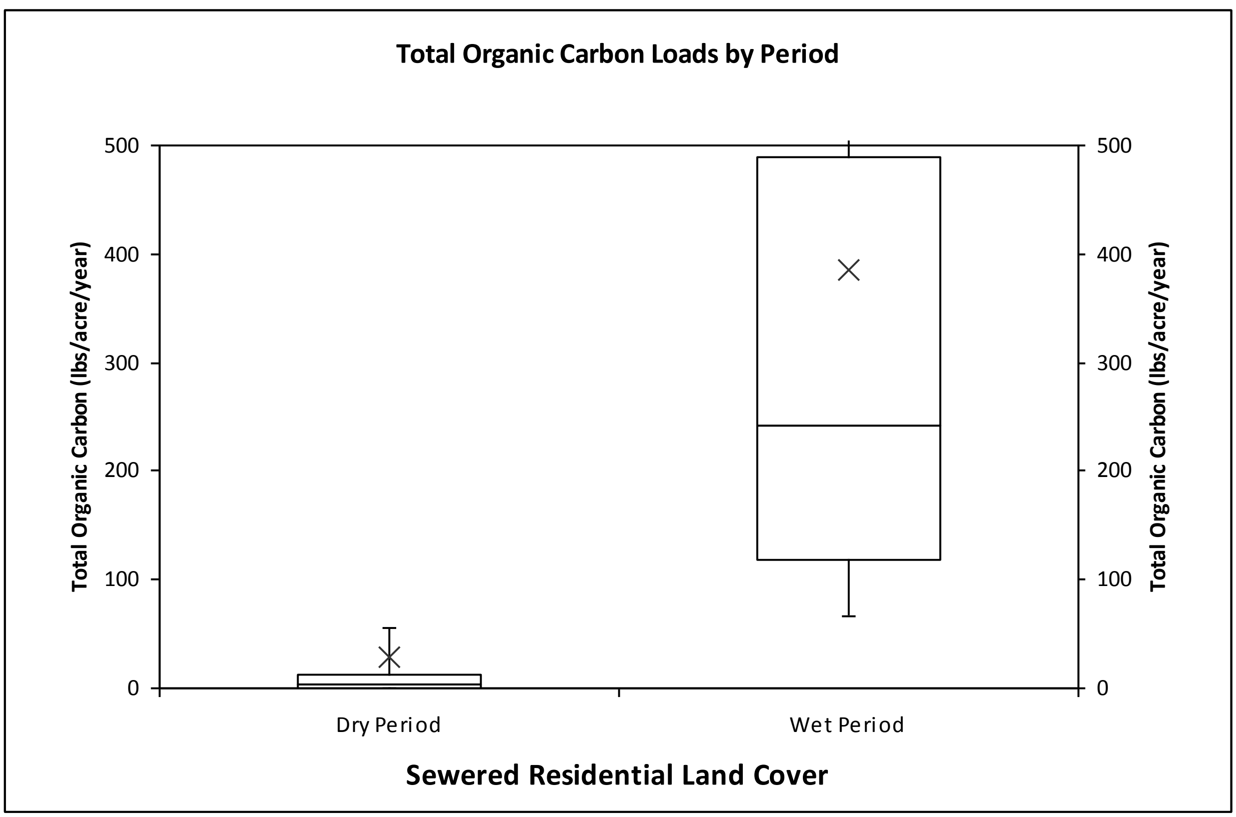

Figure 44. Distribution of Sewered Residential Land Cover Total Organic Carbon Area Loads

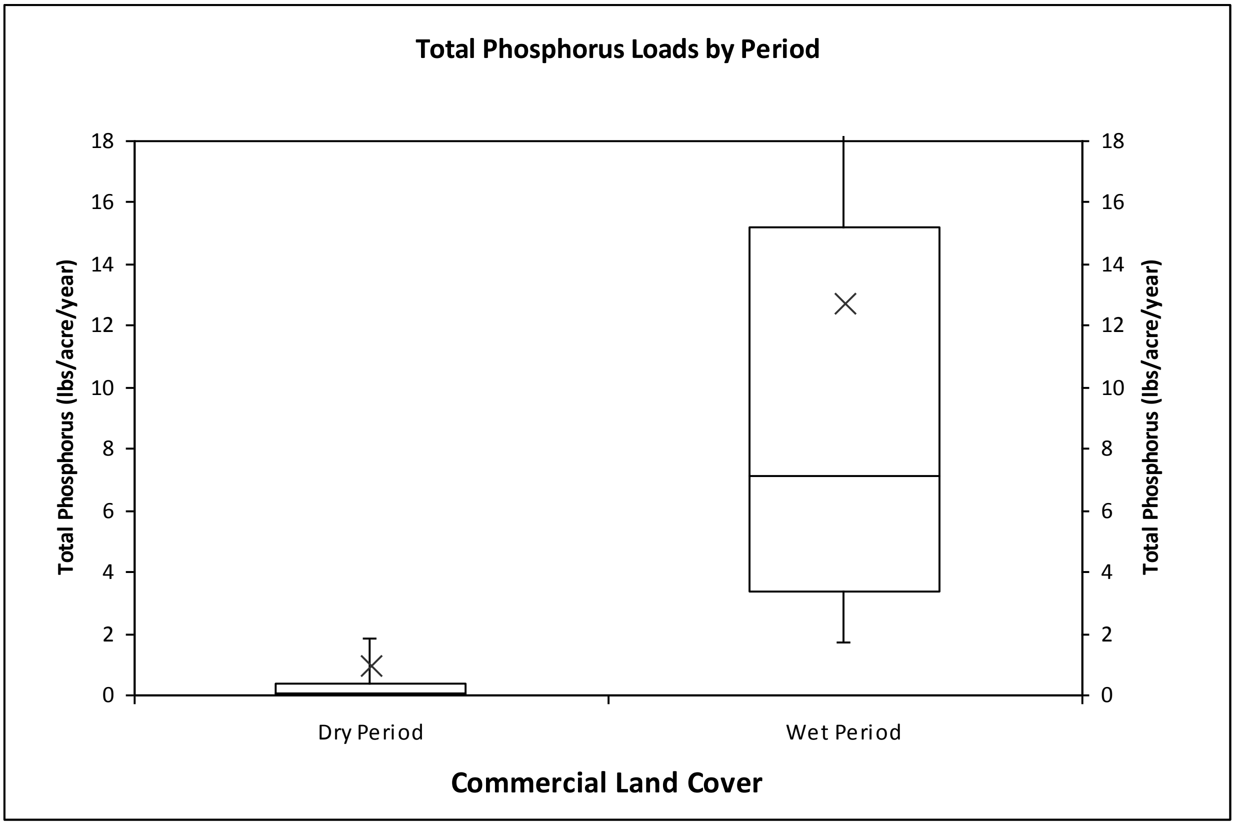

Figure 45. Distribution of Commercial Land Cover Total Phosphorus Unit Area Loads

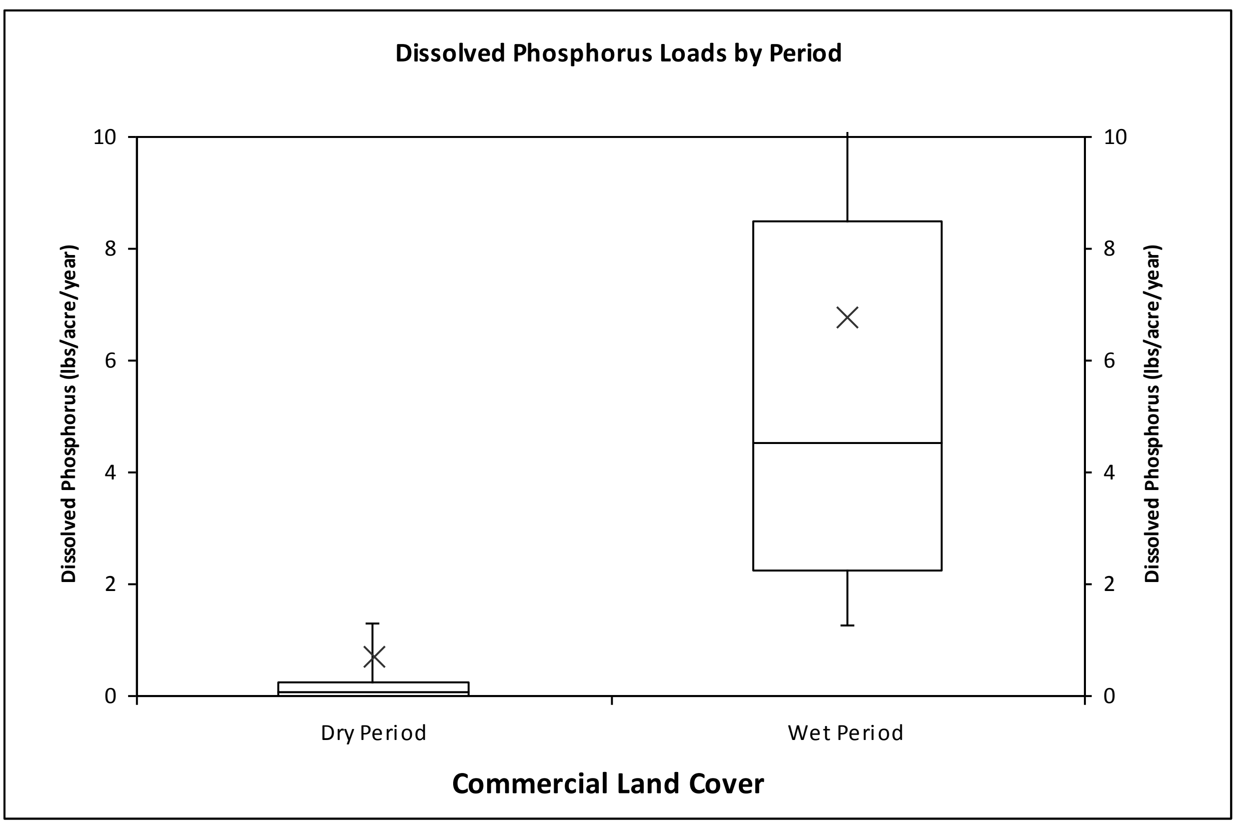

Figure 46. Distribution of Commercial Land Cover Dissolved Phosphorus Unit Area Loads

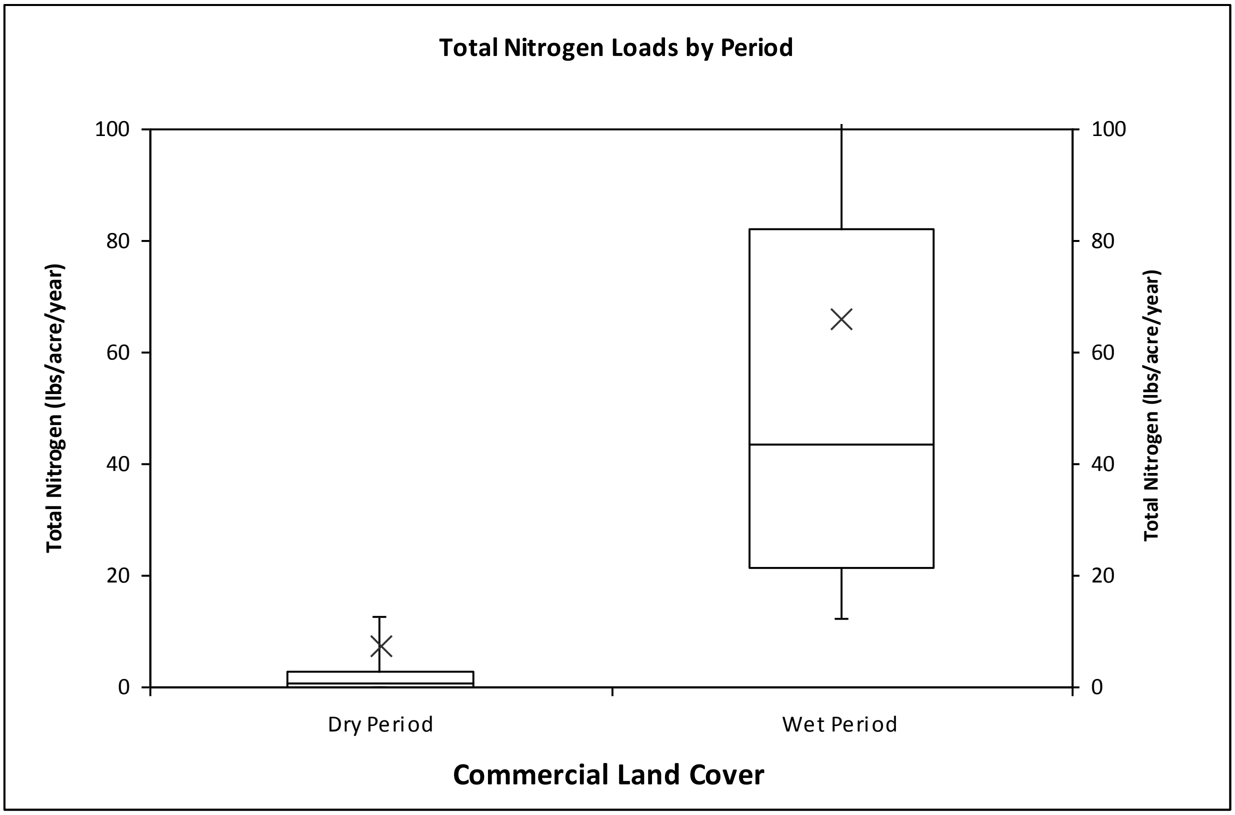

Figure 47. Distribution of Commercial Land Cover Total Nitrogen Unit Area Loads

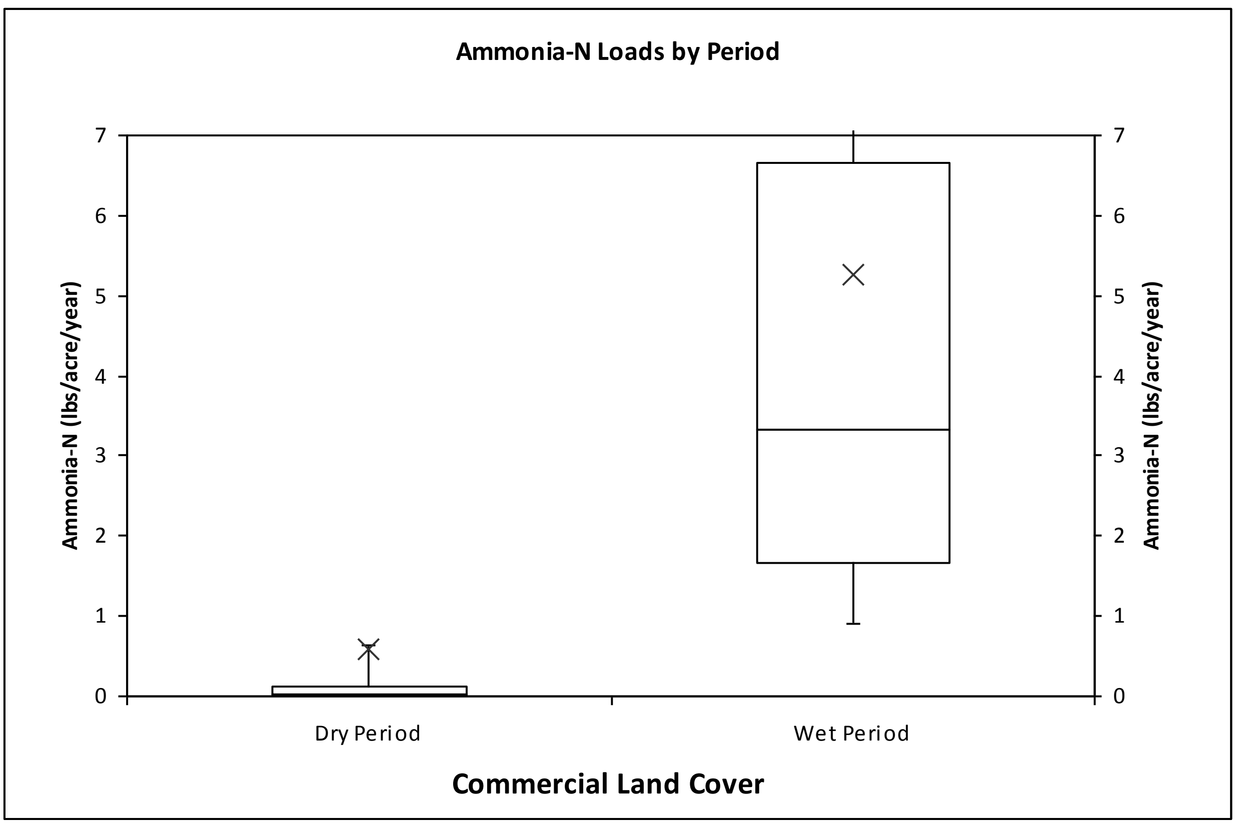

Figure 48. Distribution of Commercial Urban Land Cover Ammonia-N Unit Area Loads

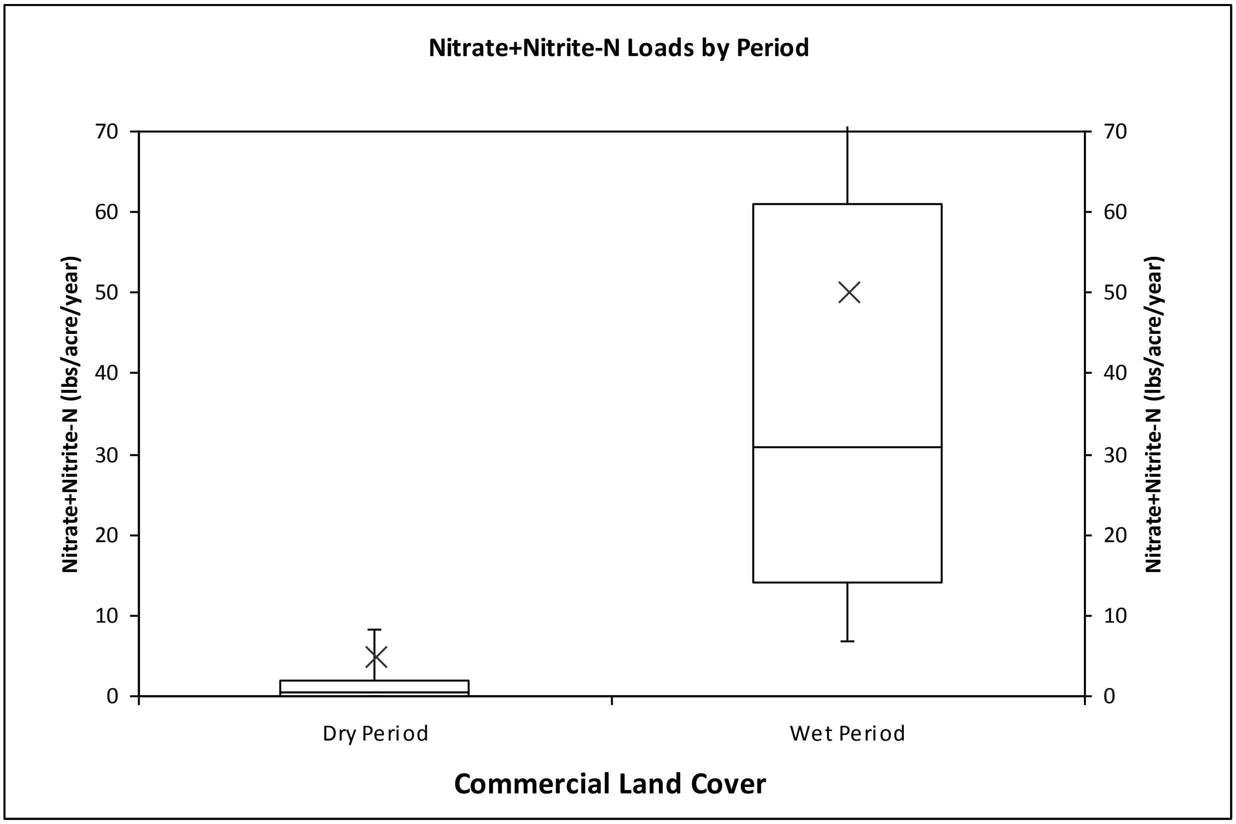

Figure 49. Distribution of Commercial Land Cover Nitrate+Nitrite-N Unit Area Loads

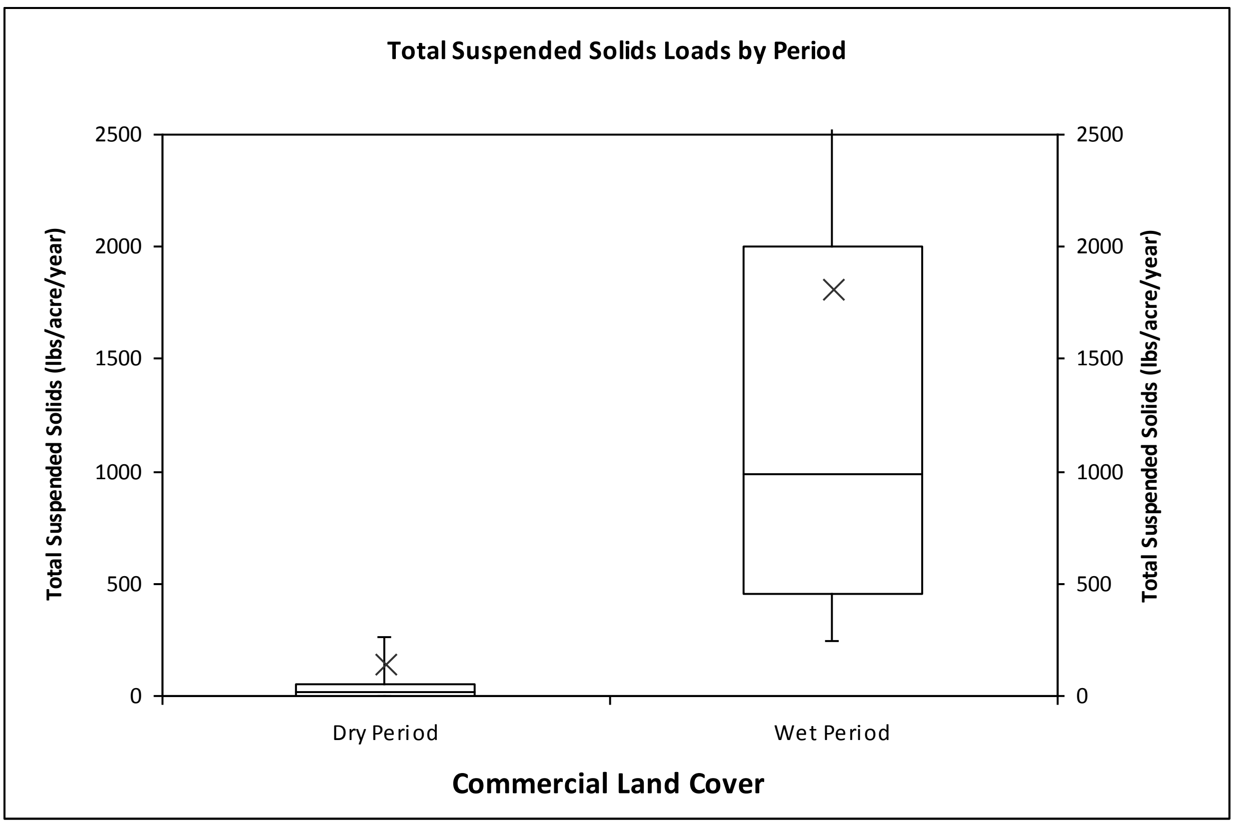

Figure 50. Distribution of Commercial Land Cover Total Suspended Solids Unit Area Loads

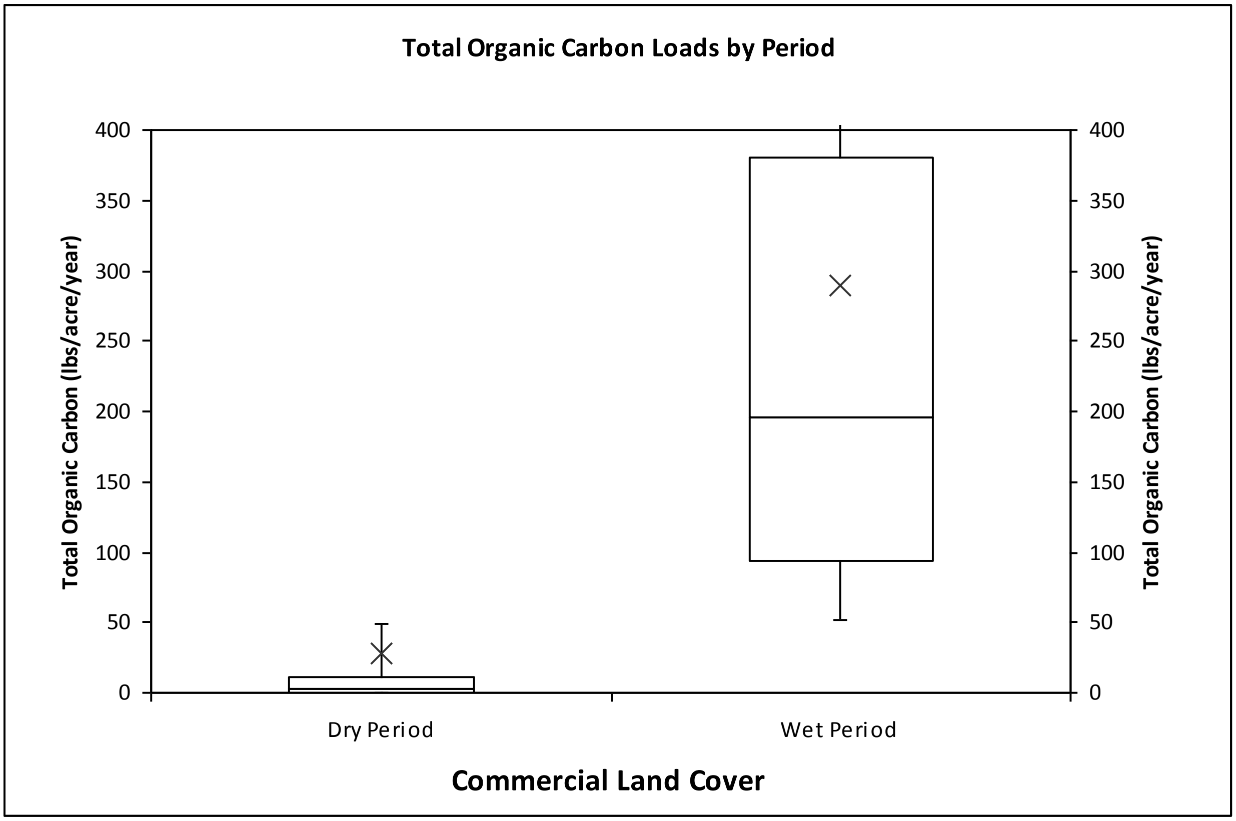

Figure 51. Distribution of Commercial Land Cover Total Organic Carbon Area Loads

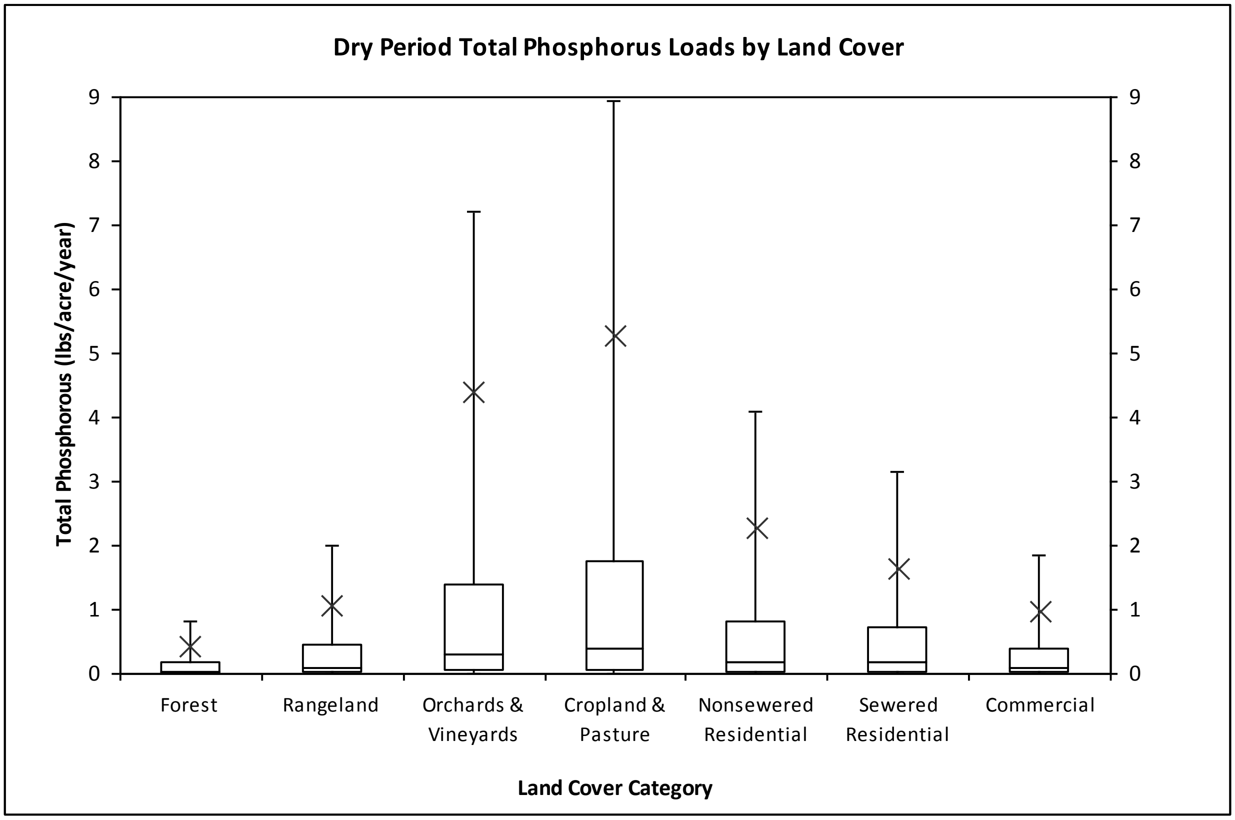

Figure 52. Comparison of the Distribution of Dry Period Total Phosphorus Unit Area Load between Land Covers.

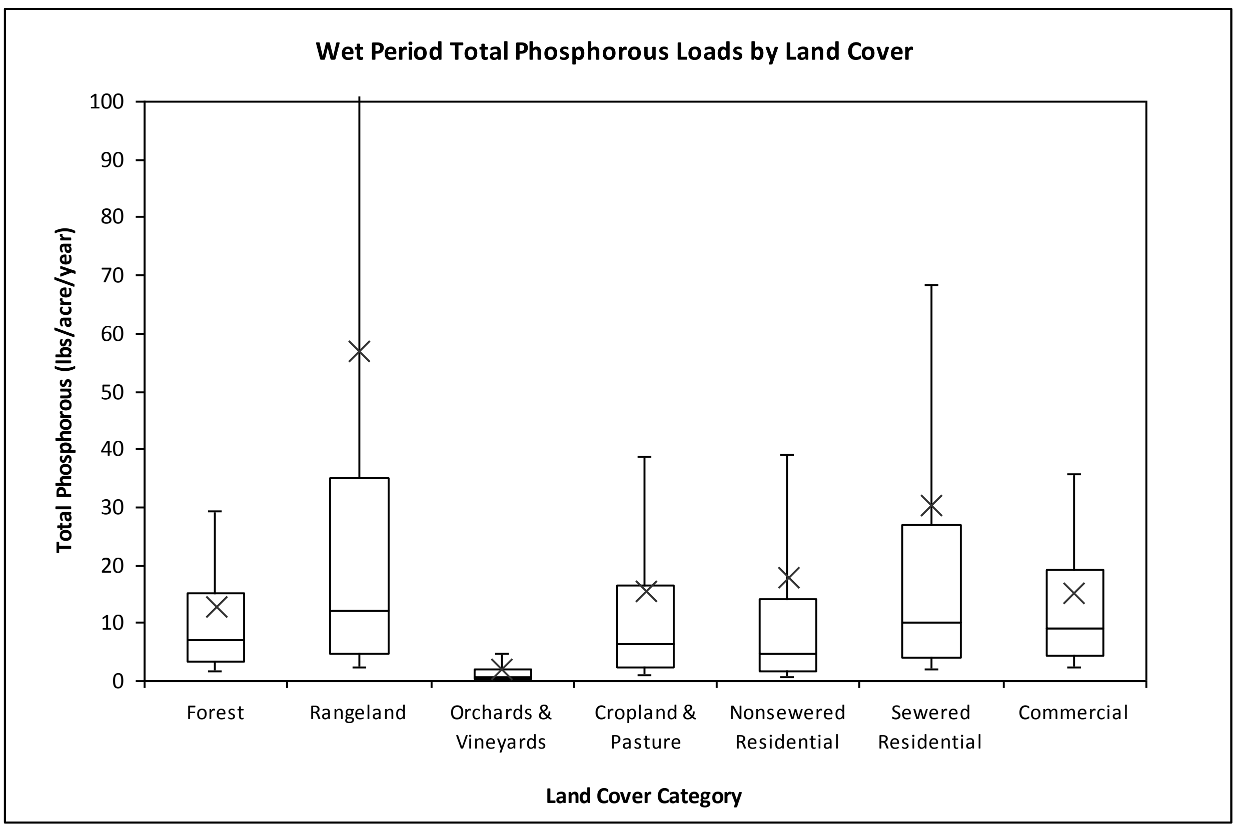

Figure 53. Comparison of the Distribution of Wet Period Total Phosphorus Unit Area Load between Land Covers.

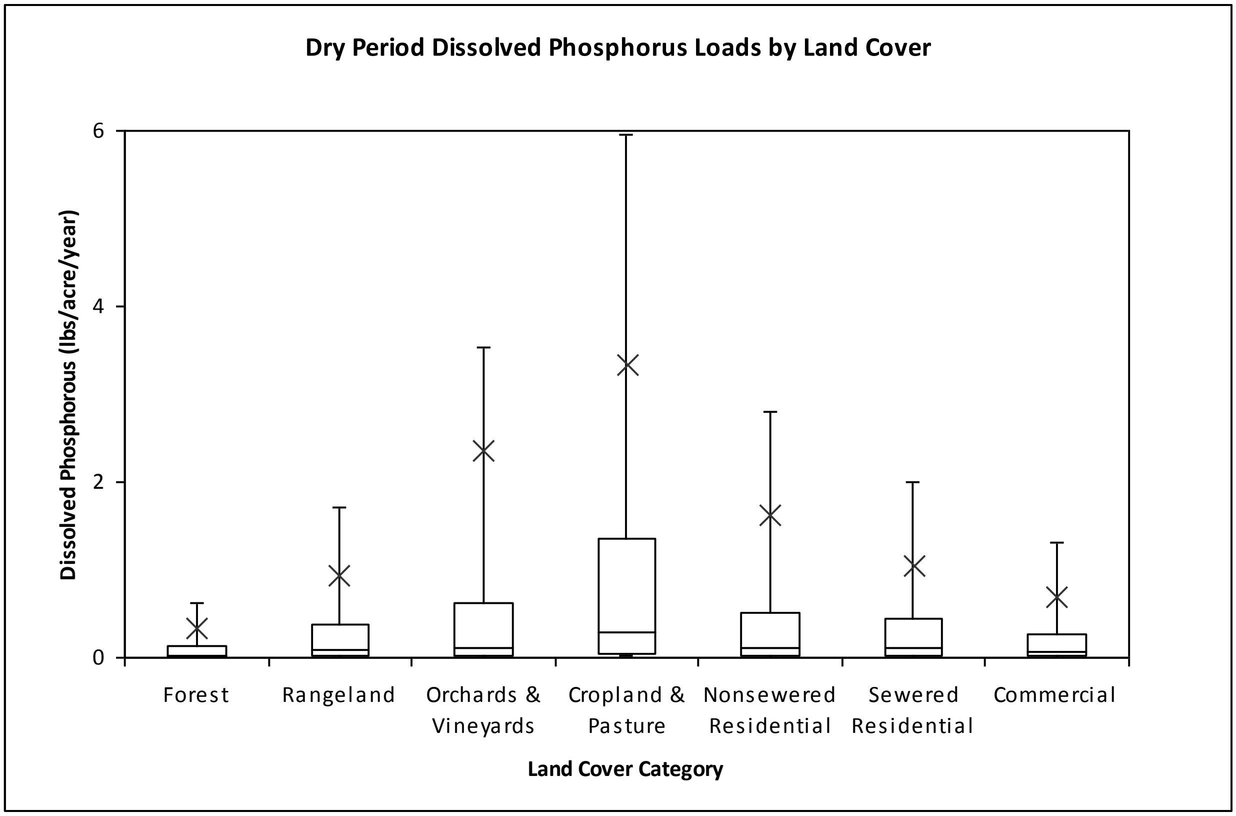

Figure 54. Comparison of the Distribution of Dry Period Dissolved Phosphorus Unit Area Load between Land Covers.

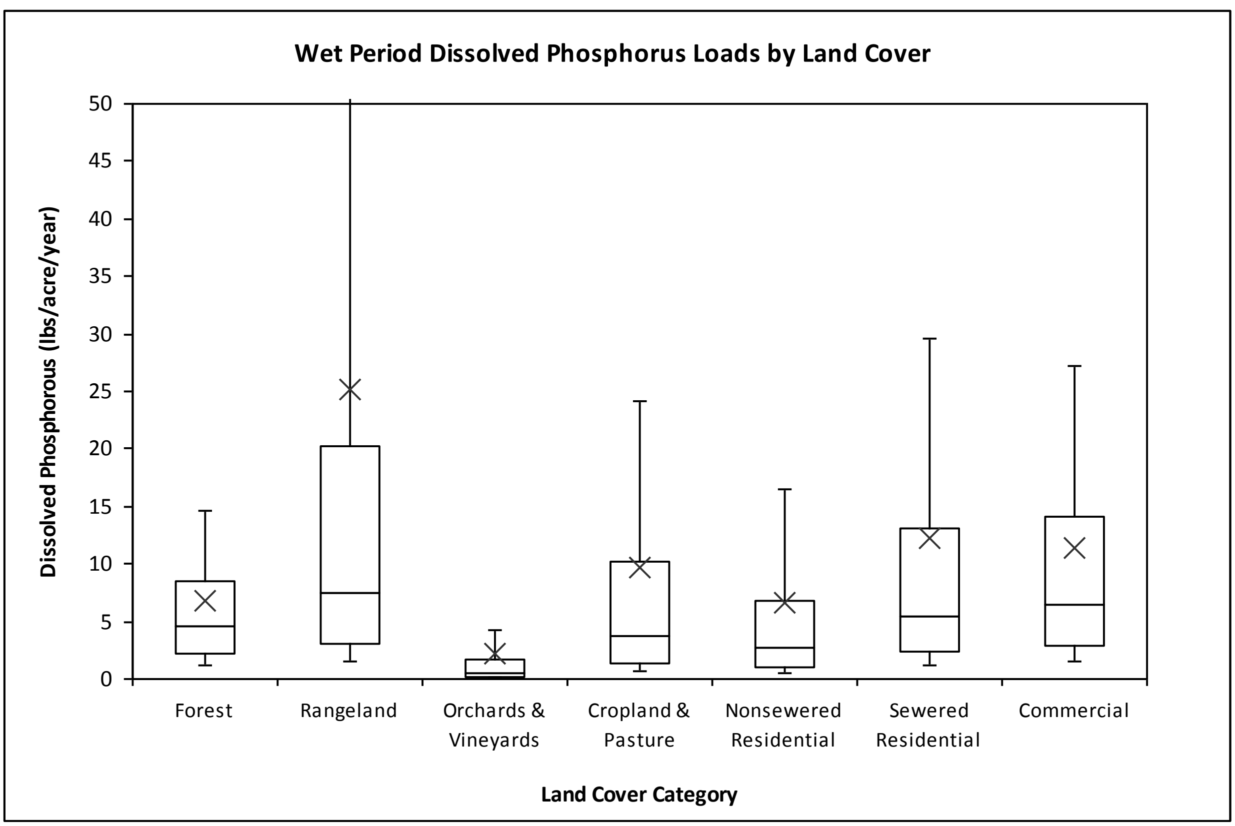

Figure 55. Comparison of the Distribution of Wet Period Dissolved Phosphorus Unit Area Load between Land Covers.

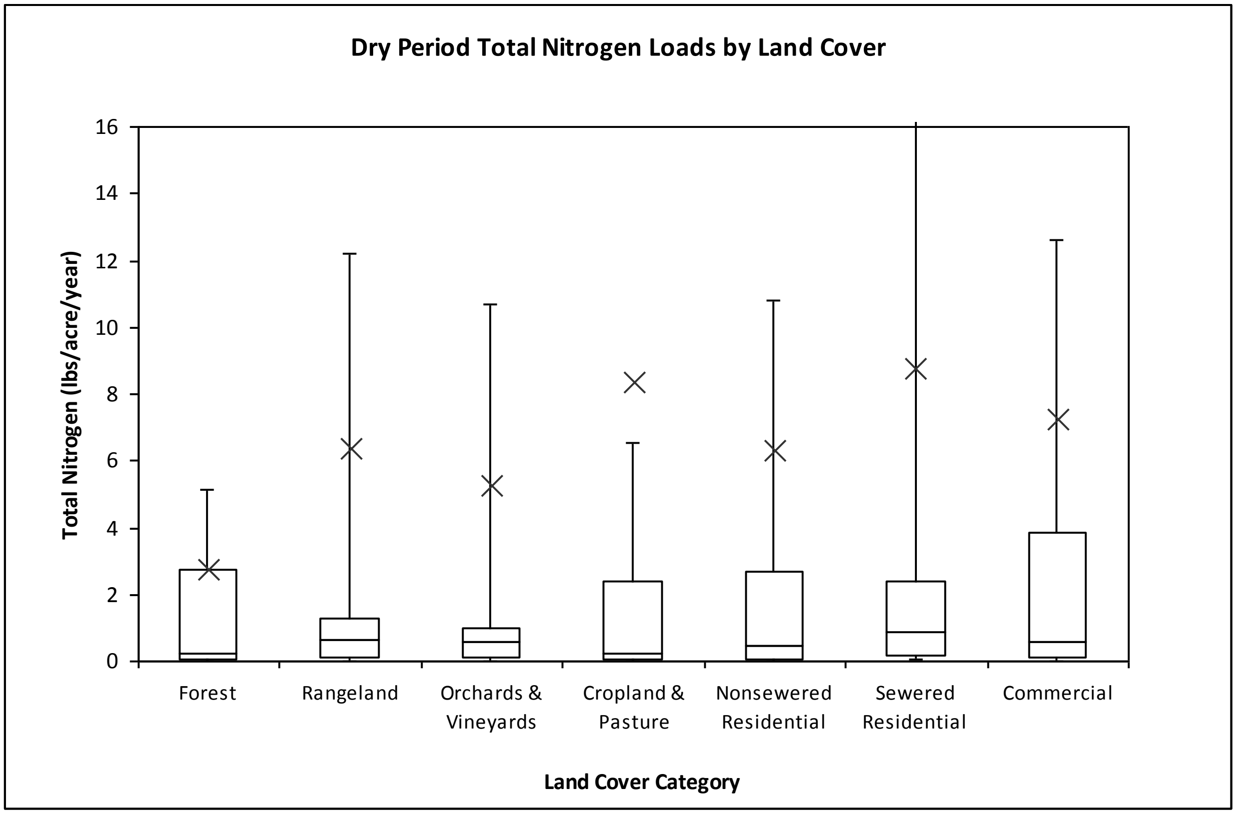

Figure 56. Comparison of the Distribution of Dry Period Total Nitrogen Unit Area Load between Land Covers.

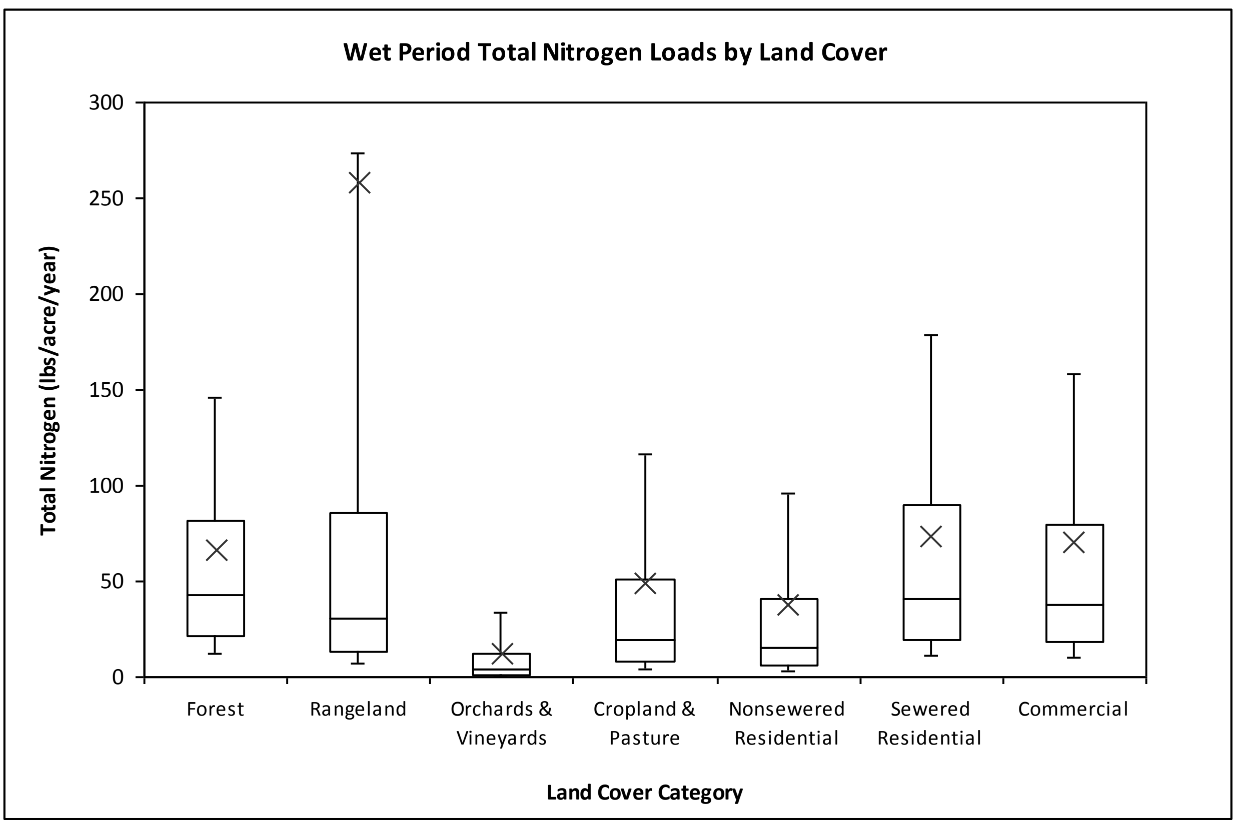

Figure 57. Comparison of the Distribution of Wet Period Total Nitrogen Unit Area Load between Land Covers.

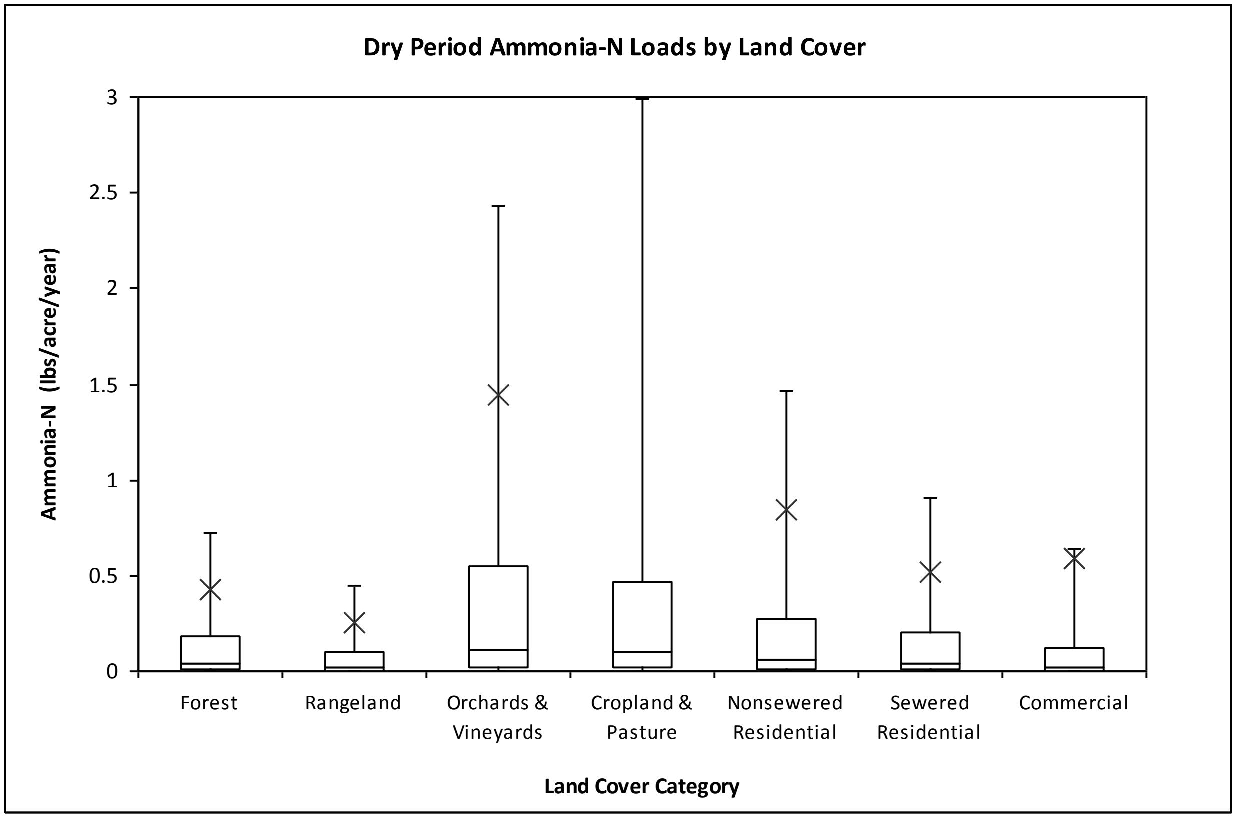

Figure 58. Comparison of the Distribution of Dry Period Ammonia-N Unit Area Load between Land Covers.

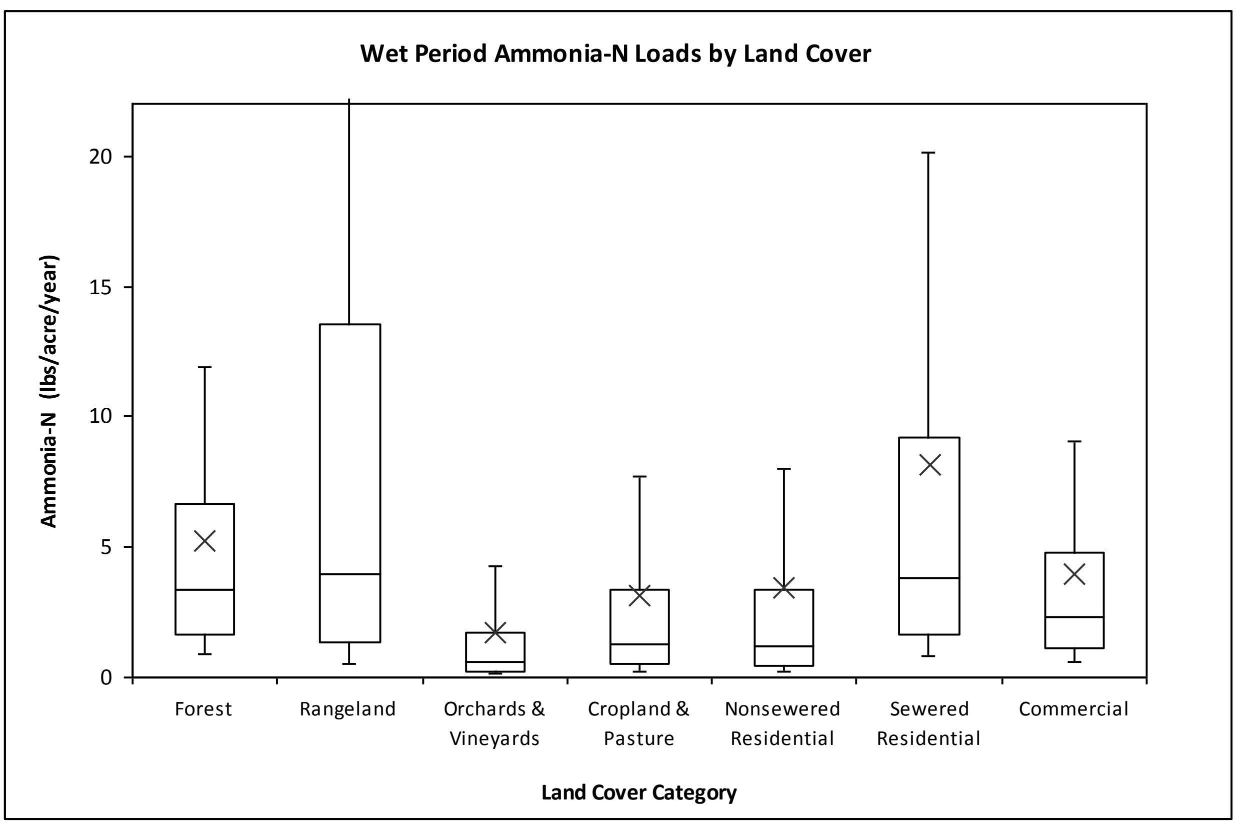

Figure 59. Comparison of the Distribution of Wet Period Ammonia-N Unit Area Load between Land Covers.

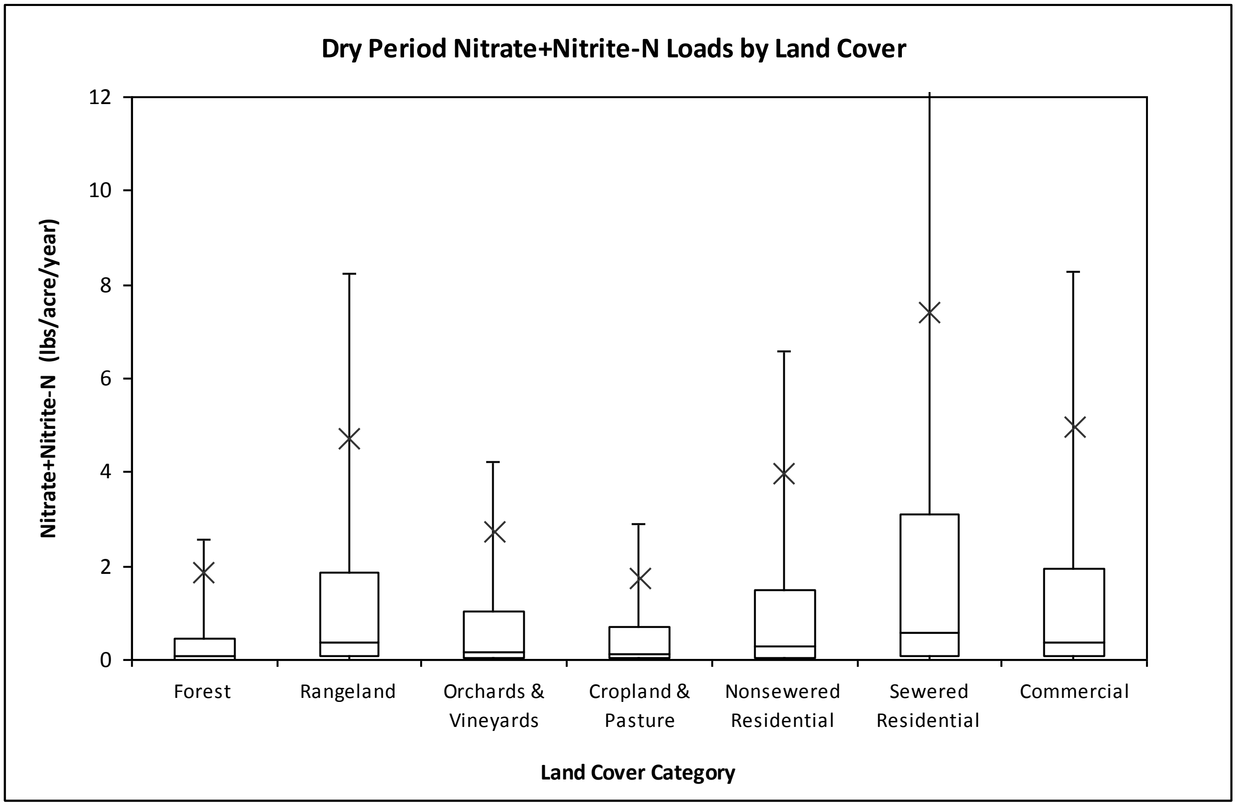

Figure 60. Comparison of the Distribution of Dry Period Nitrate-Nitrite-N Unit Area Load between Land Covers.

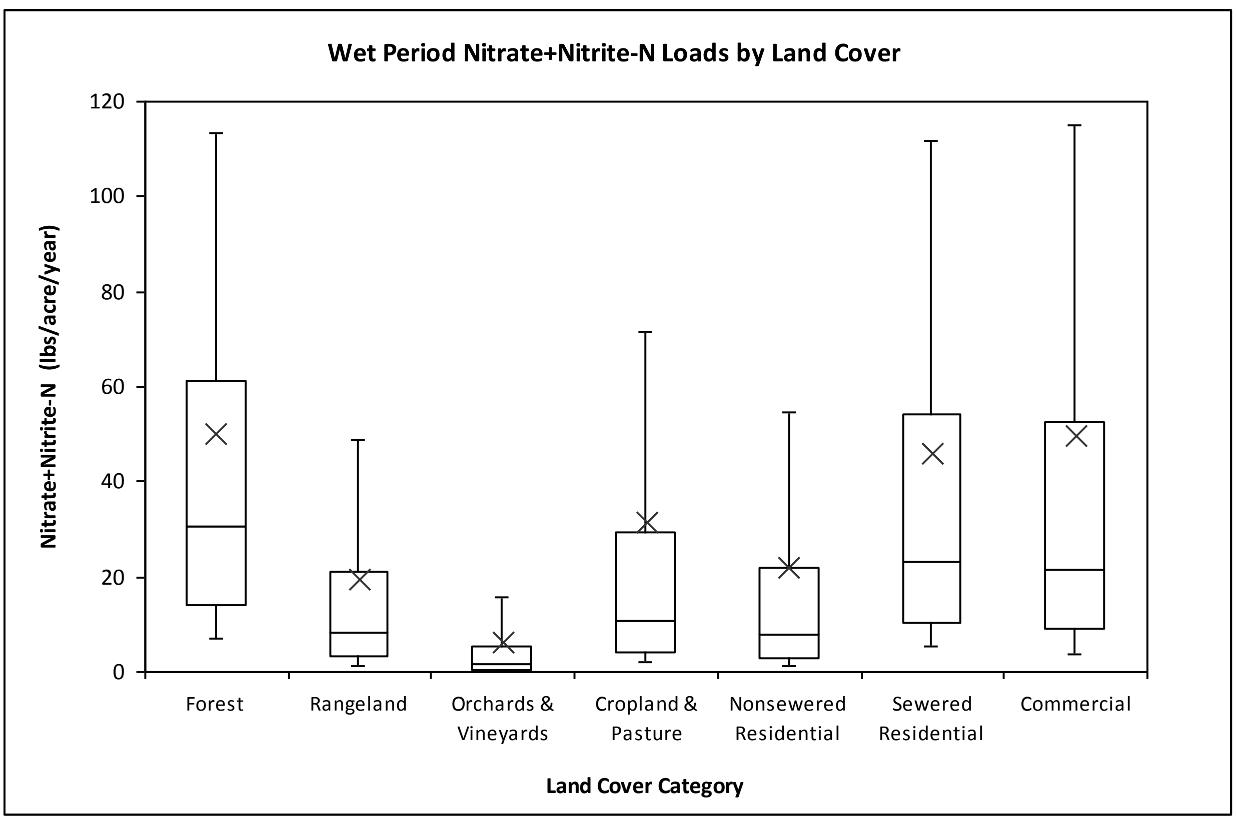

Figure 61. Comparison of the Distribution of Wet Period Nitrate+Nitrite-N Unit Area Load between Land Covers.

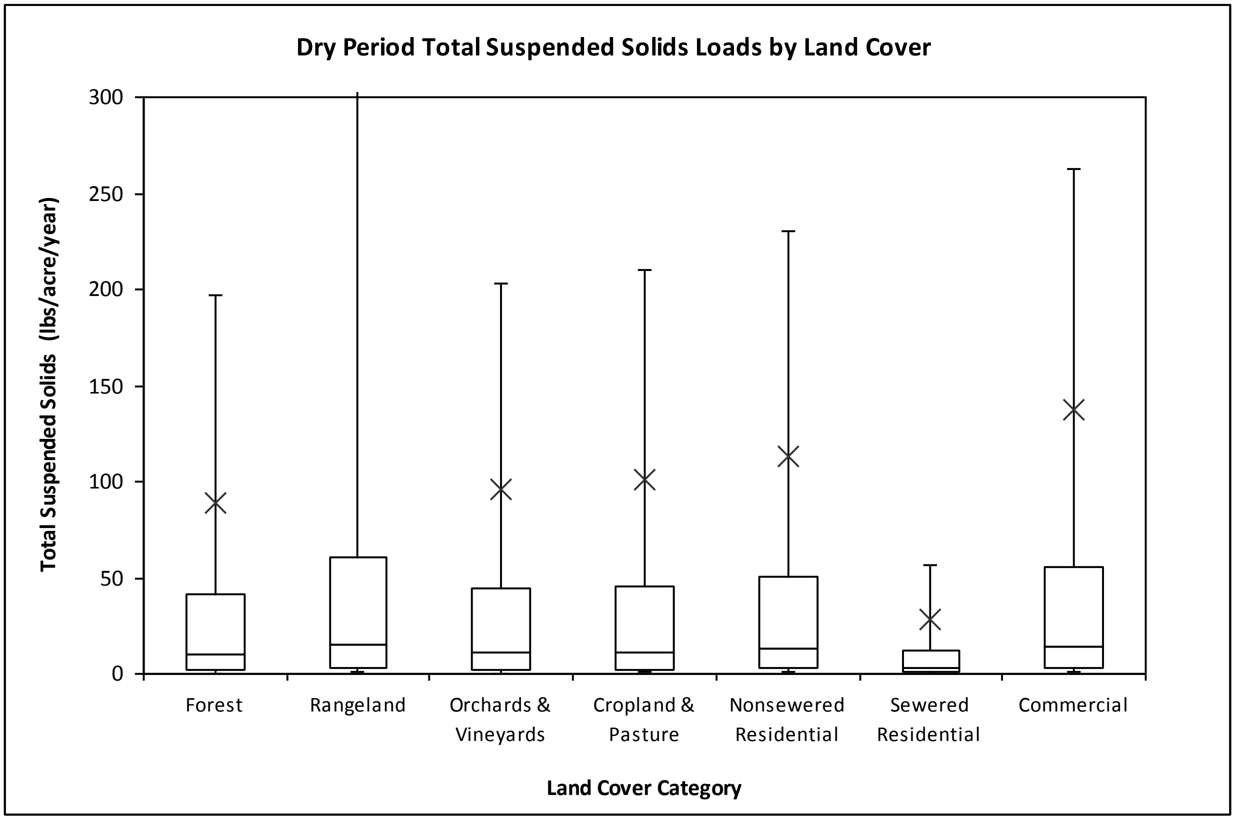

Figure 62. Comparison of the Distribution of Dry Period Total Suspended Solids Unit Area Load between Land Covers.

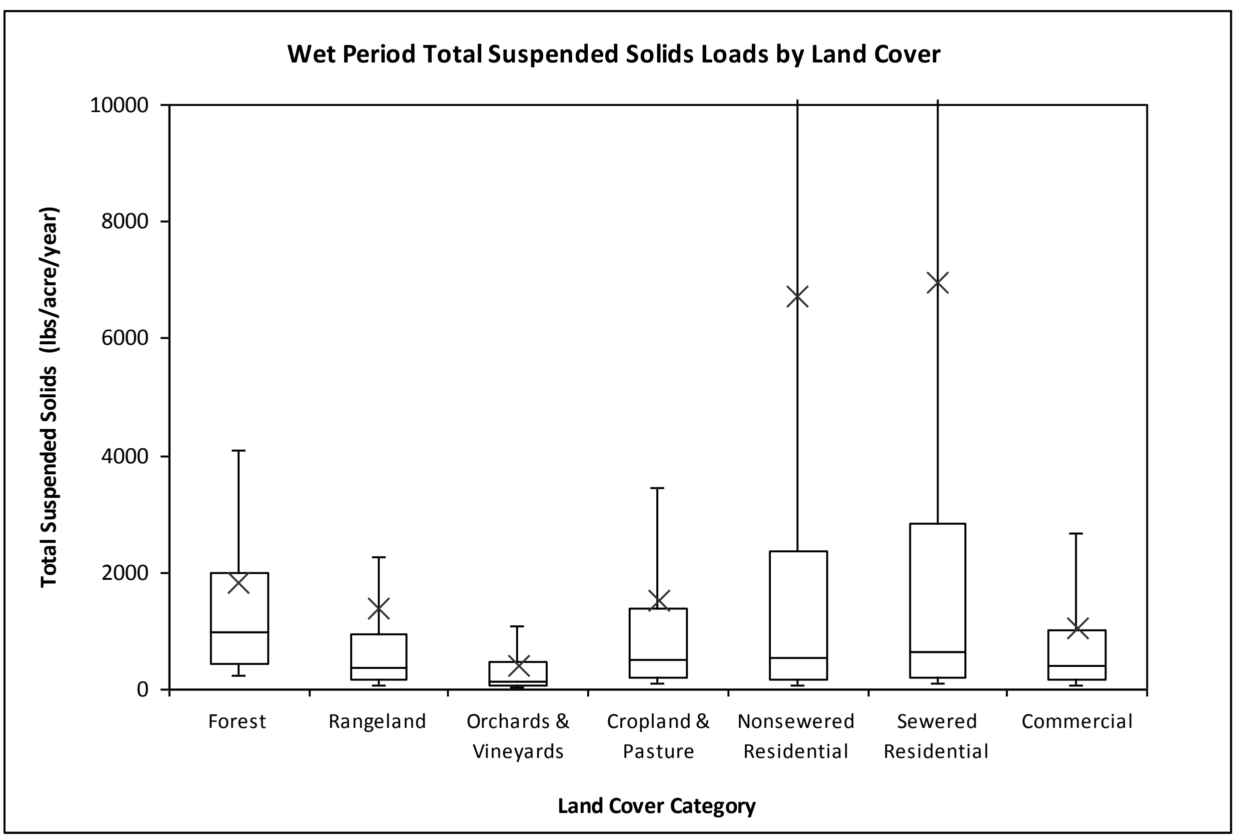

Figure 63. Comparison of the Distribution of Wet Period Total Suspended Solids Unit Area Load between Land Covers.

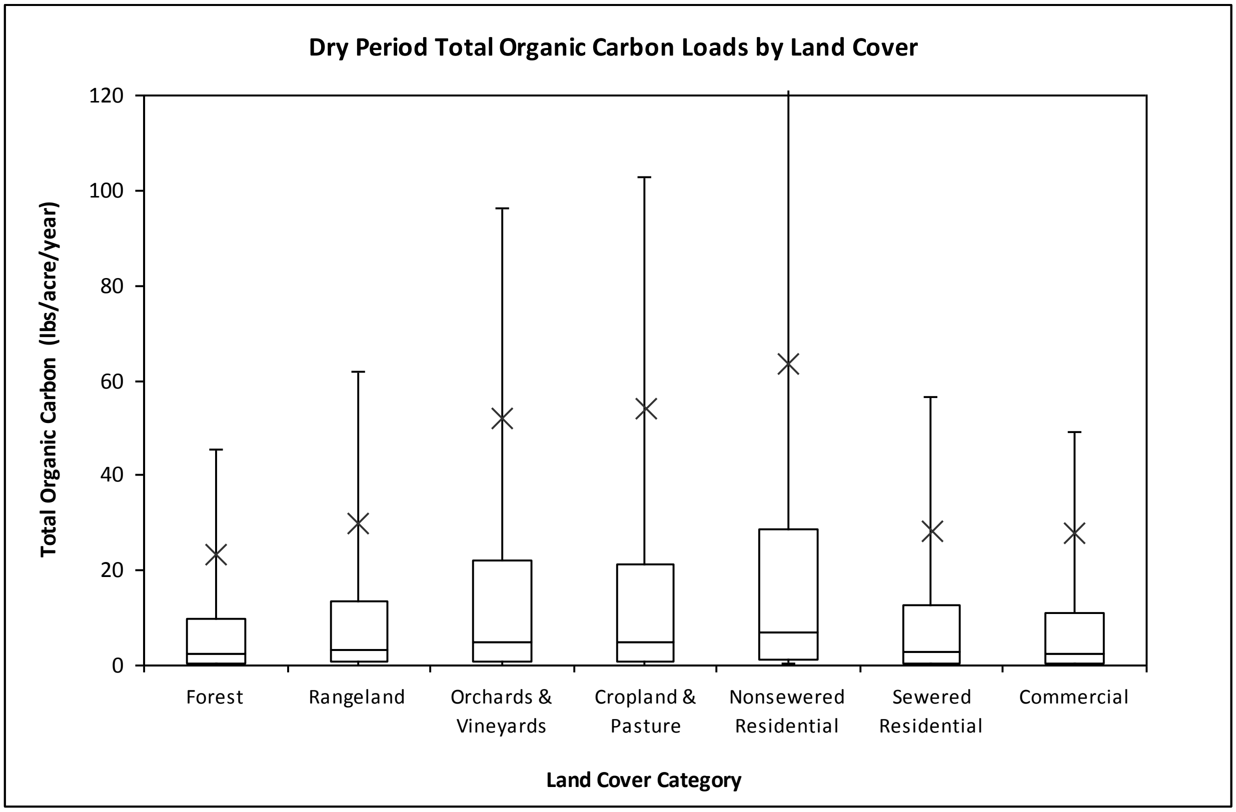

Figure 64. Comparison of the Distribution of Dry Period Total Organic Carbon Unit Area Load between Land Covers.

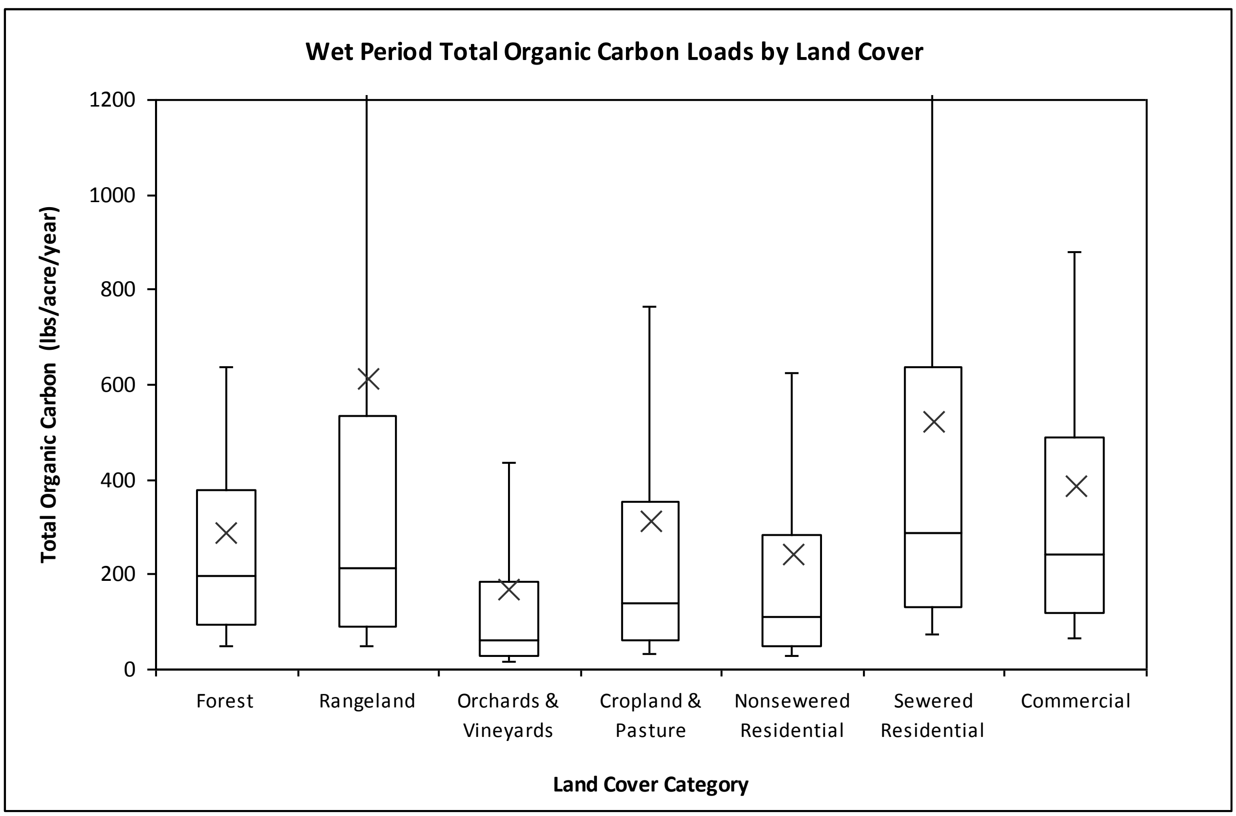

Figure 65. Comparison of the Distribution of Wet Period Total Organic Carbon Unit Area Load between Land Covers.

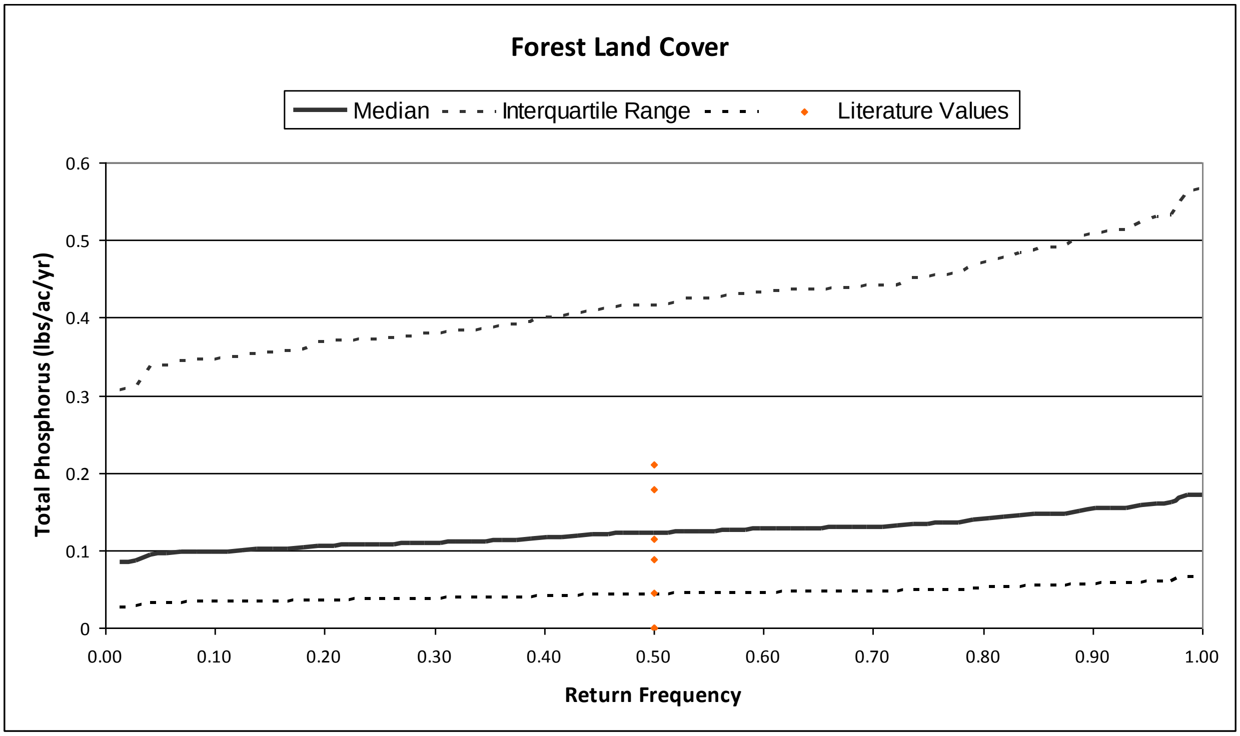

Figure 66. Forest Land Cover Total Phosphorus Load Duration Curve

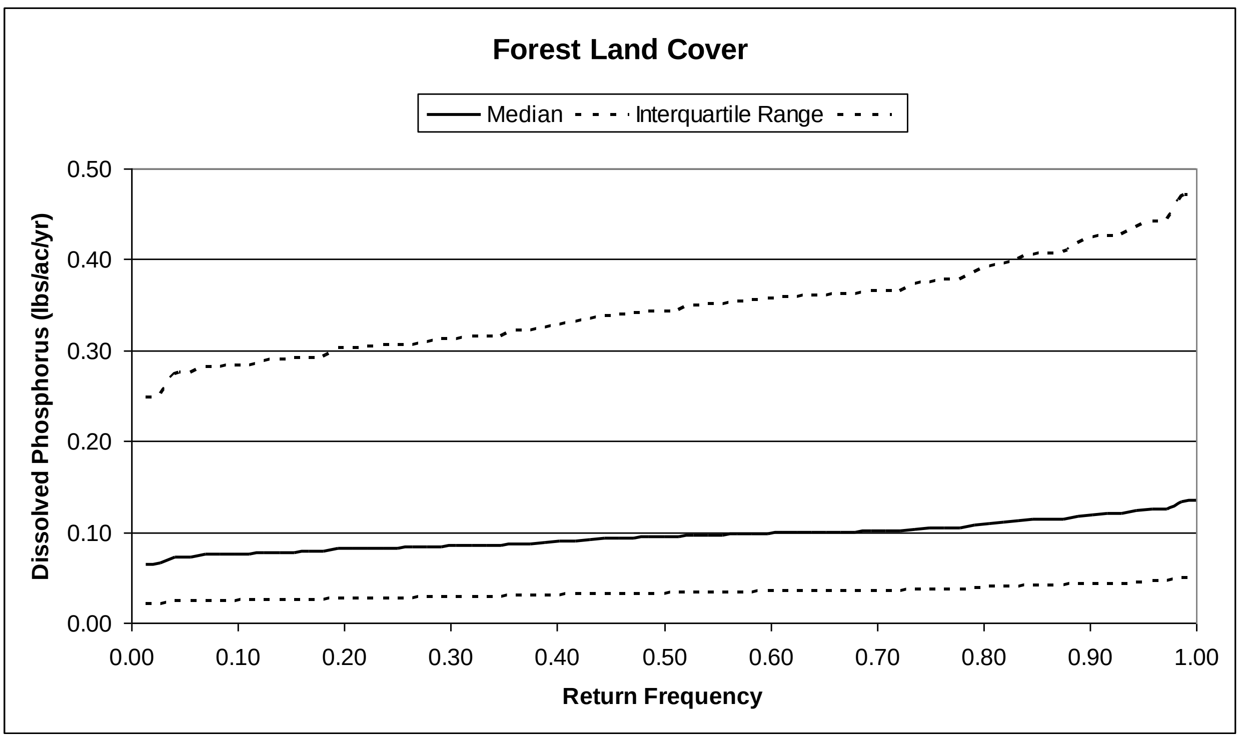

Figure 67. Forest Land Cover Dissolved Phosphorus Load Duration Curve

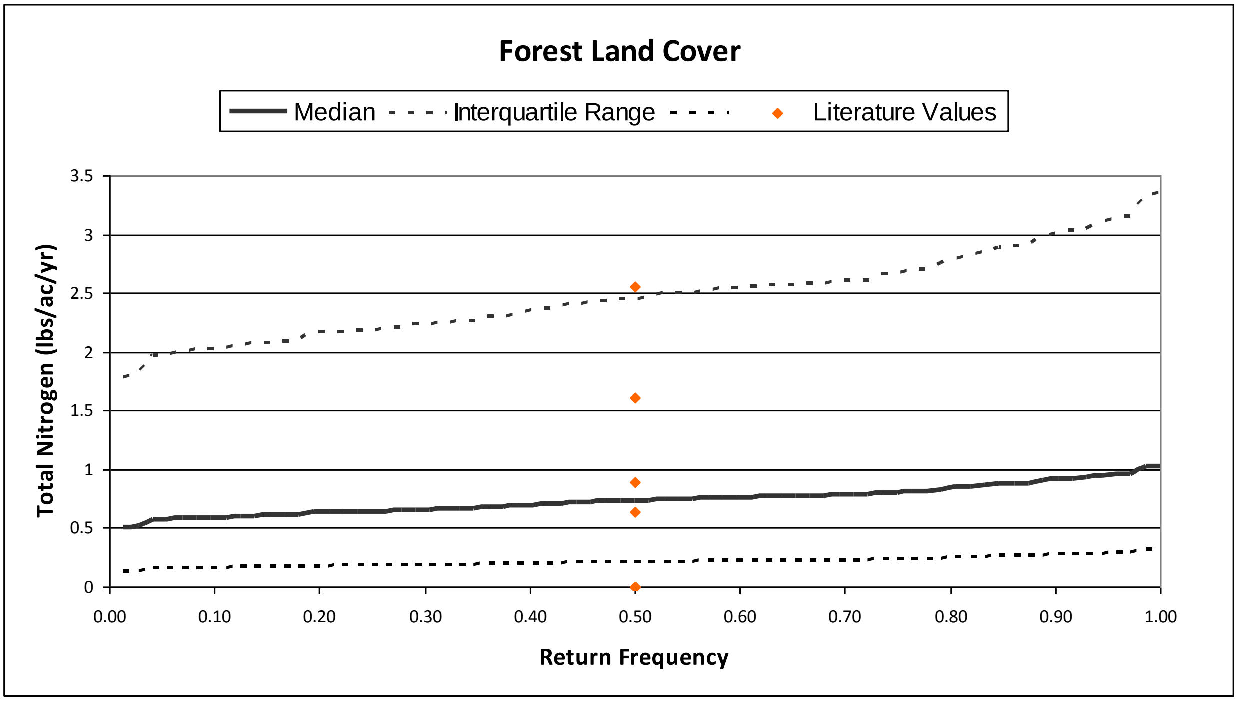

Figure 68. Forest Land Cover Total Nitrogen Load Duration Curve

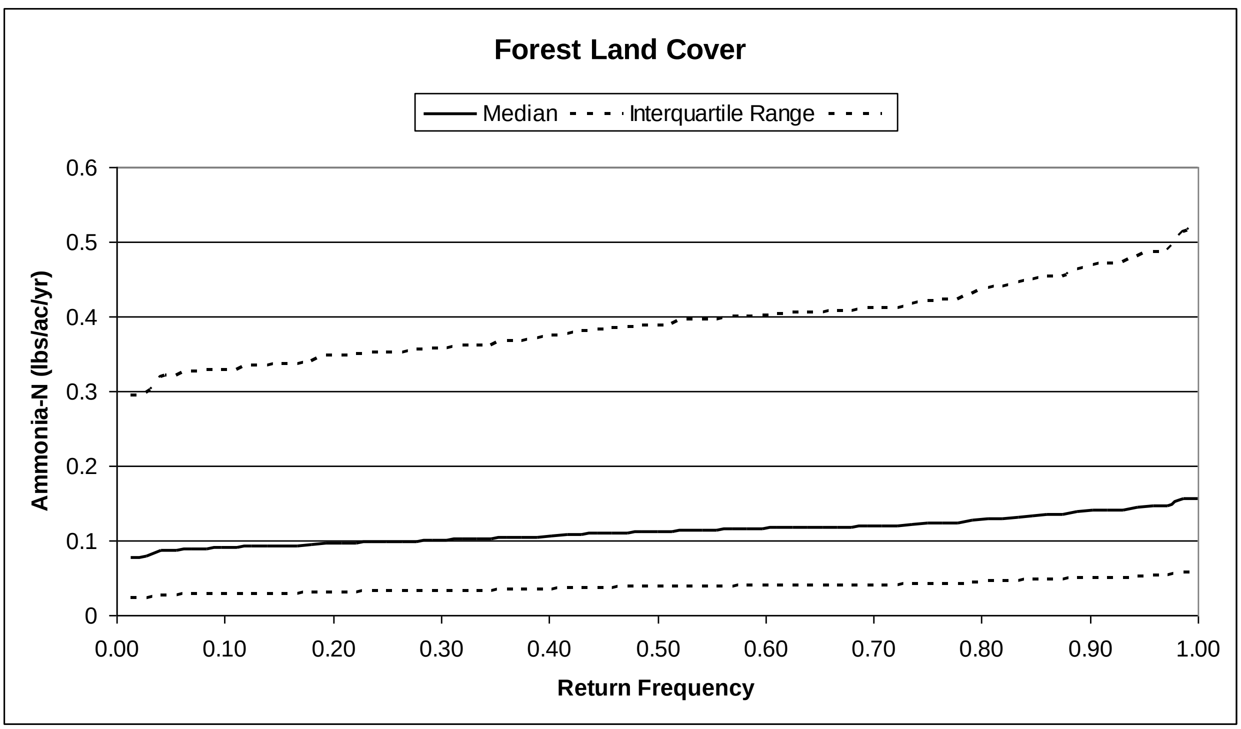

Figure 69. Forest Land Cover Ammonia-N Load Duration Curve

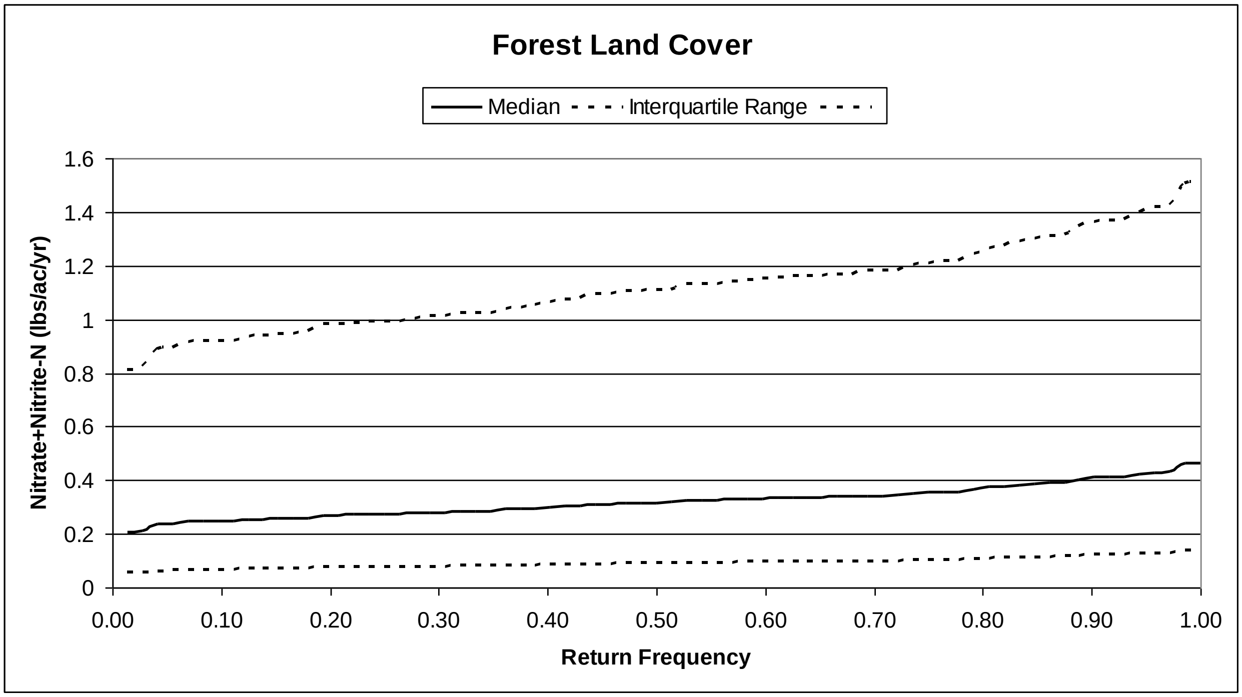

Figure 70. Forest Land Cover Nitrate+Nitrite-N Load Duration Curve

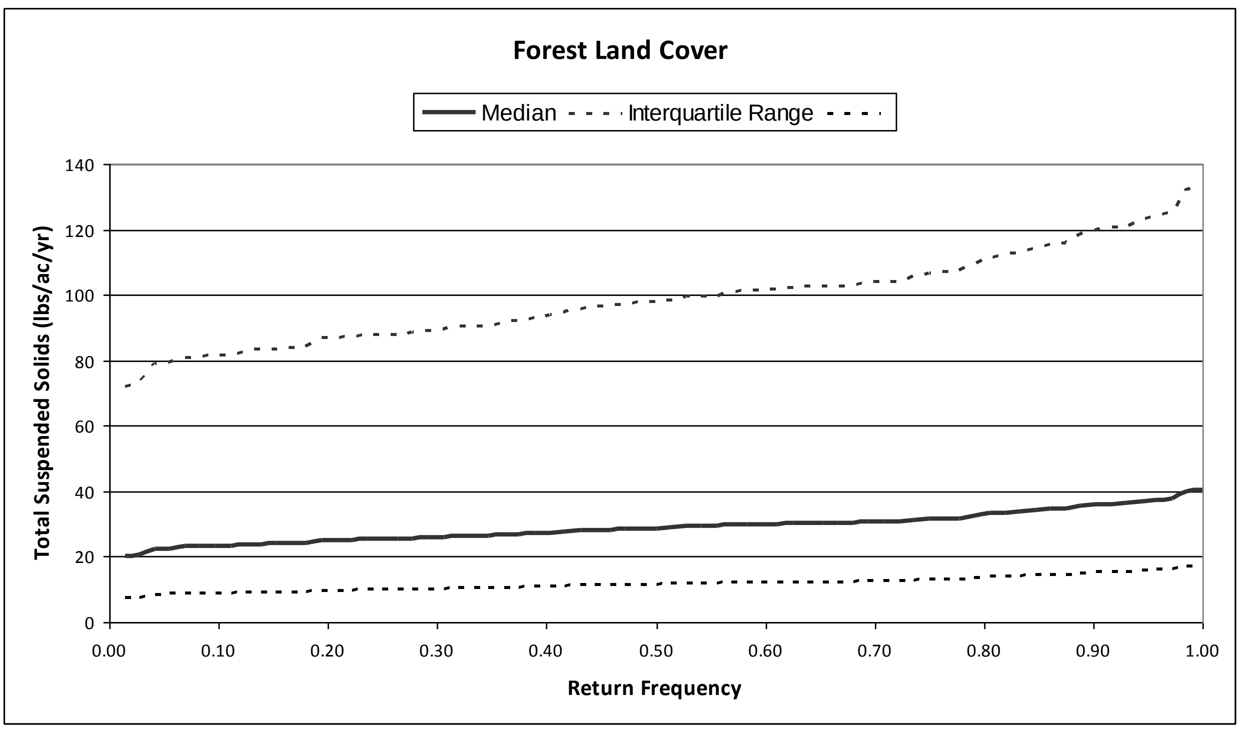

Figure 71. Forest Land Cover Total Suspended Solids Load Duration Curve

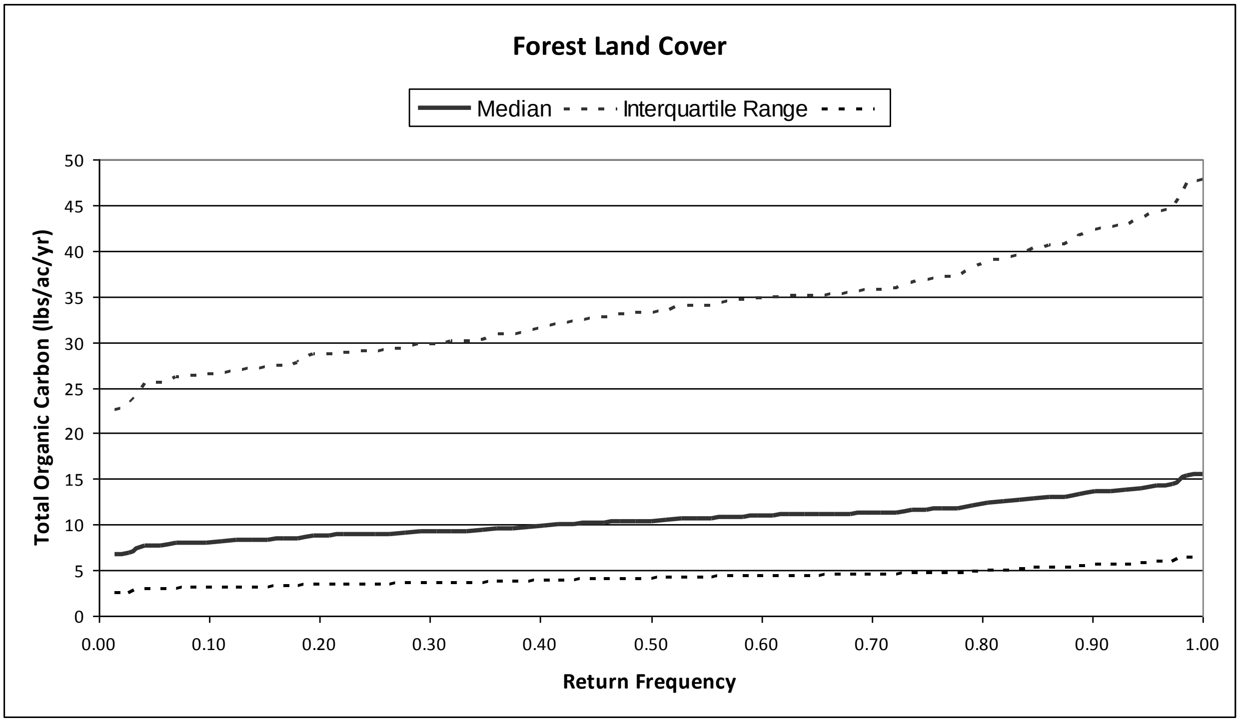

Figure 72. Forest Land Cover Total Organic Carbon Load Duration Curve

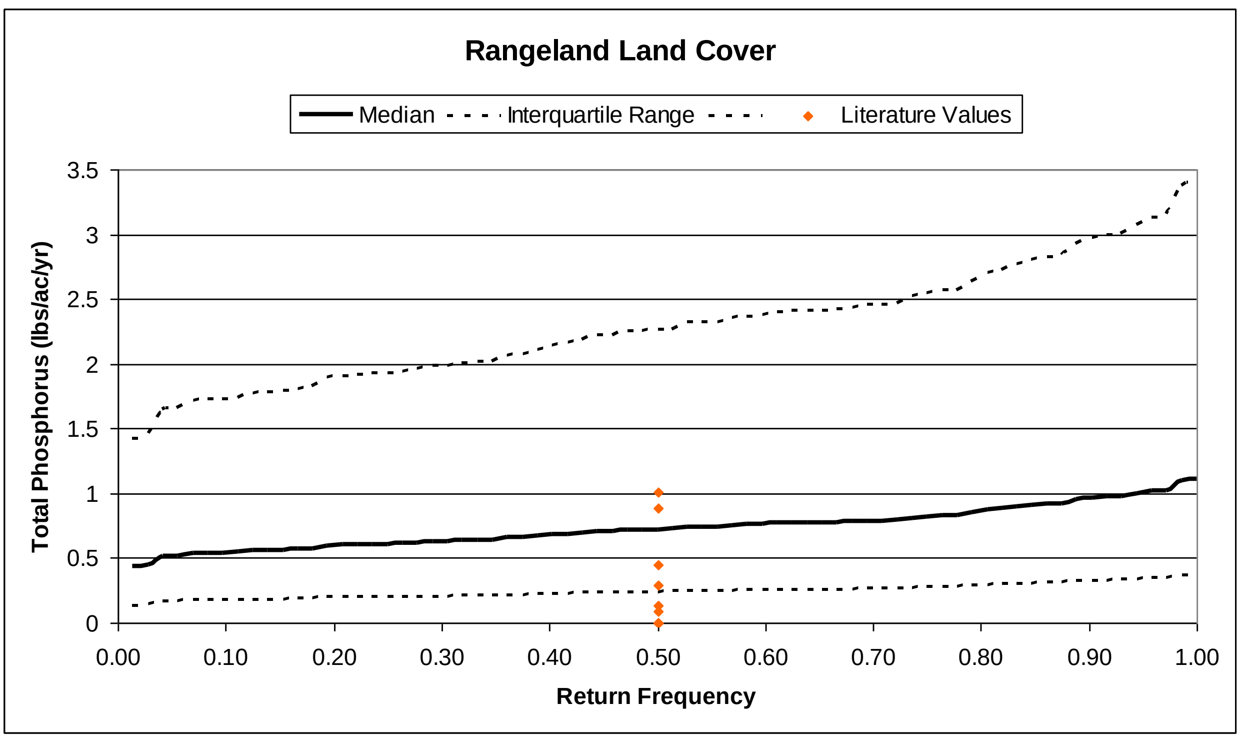

Figure 73. Rangeland Land Cover Total Phosphorus Load Duration Curve

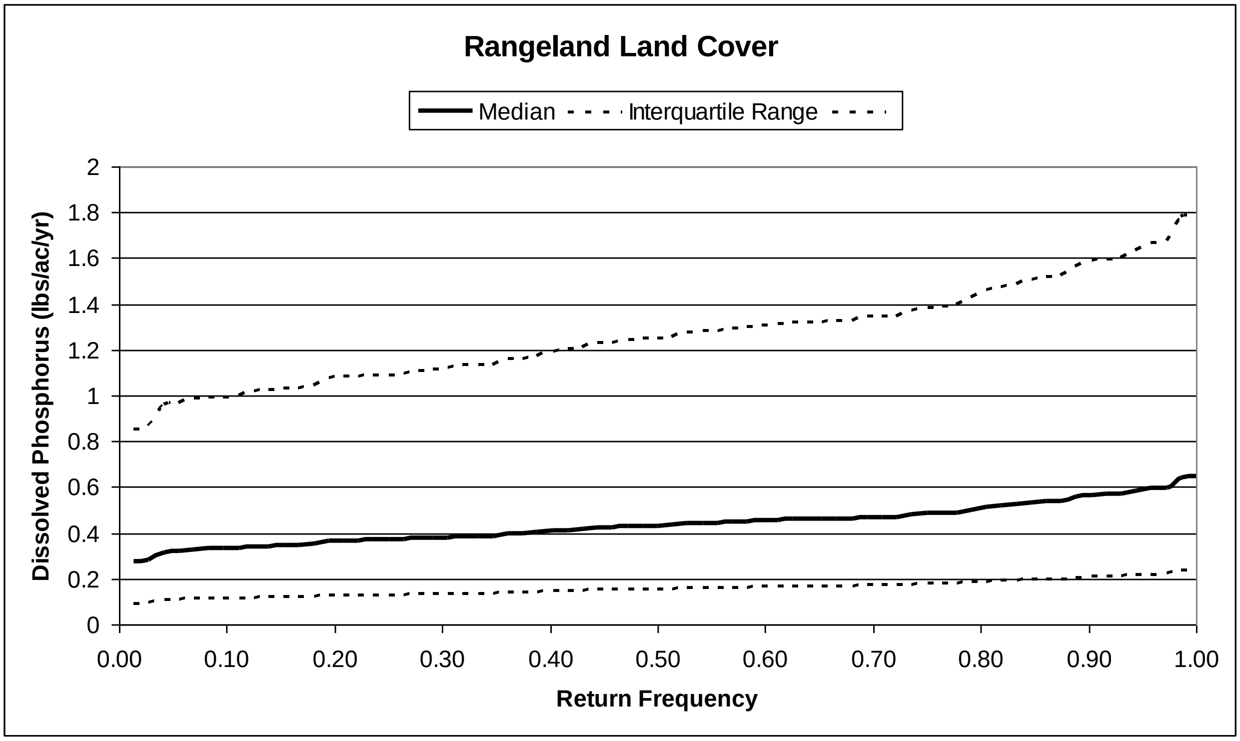

Figure 74. Rangeland Land Cover Dissolved Phosphorus Load Duration Curve

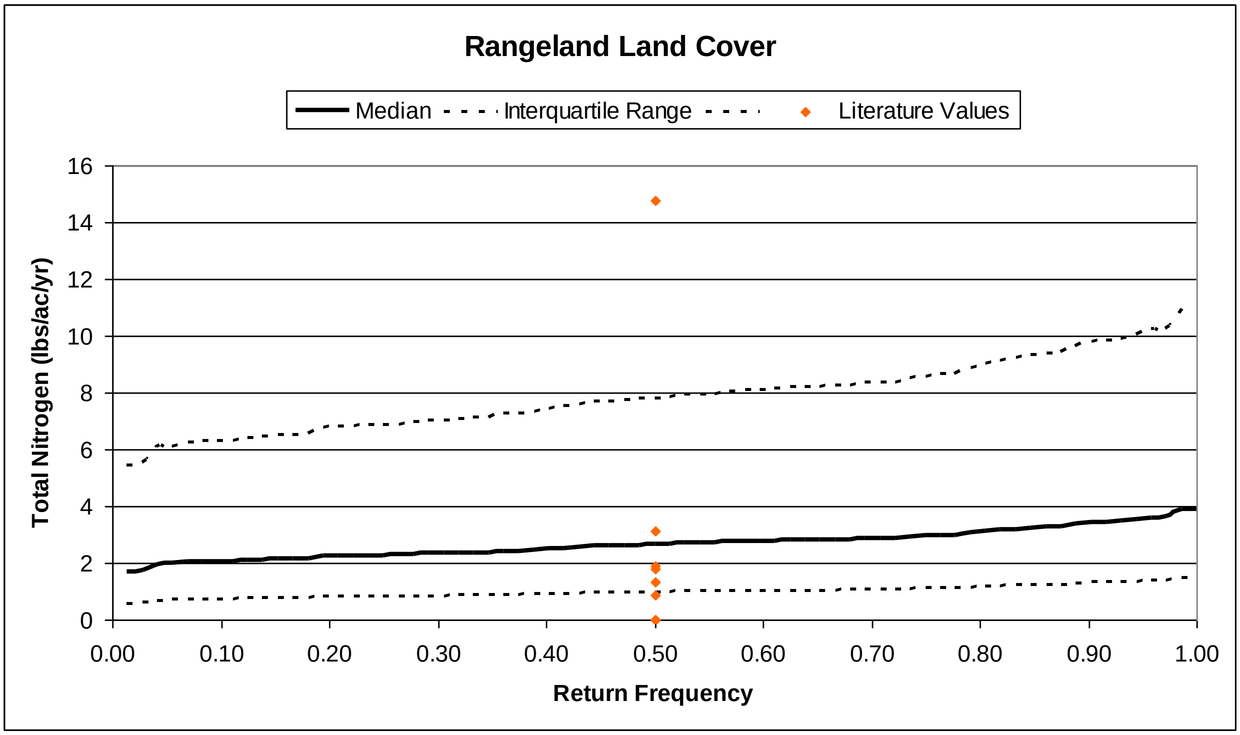

Figure 75. Rangeland Land Cover Total Nitrogen Load Duration Curve

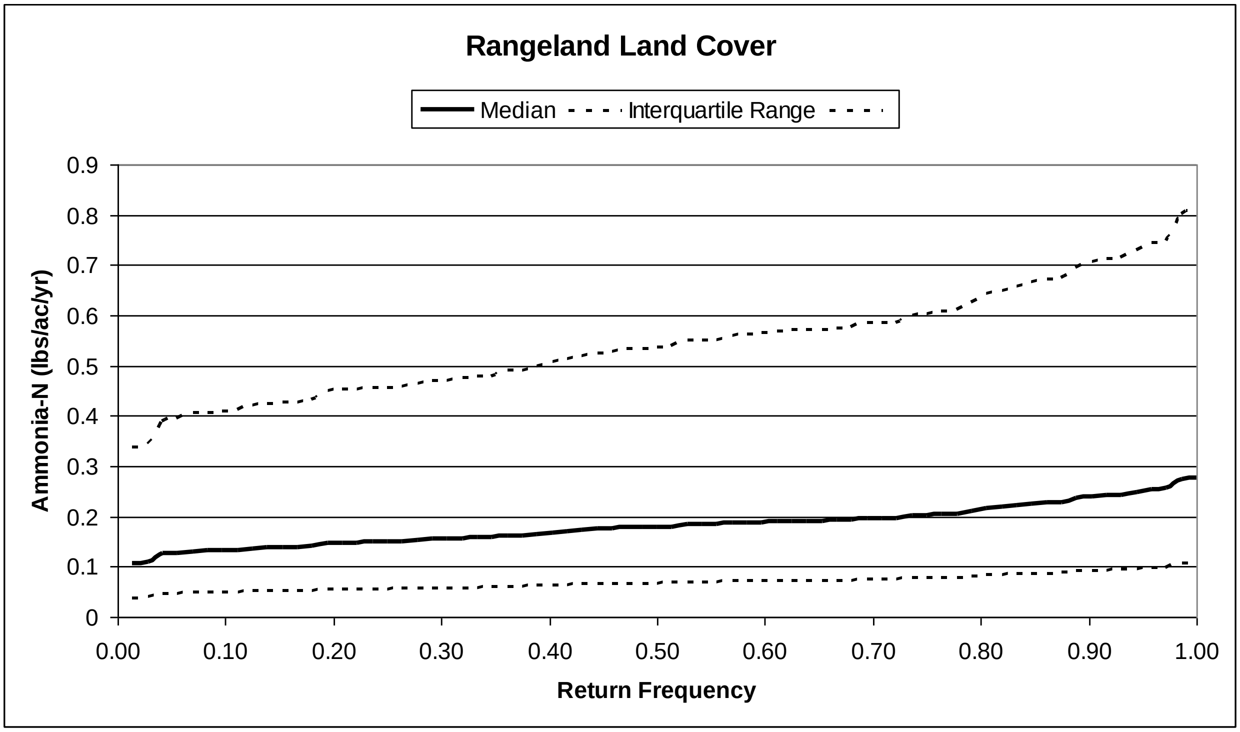

Figure 76. Rangeland Land Cover Ammonia-N Load Duration Curve

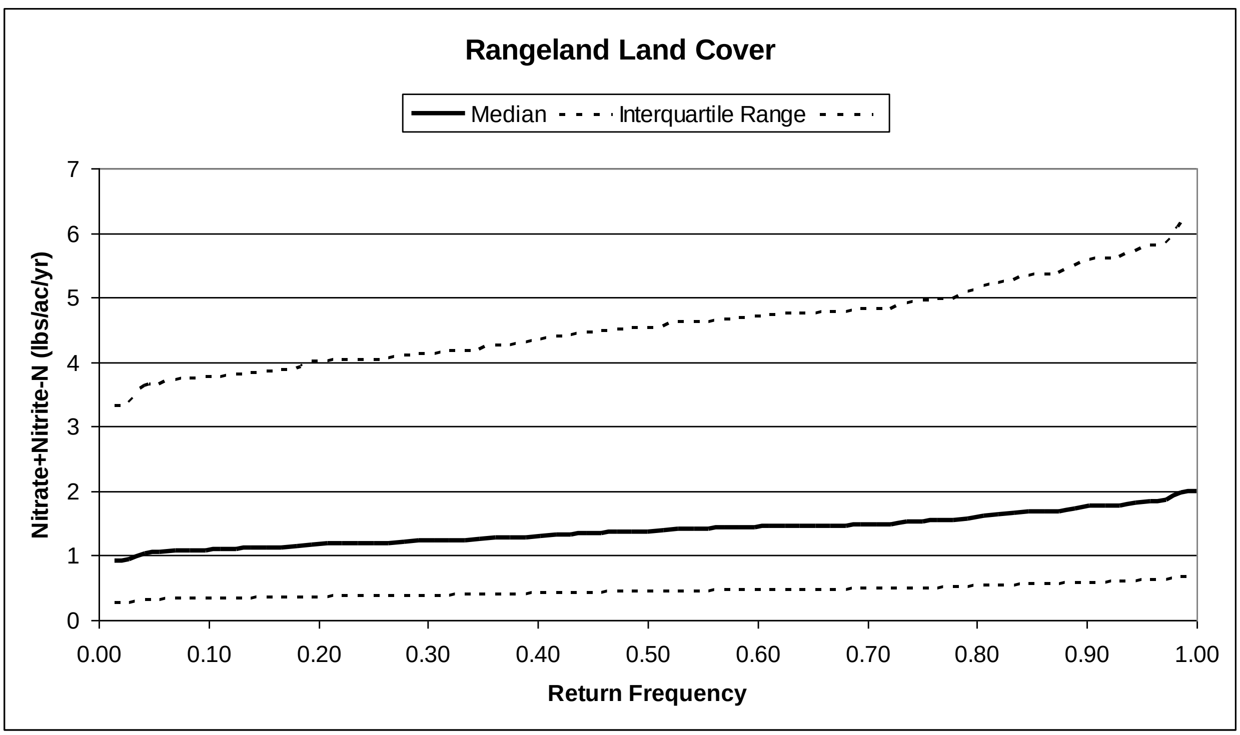

Figure 77. Rangeland Land Cover Nitrate+Nitrite-N Load Duration Curve

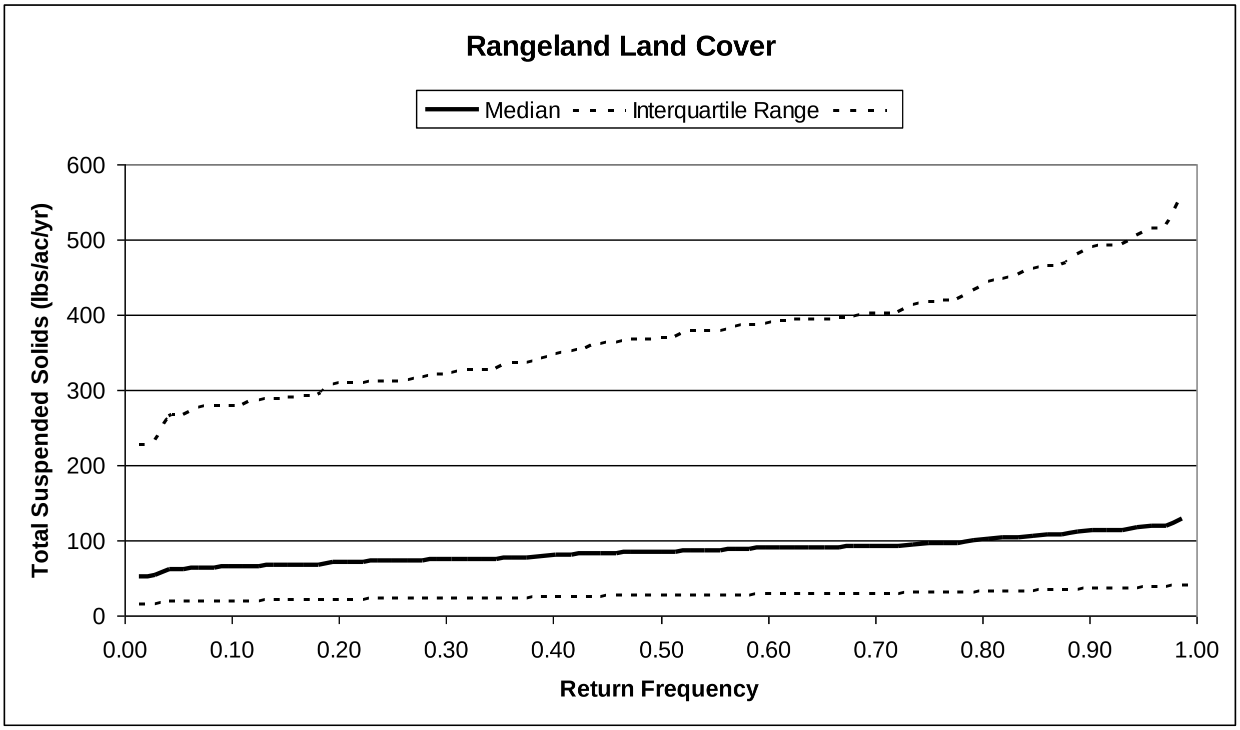

Figure 78. Rangeland Land Cover Total Suspended Solids Load Duration Curve

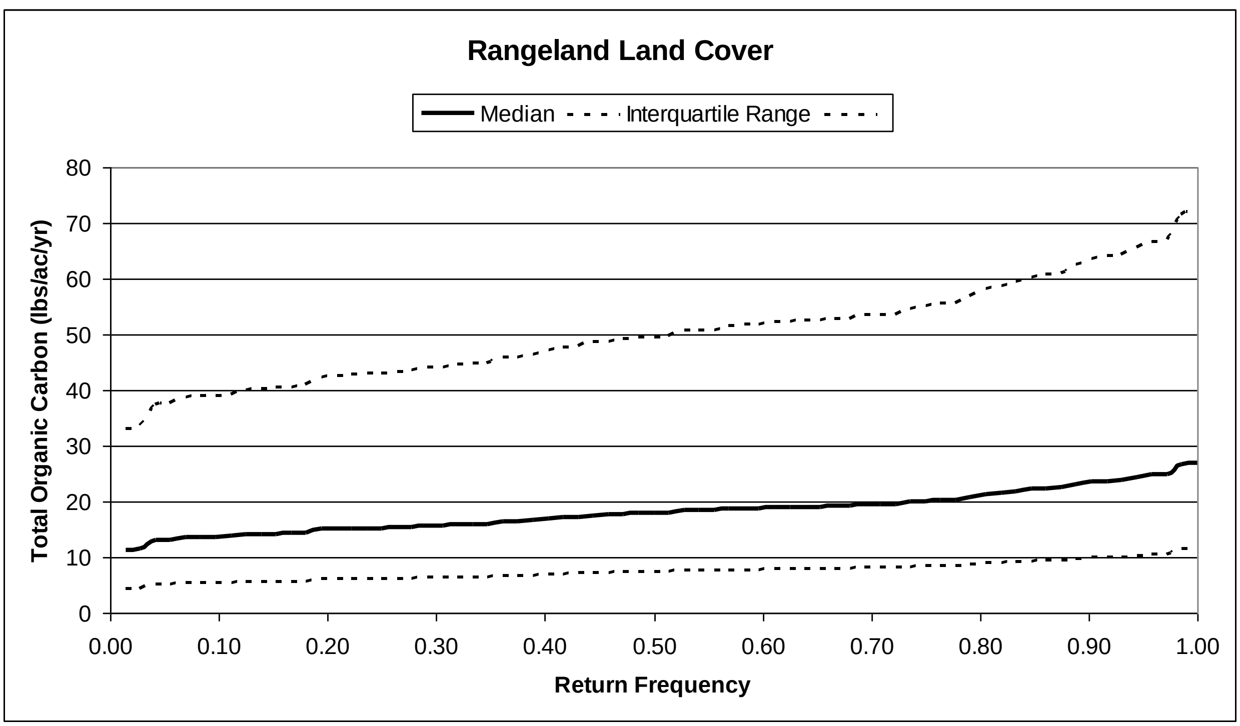

Figure 79. Rangeland Land Cover Total Organic Carbon Load Duration Curve

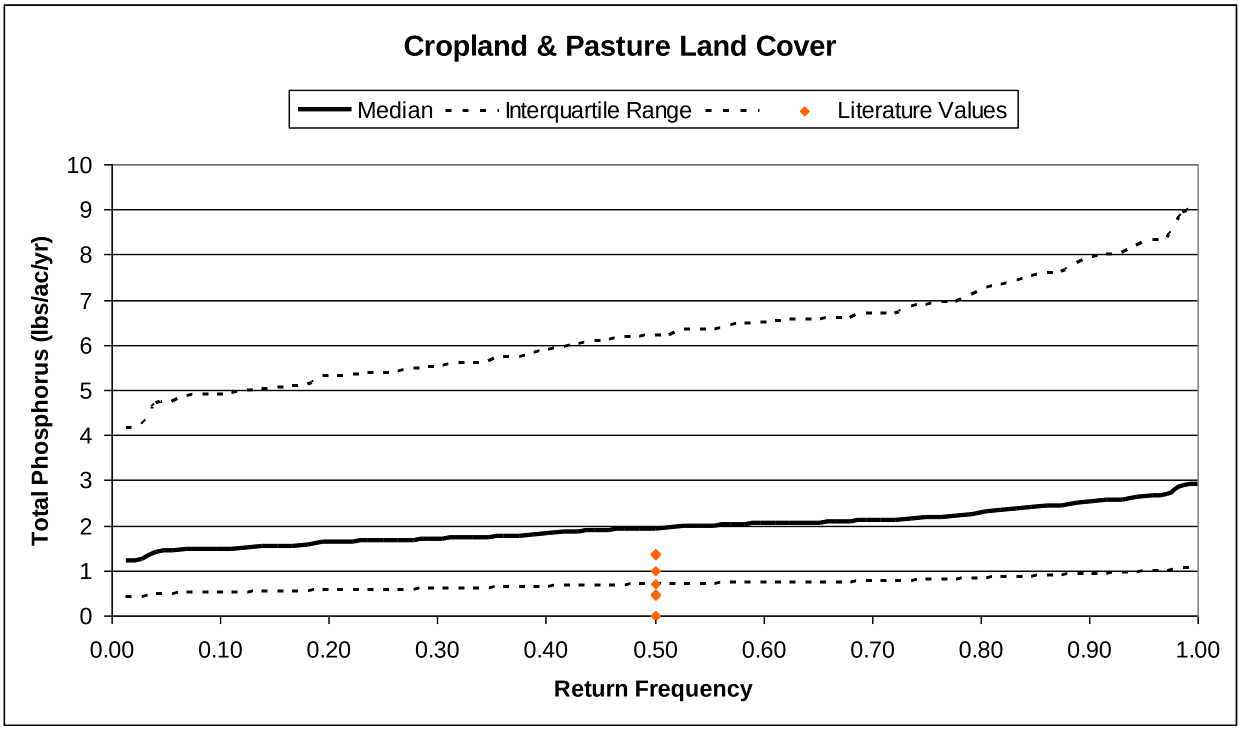

Figure 80. Crop and Pasture Land Cover Total Phosphorus Load Duration Curve

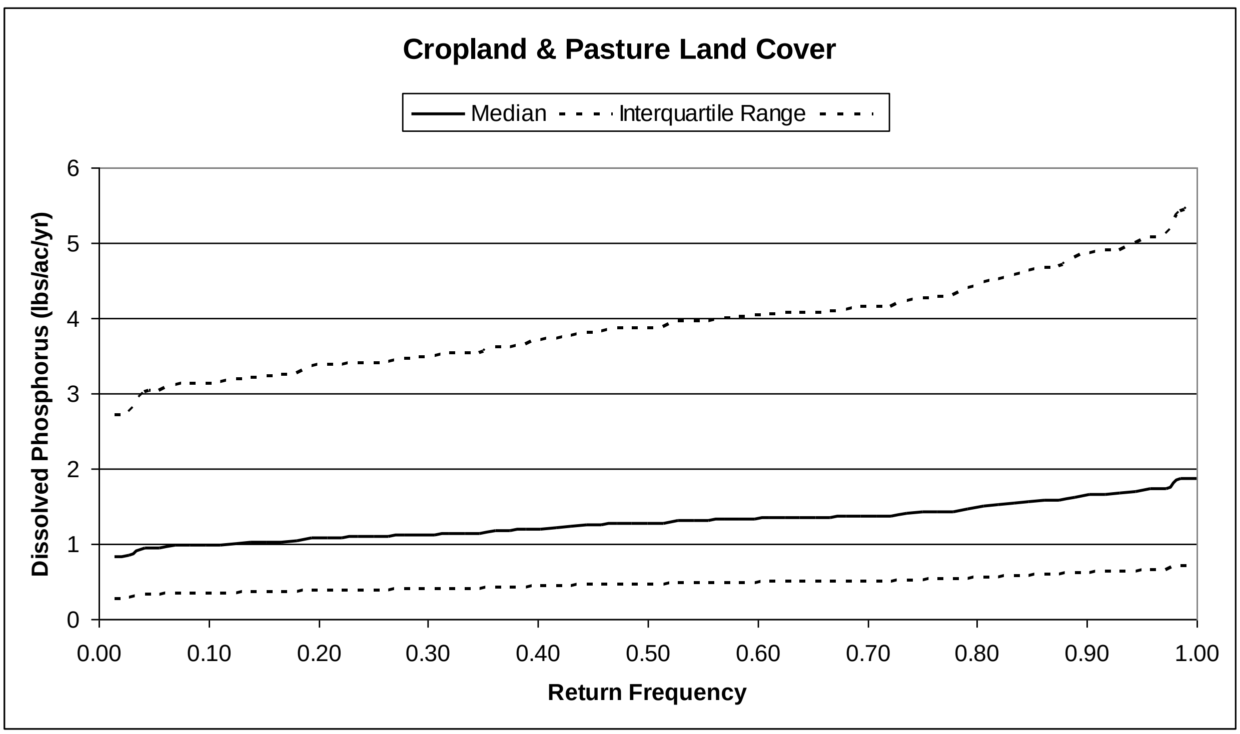

Figure 81. Crop and Pasture Land Cover Dissolved Phosphorus Load Duration Curve

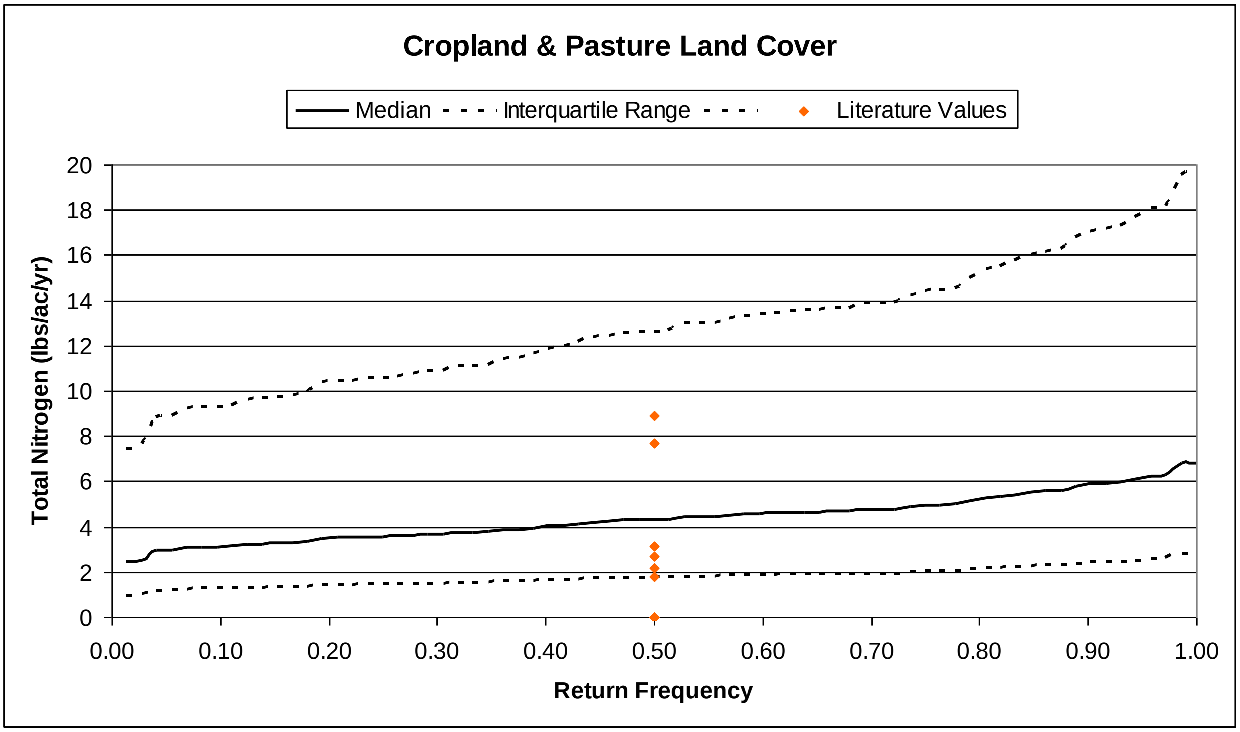

Figure 82. Crop and Pasture Land Cover Total Nitrogen Load Duration Curve

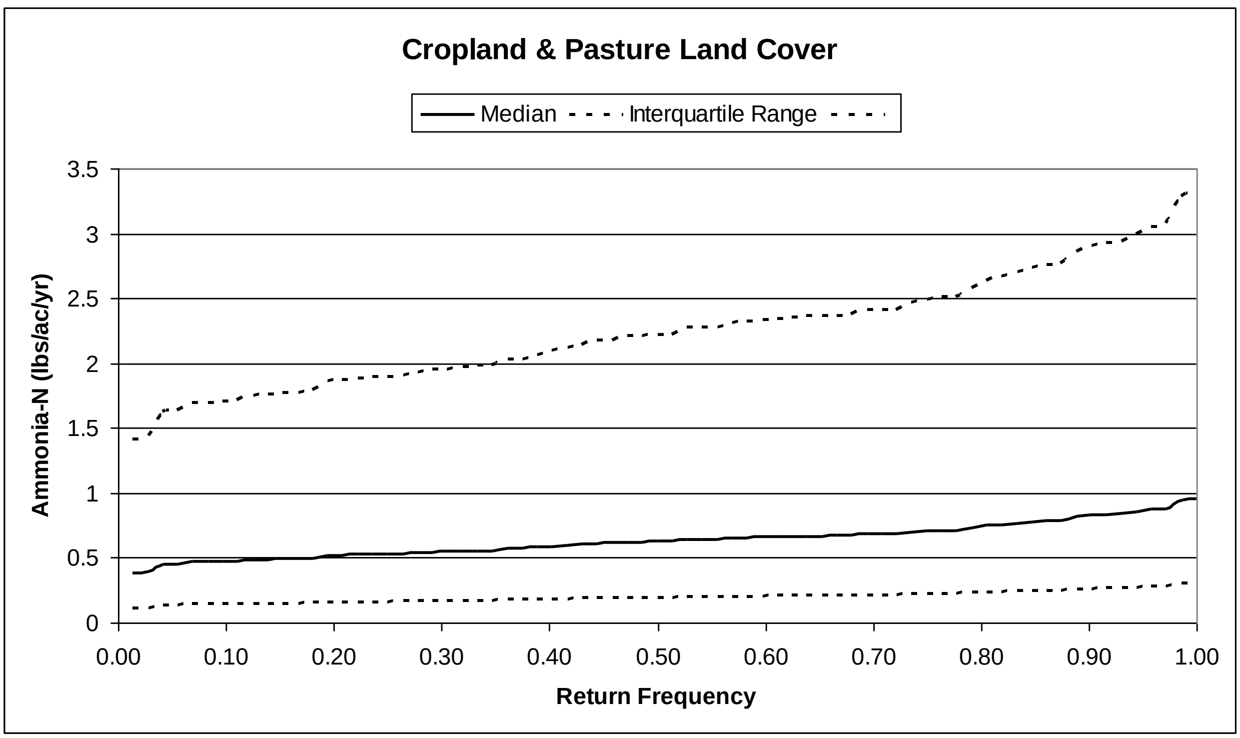

Figure 83. Crop and Pasture Land Cover Ammonia-N Load Duration Curve

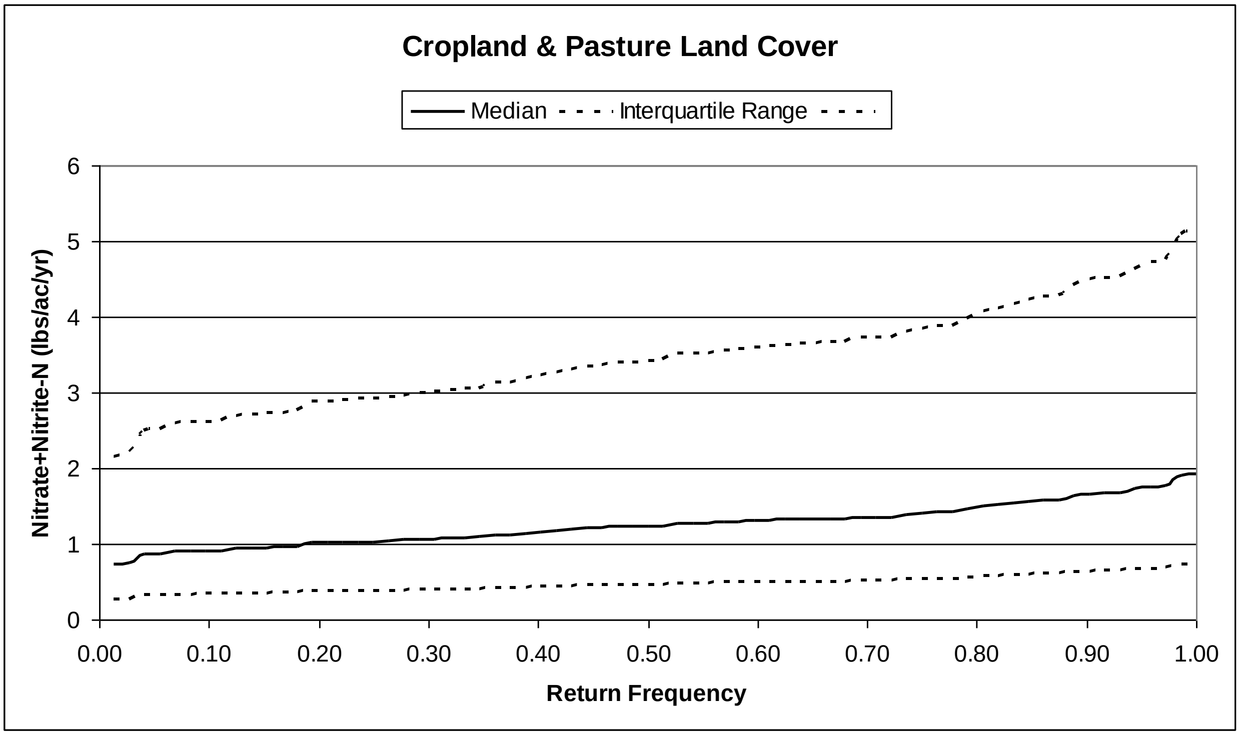

Figure 84. Crop and Pasture Land Cover Nitrate+Nitrite-N Load Duration Curve

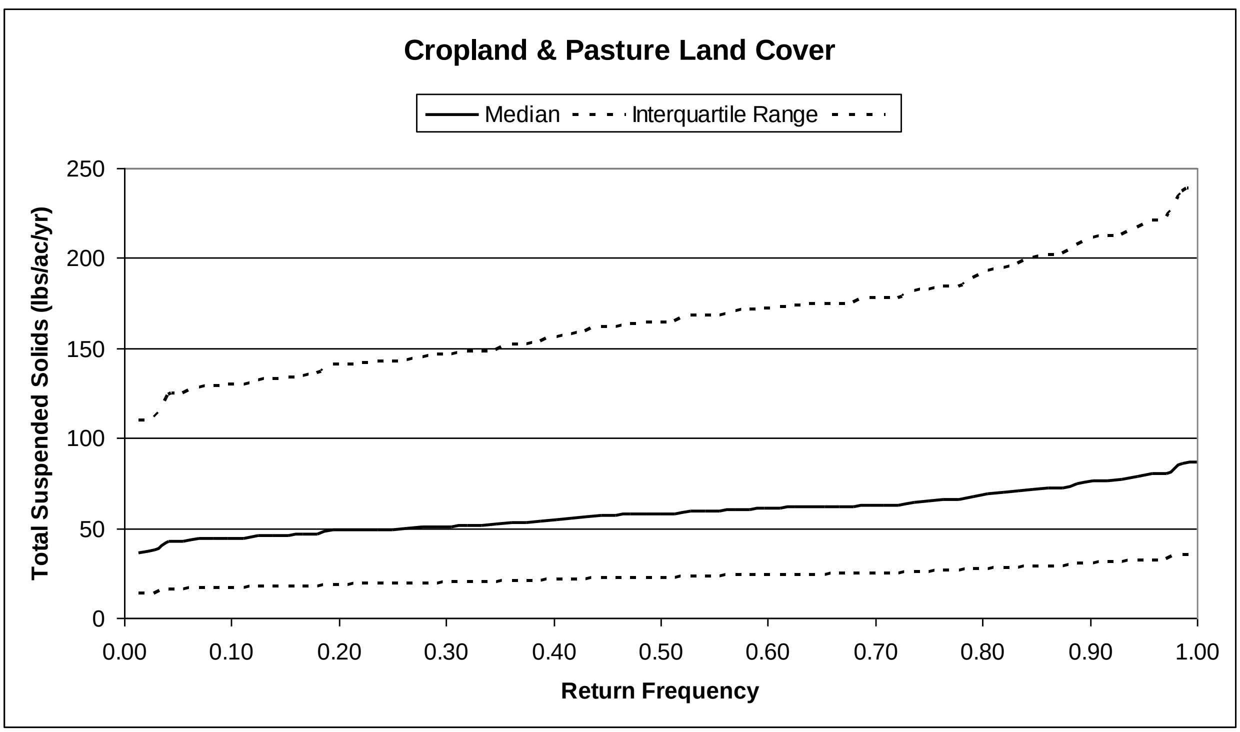

Figure 85. Crop and Pasture Land Cover Total Suspended Solids Load Duration Curve

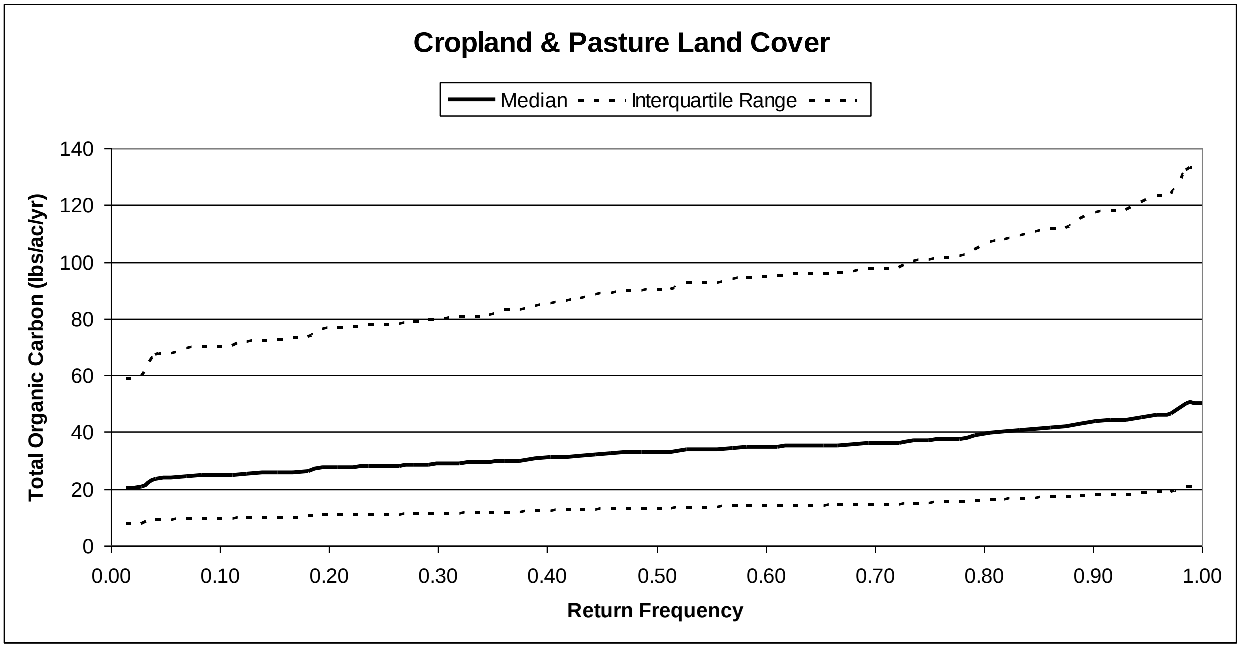

Figure 86. Crop and Pasture Land Cover Total Organic Carbon Load Duration Curve

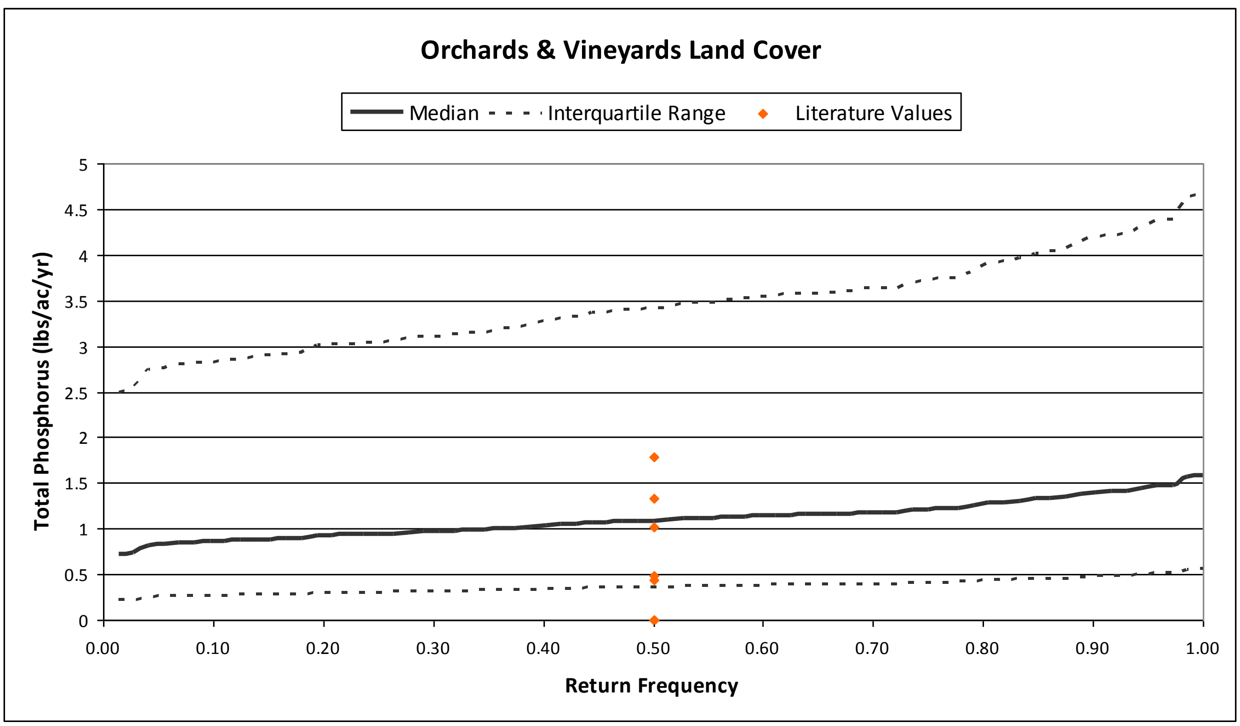

Figure 87. Orchards & Vineyards Land Cover Total Phosphorus Load Duration Curve

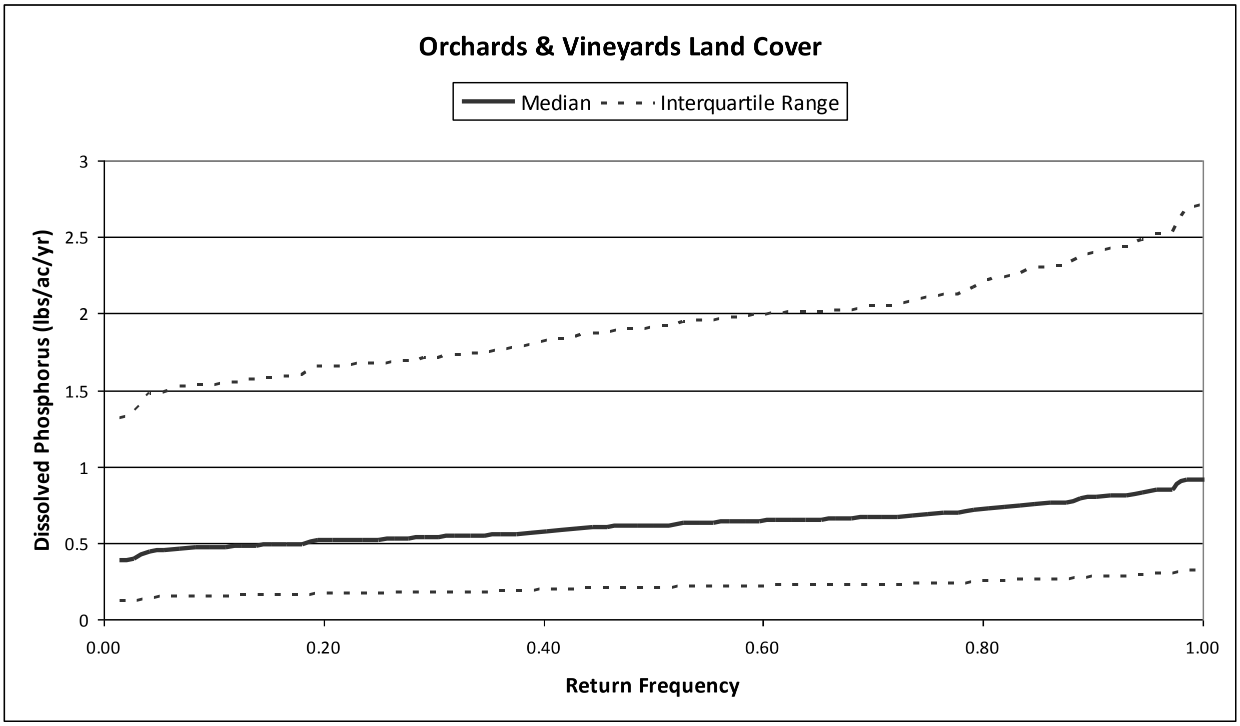

Figure 88. Orchards & Vineyards Land Cover Dissolved Phosphorus Load Duration Curve

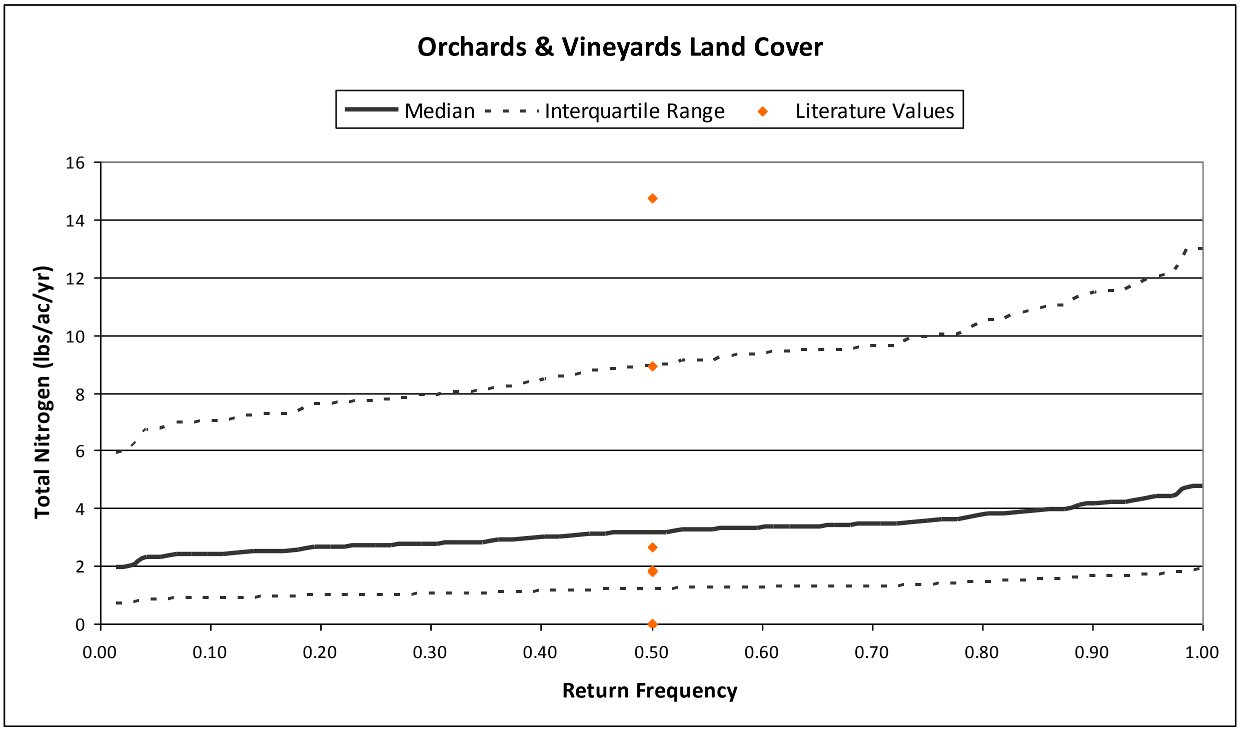

Figure 89. Orchards & Vineyards Land Cover Total Nitrogen Load Duration Curve

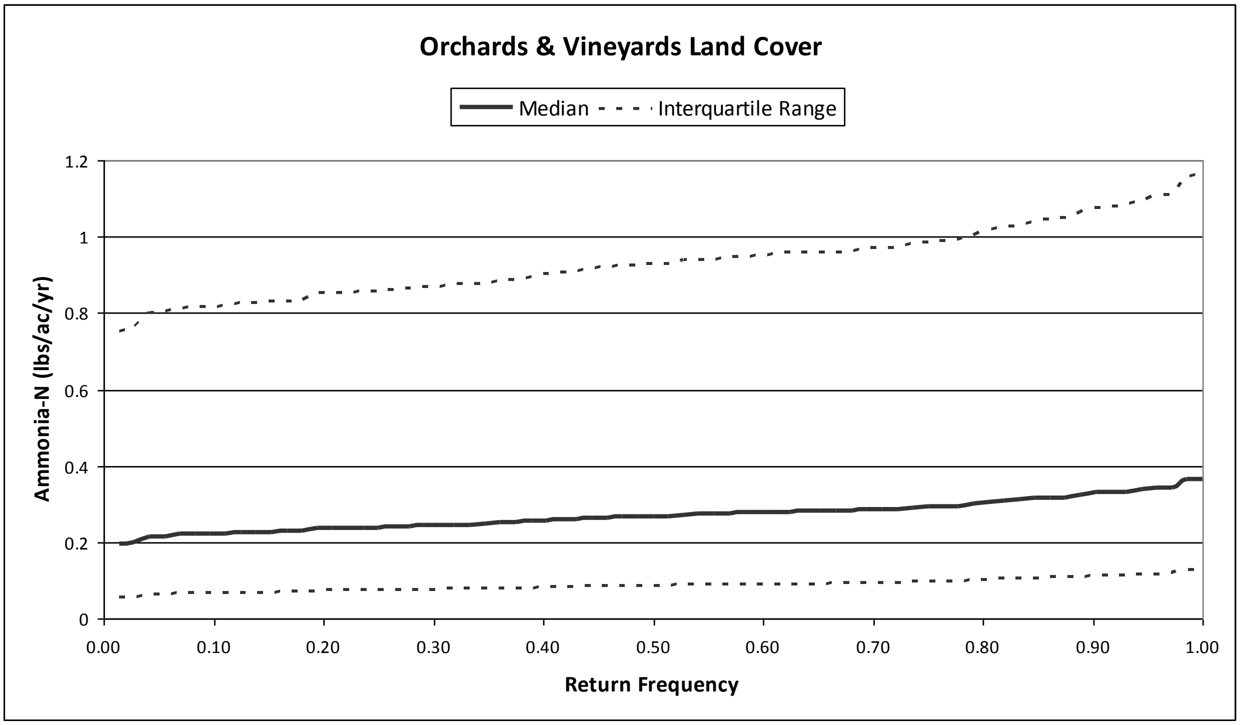

Figure 90. Orchards & Vineyards Land Cover Ammonia-N Load Duration Curve

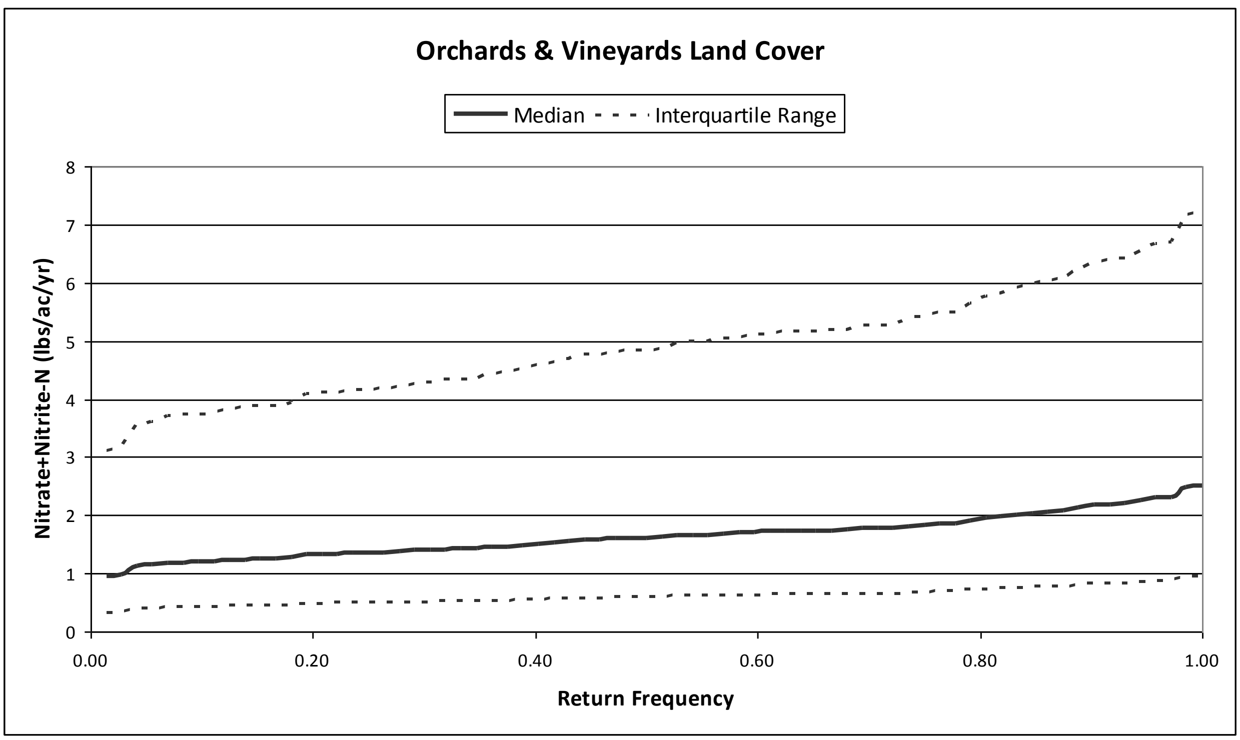

Figure 91. Orchards & Vineyards Land Cover Nitrate+Nitrite-N Load Duration Curve

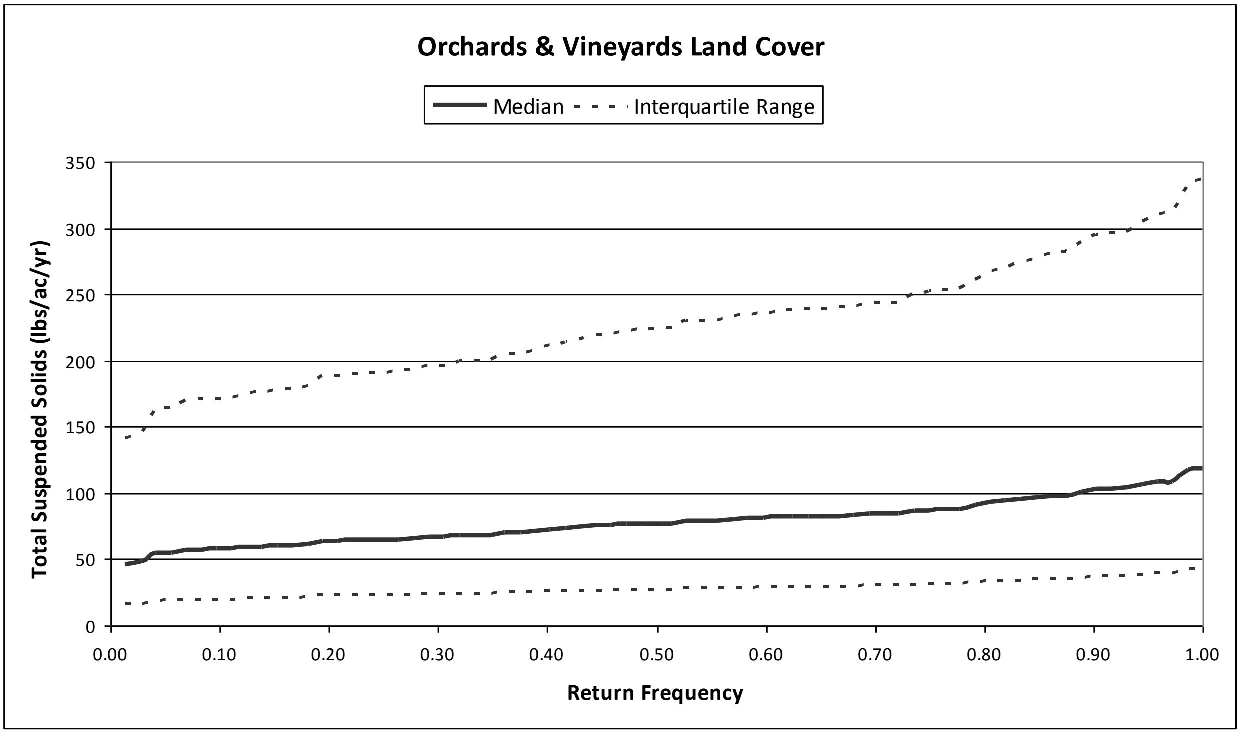

Figure 92. Orchards & Vineyards Land Cover Total Suspended Solids Load Duration Curve

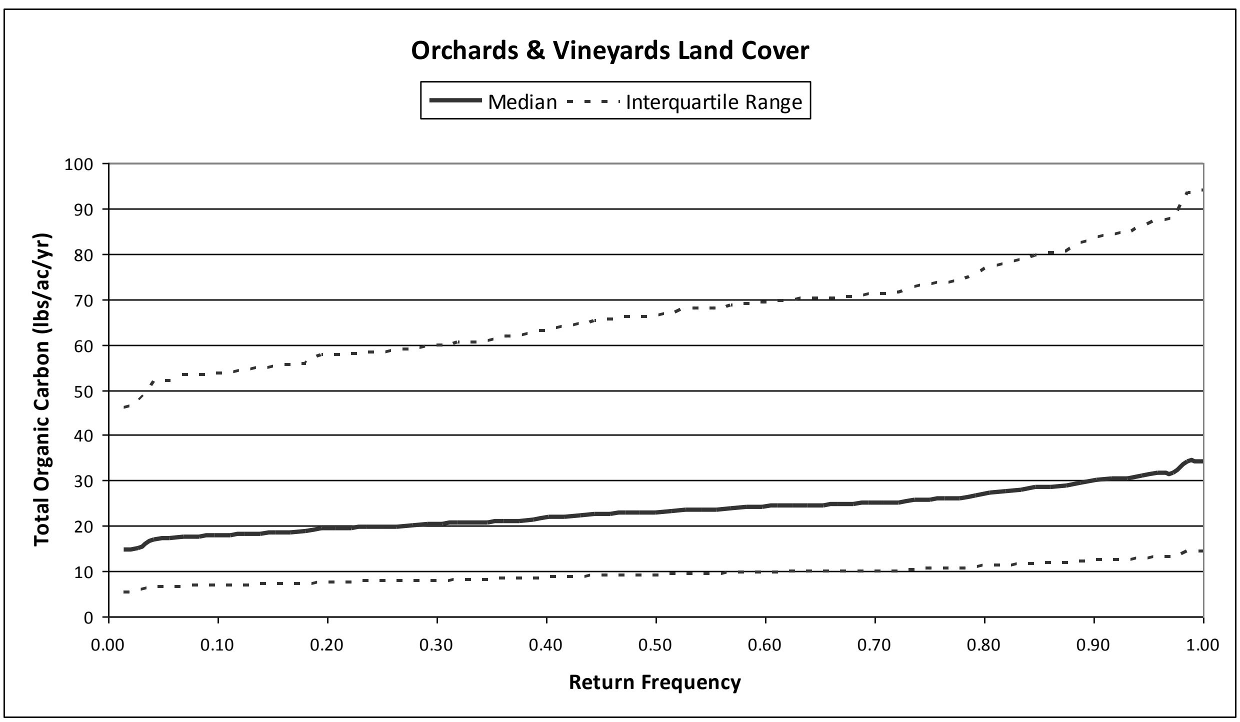

Figure 93. Orchards & Vineyards Land Cover Total Organic Carbon Load Duration Curve

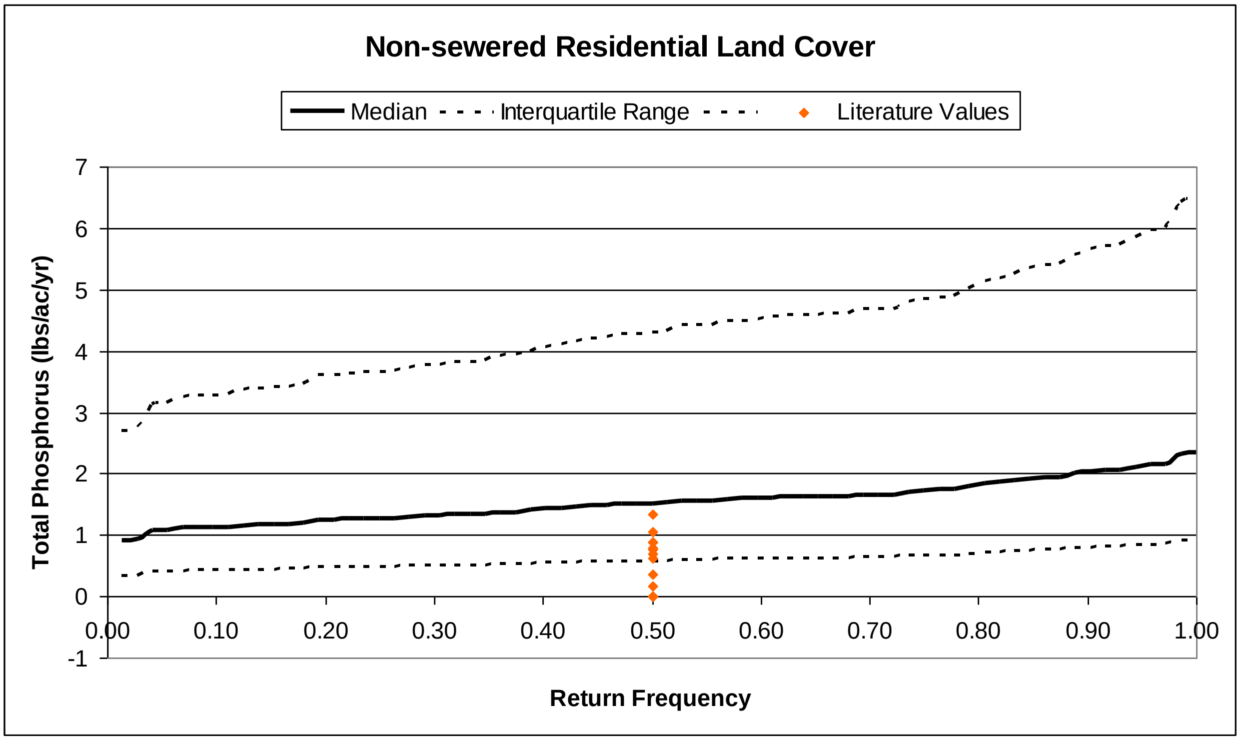

Figure 94. Nonsewered Residential Land Cover Total Phosphorus Load Duration Curve

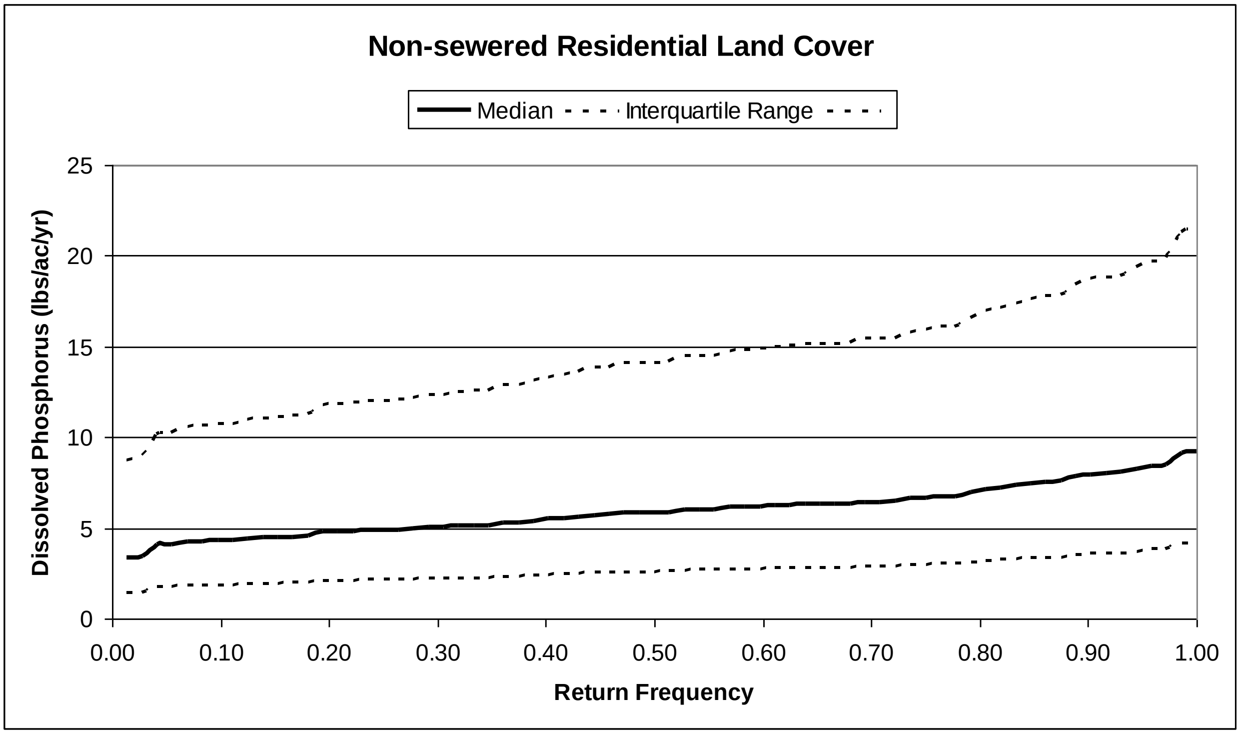

Figure 95. Nonsewered Residential Land Cover Dissolved Phosphorus Load Duration Curve

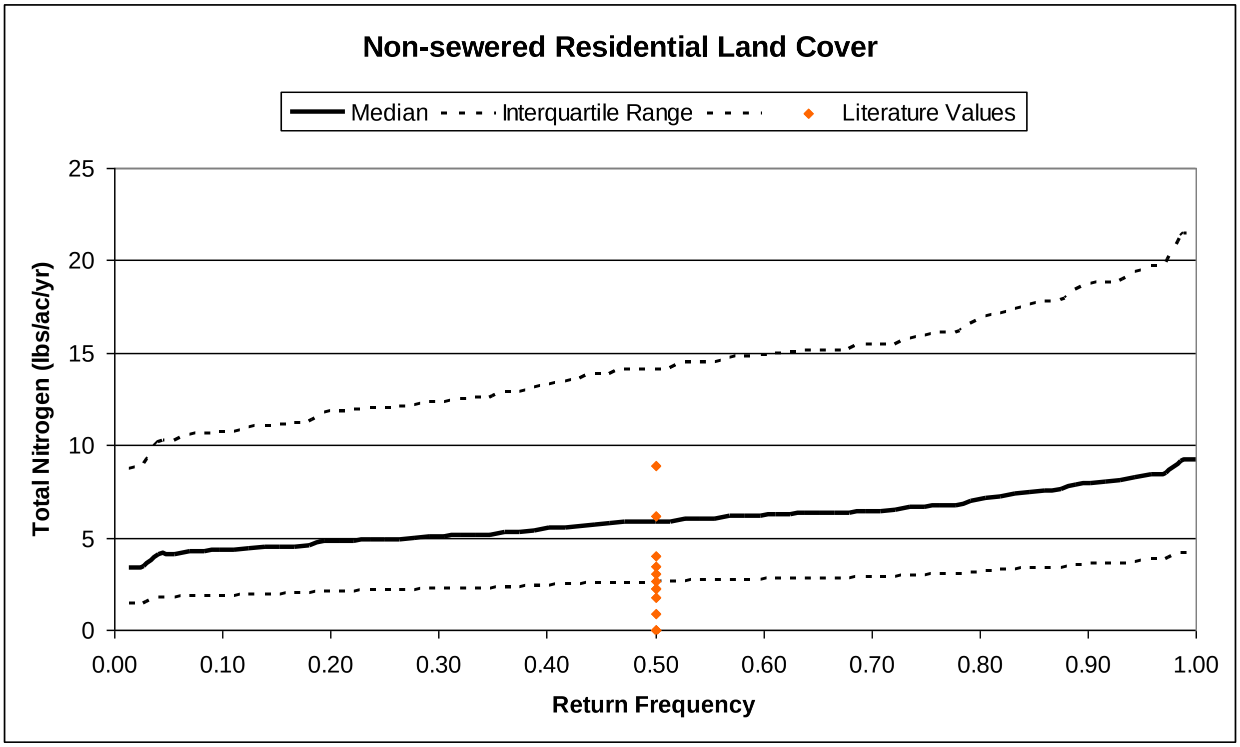

Figure 96. Nonsewered Residential Land Cover Total Nitrogen Load Duration Curve

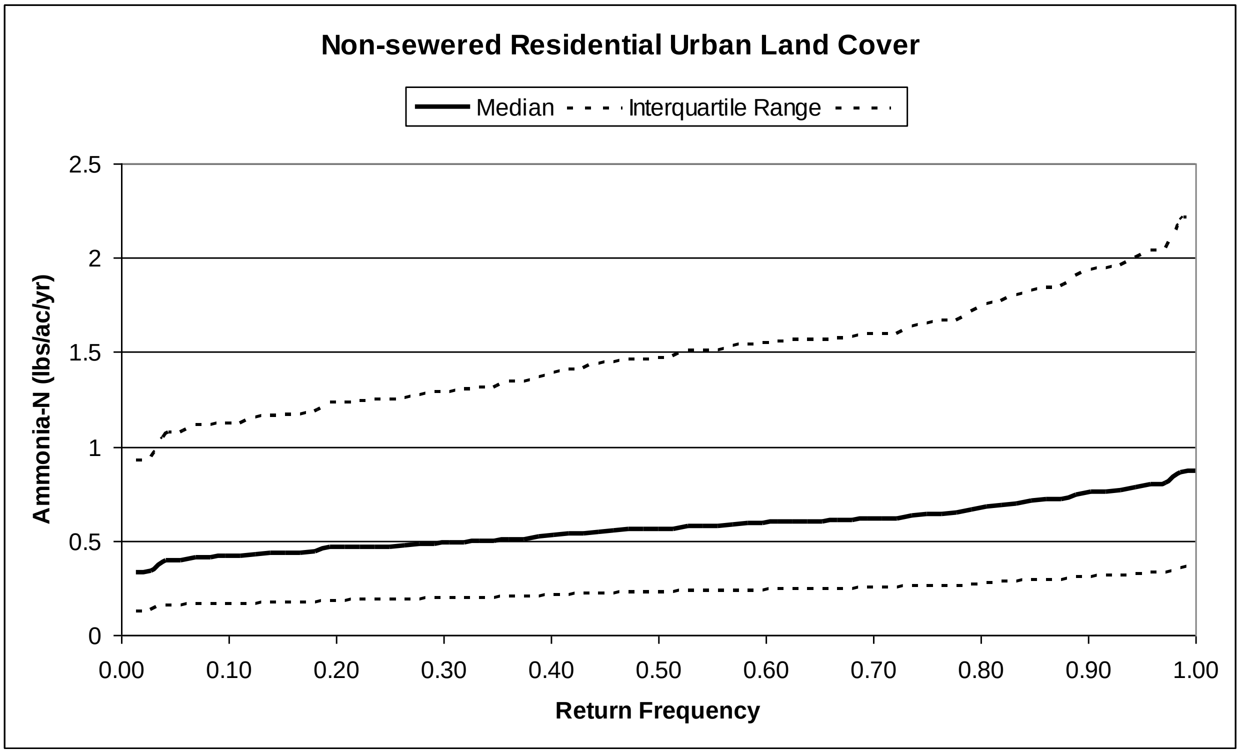

Figure 97. Nonsewered Residential Land Cover Ammonia-N Load Duration Curve

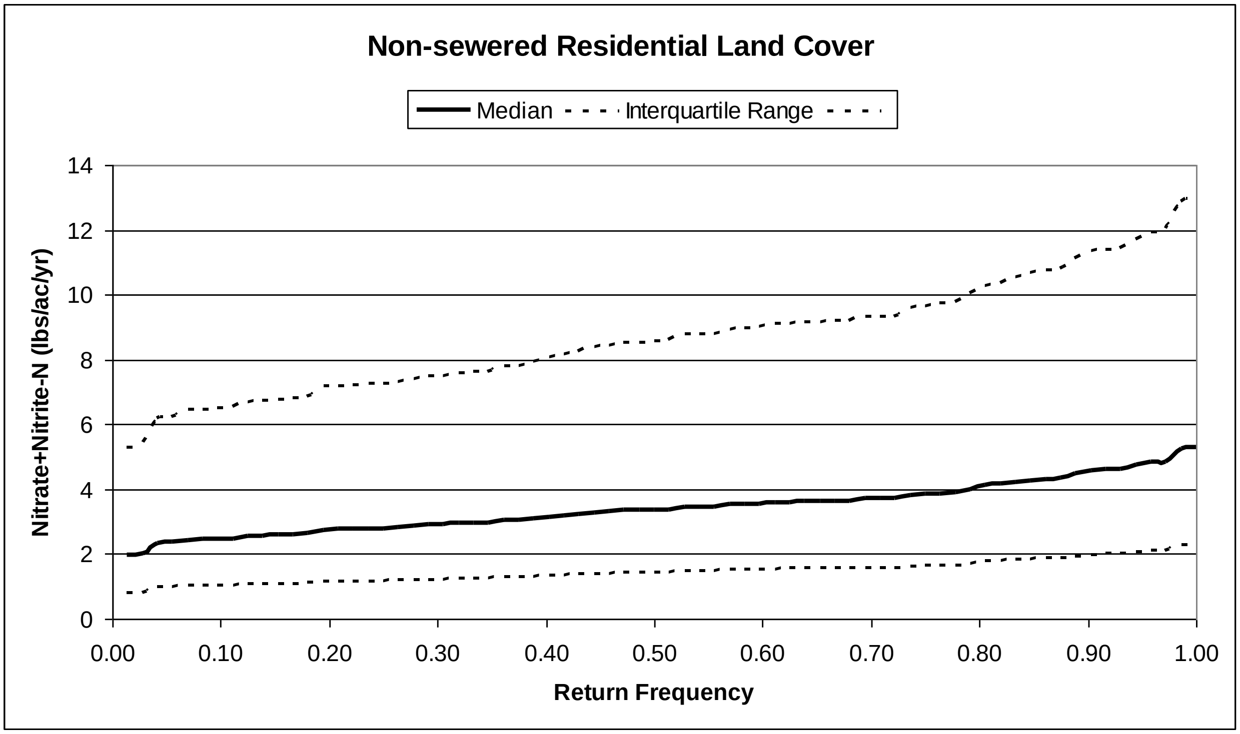

Figure 98. Nonsewered Residential Land Cover Nitrate+Nitrite-N Load Duration Curve

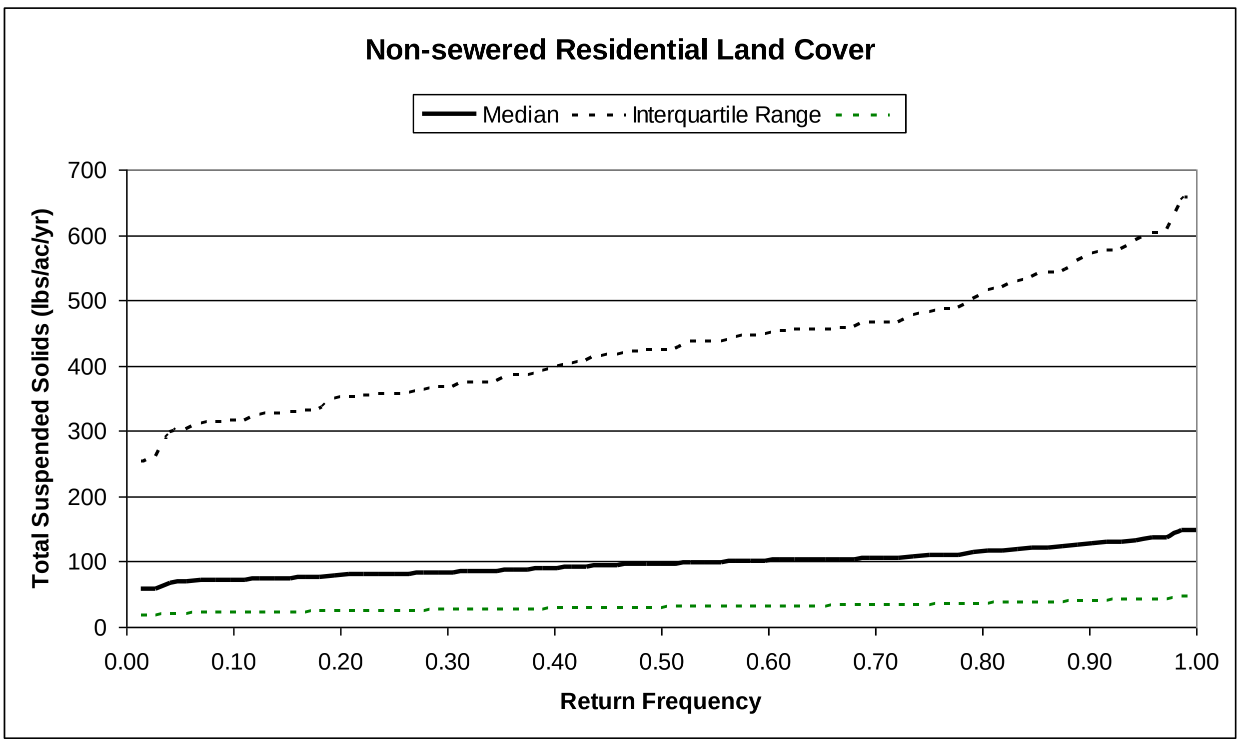

Figure 99. Nonsewered Residential Land Cover Total Suspended Solids Load Duration Curve

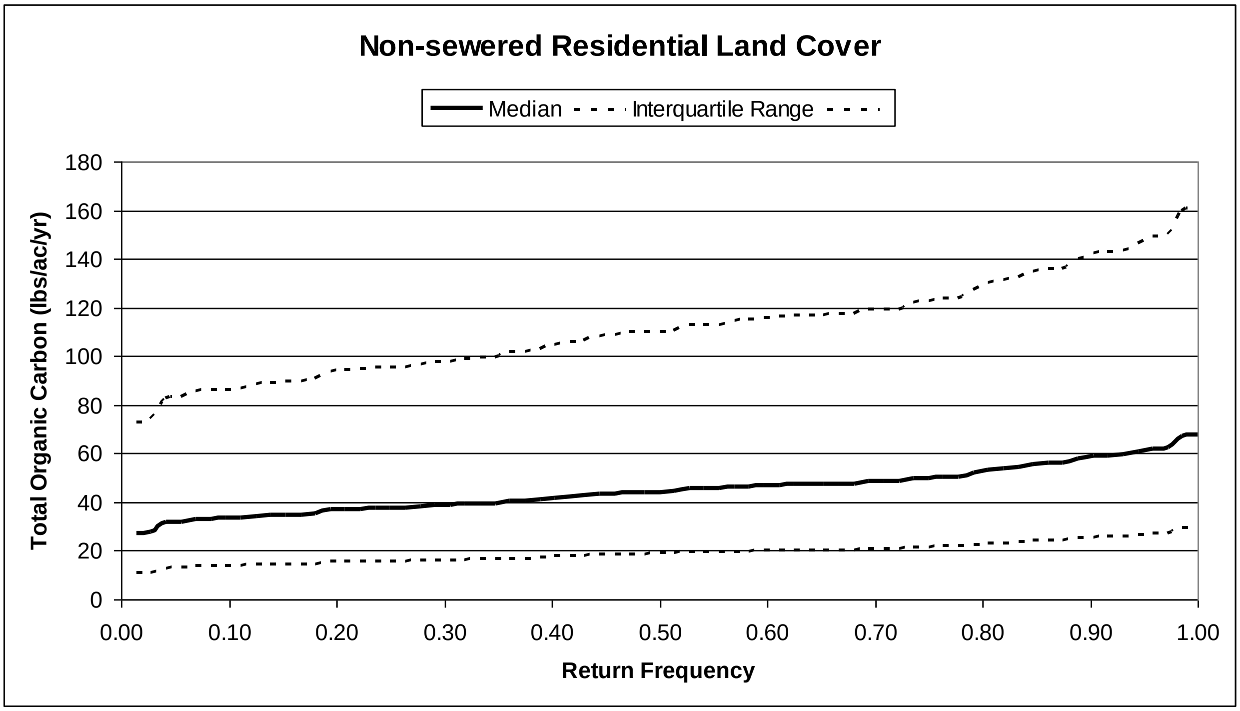

Figure 100. Nonsewered Residential Land Cover Total Organic Carbon Load Duration Curve

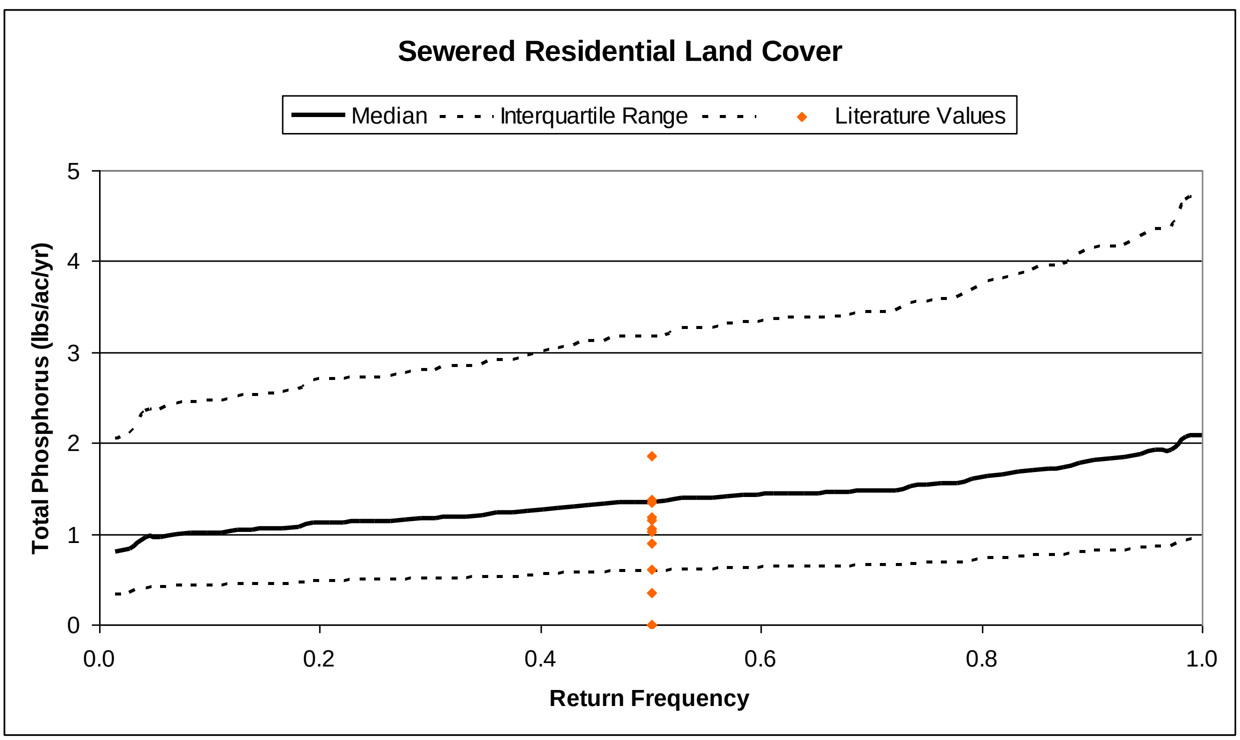

Figure 101. Sewered Residential Land Cover Total Phosphorus Load Duration Curve

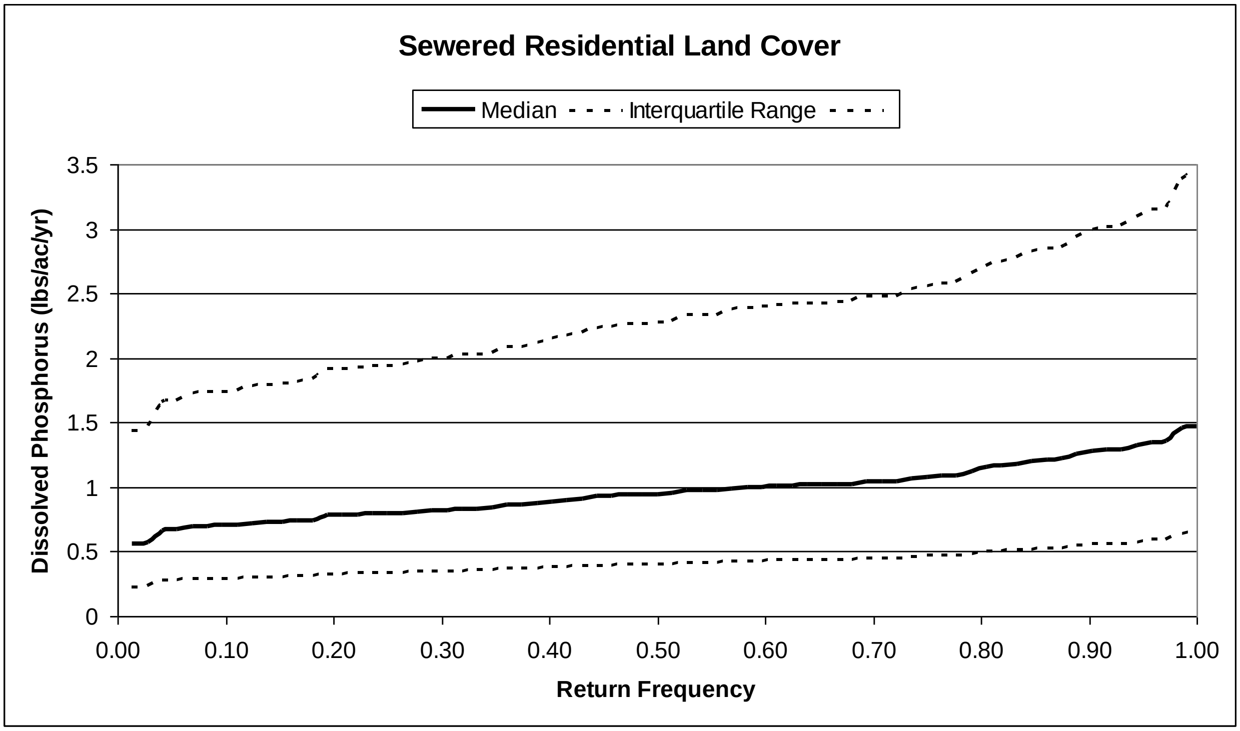

Figure 102. Sewered Residential Land Cover Dissolved Phosphorus Load Duration Curve

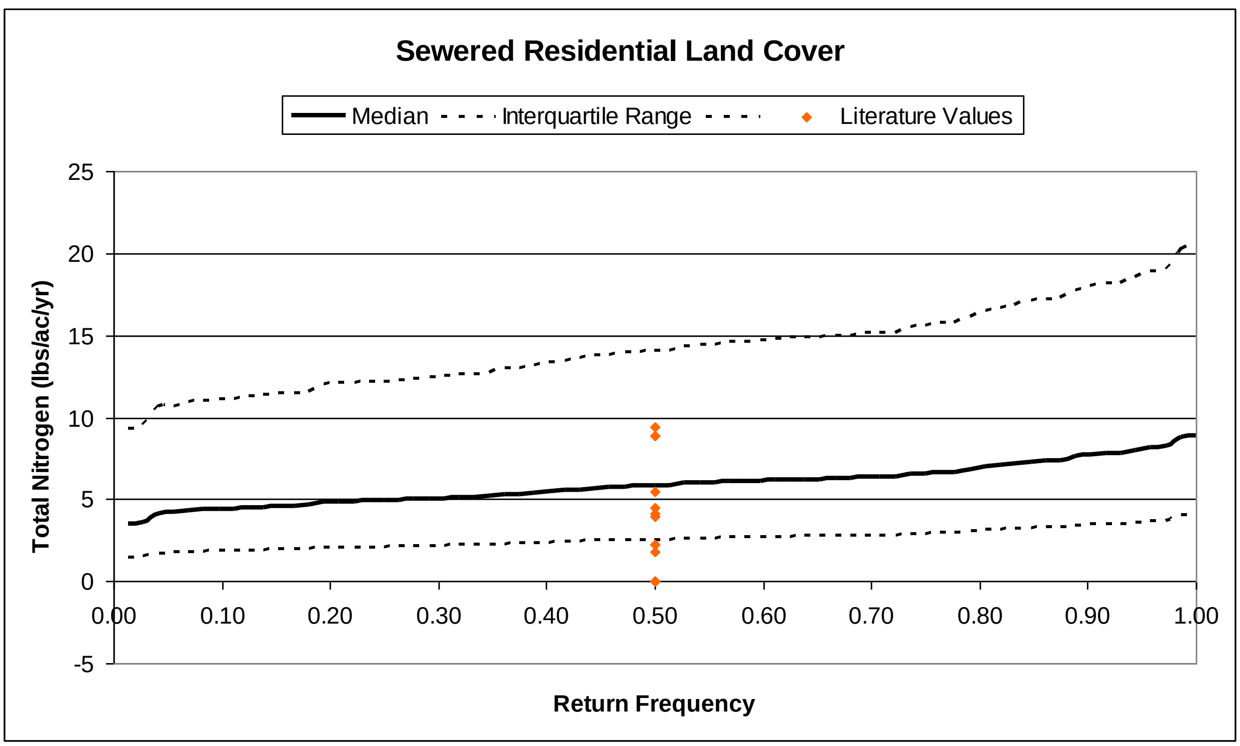

Figure 103. Sewered Residential Land Cover Total Nitrogen Load Duration Curve

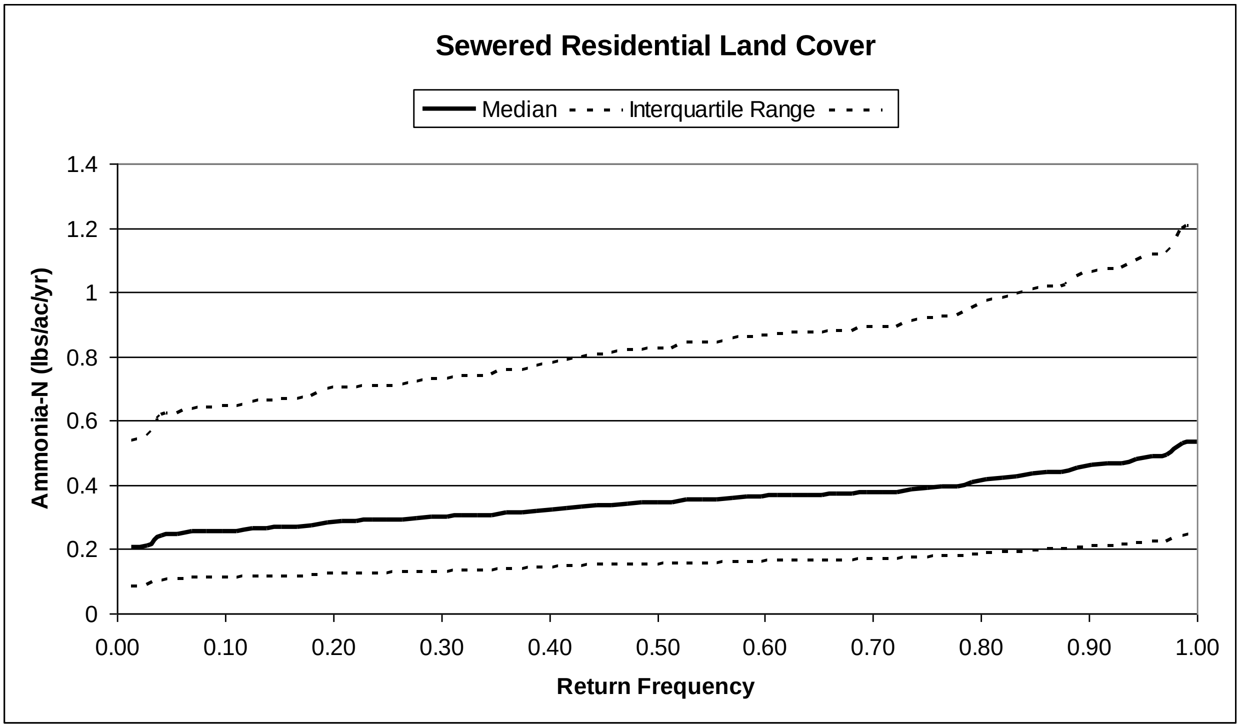

Figure 104. Sewered Residential Land Cover Ammonia-N Load Duration Curve

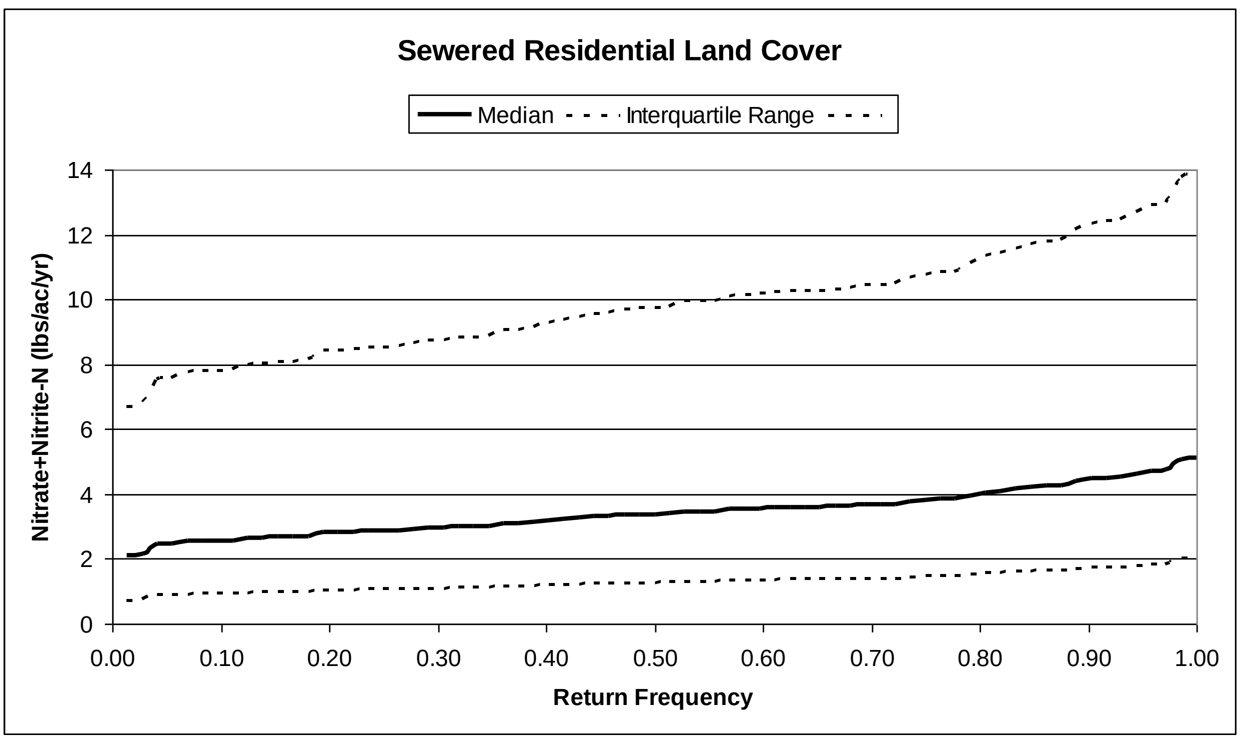

Figure 105. Sewered Residential Land Cover Nitrate+Nitrite-N Load Duration Curve

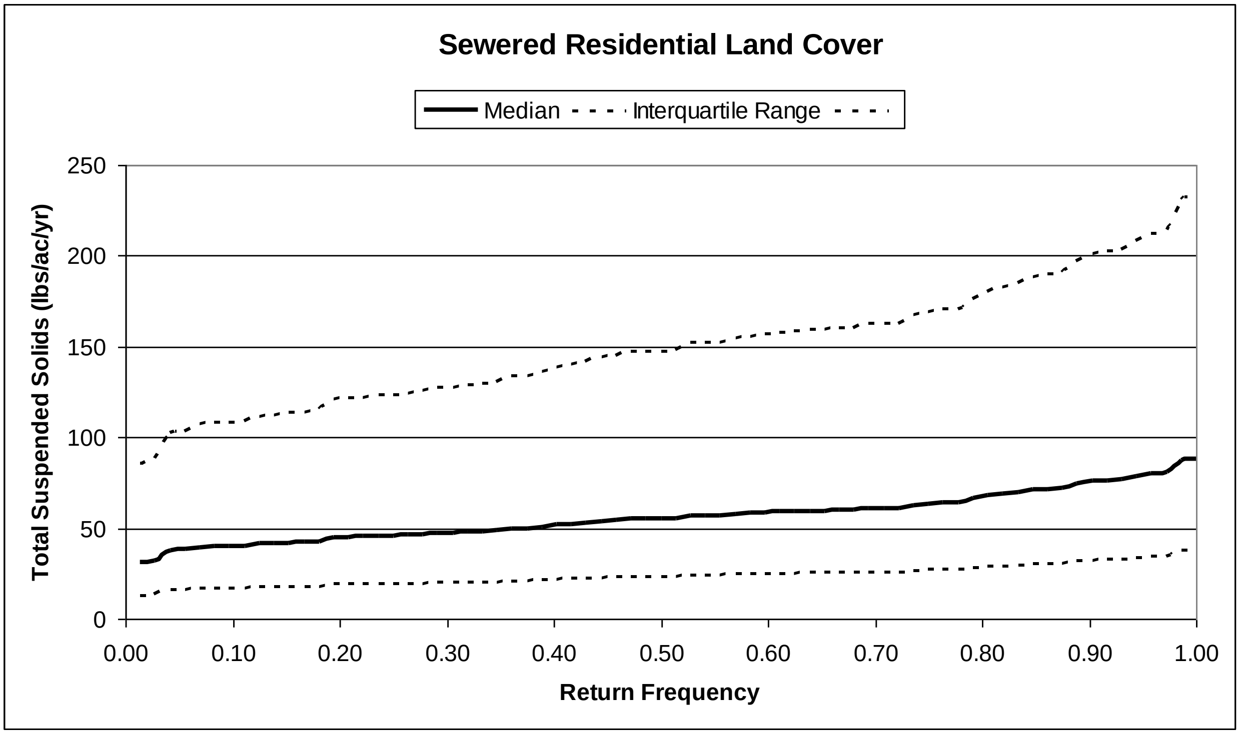

Figure 106. Sewered Residential Land Cover Total Suspended Solids Load Duration Curve

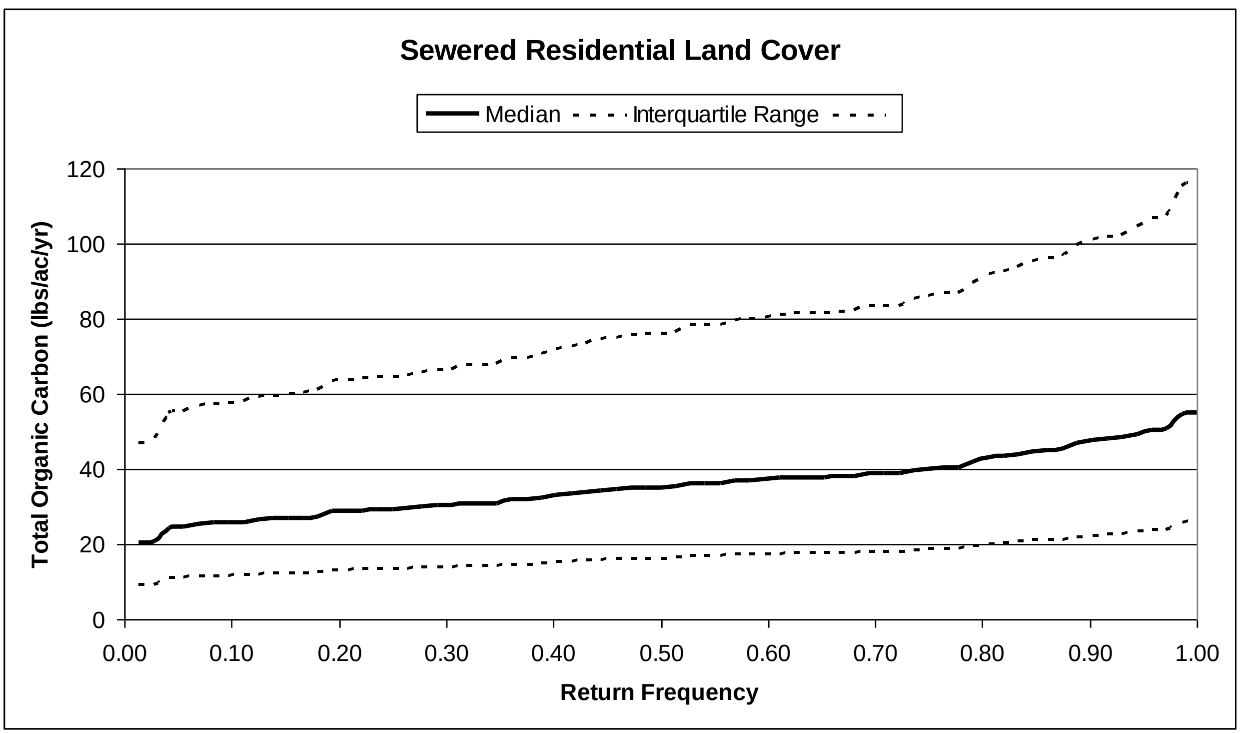

Figure 107. Sewered Residential Land Cover Total Organic Carbon Load Duration Curve

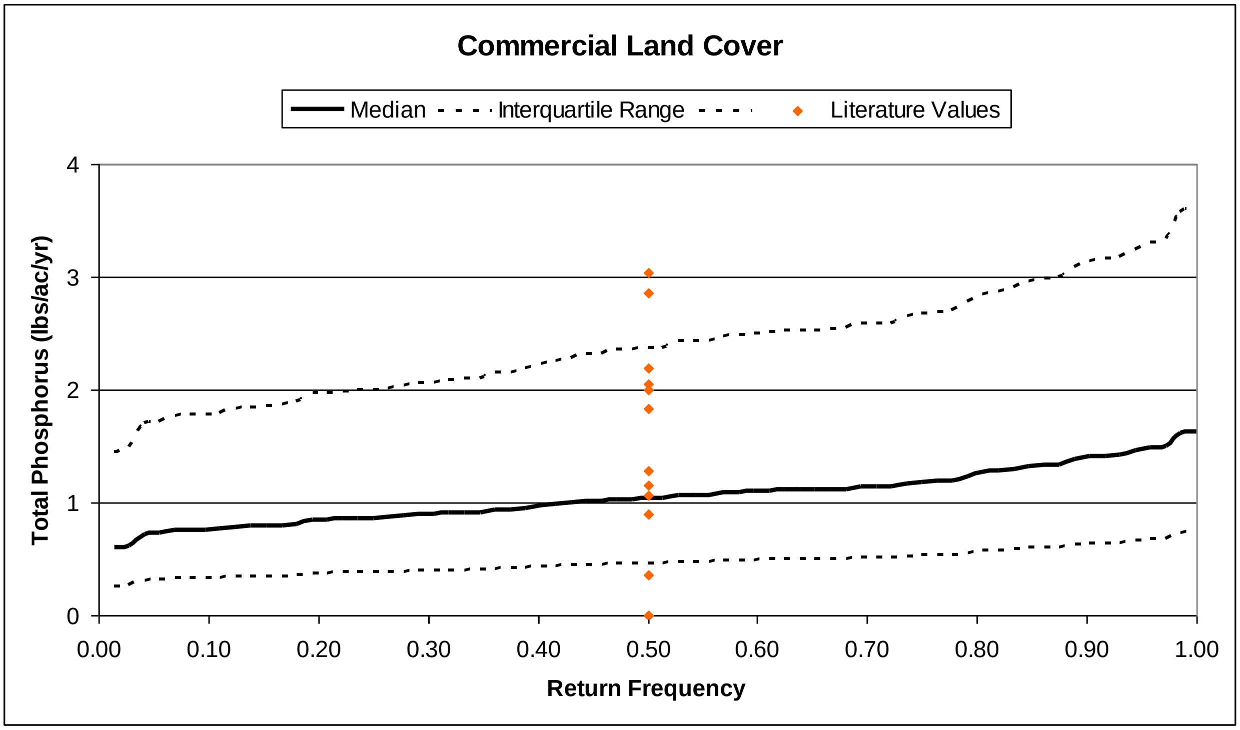

Figure 108. Commercial Land Cover Total Phosphorus Load Duration Curve

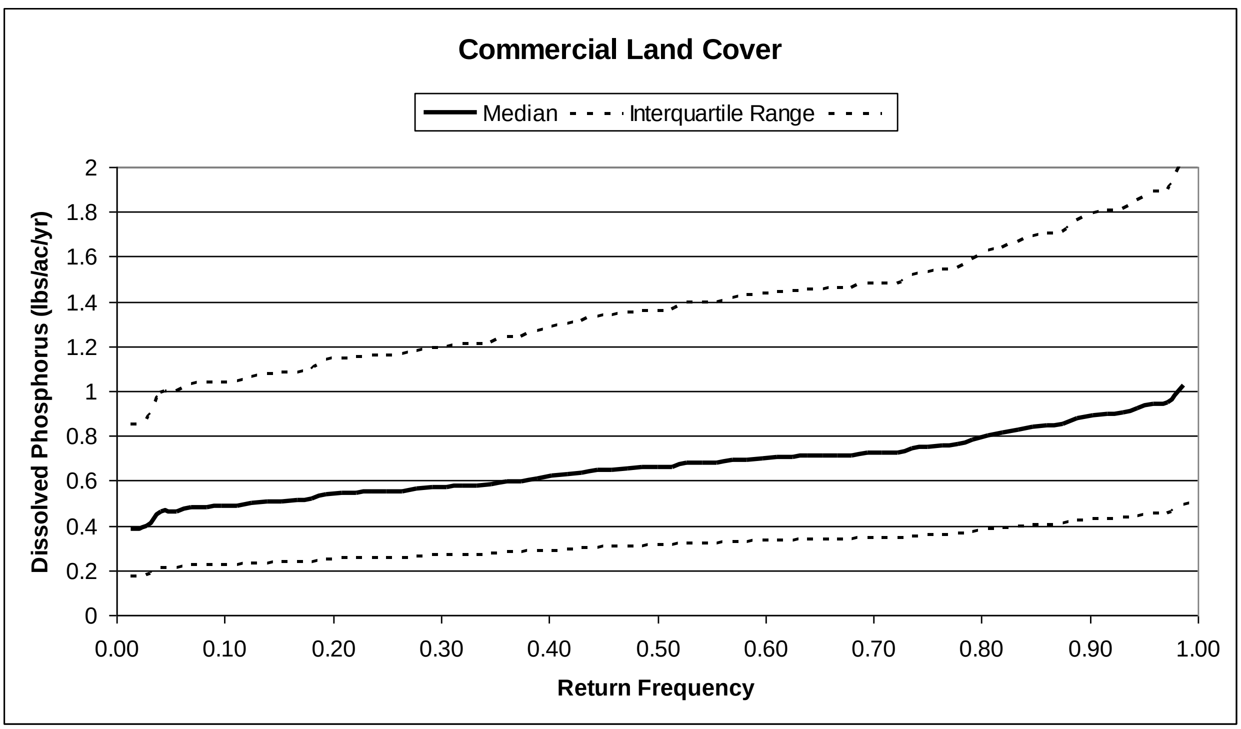

Figure 109. Commercial Land Cover Dissolved Phosphorus Load Duration Curve

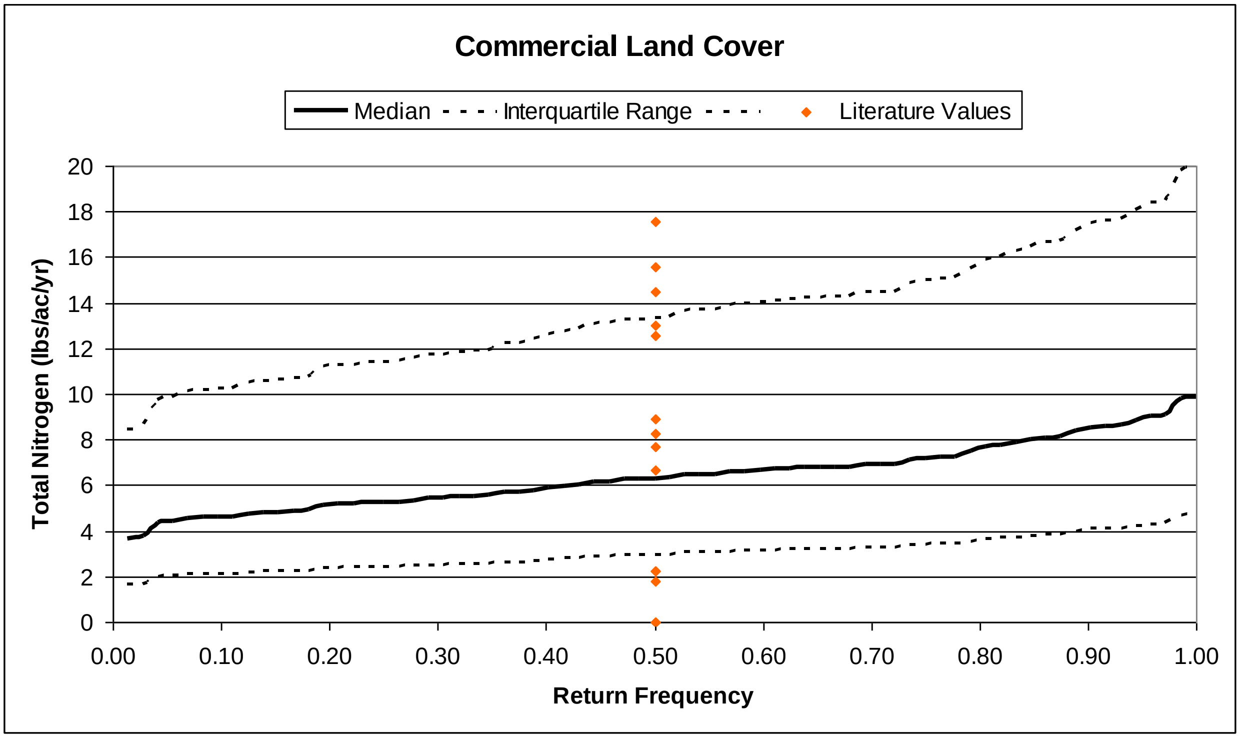

Figure 110. Commercial Land Cover Total Nitrogen Load Duration Curve

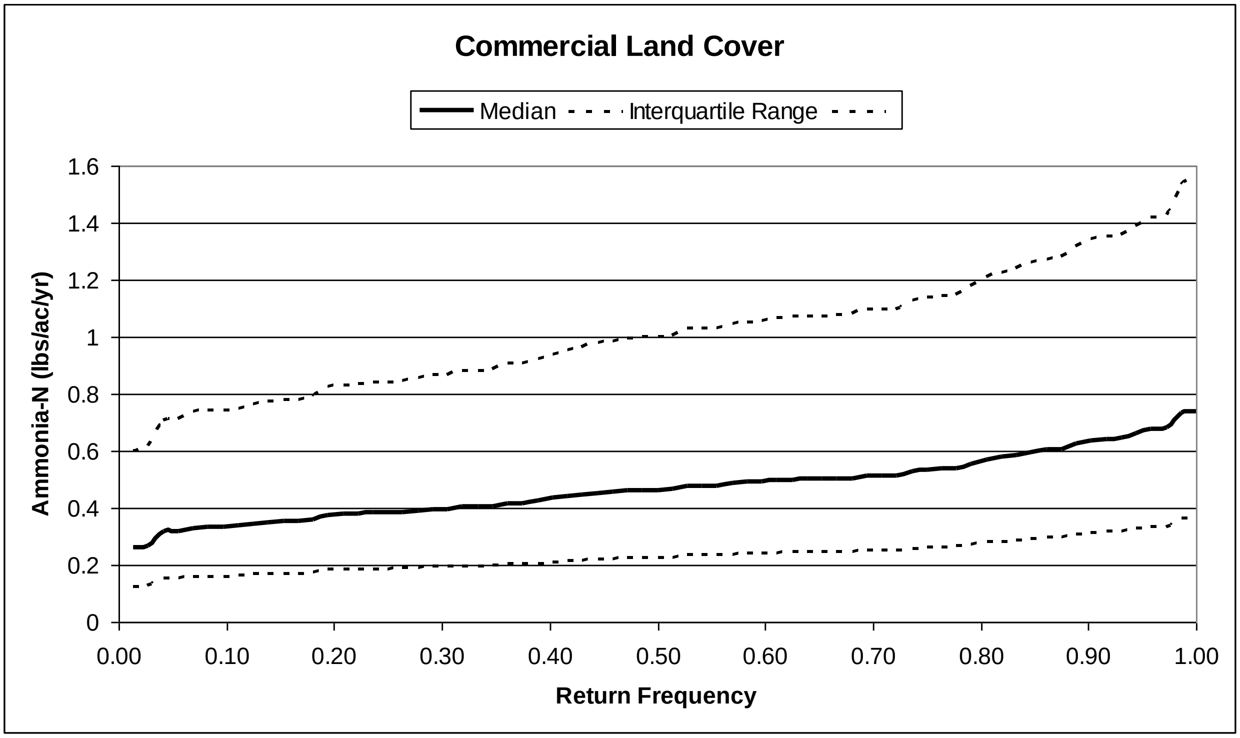

Figure 111. Commercial Land Cover Ammonia-N Load Duration Curve

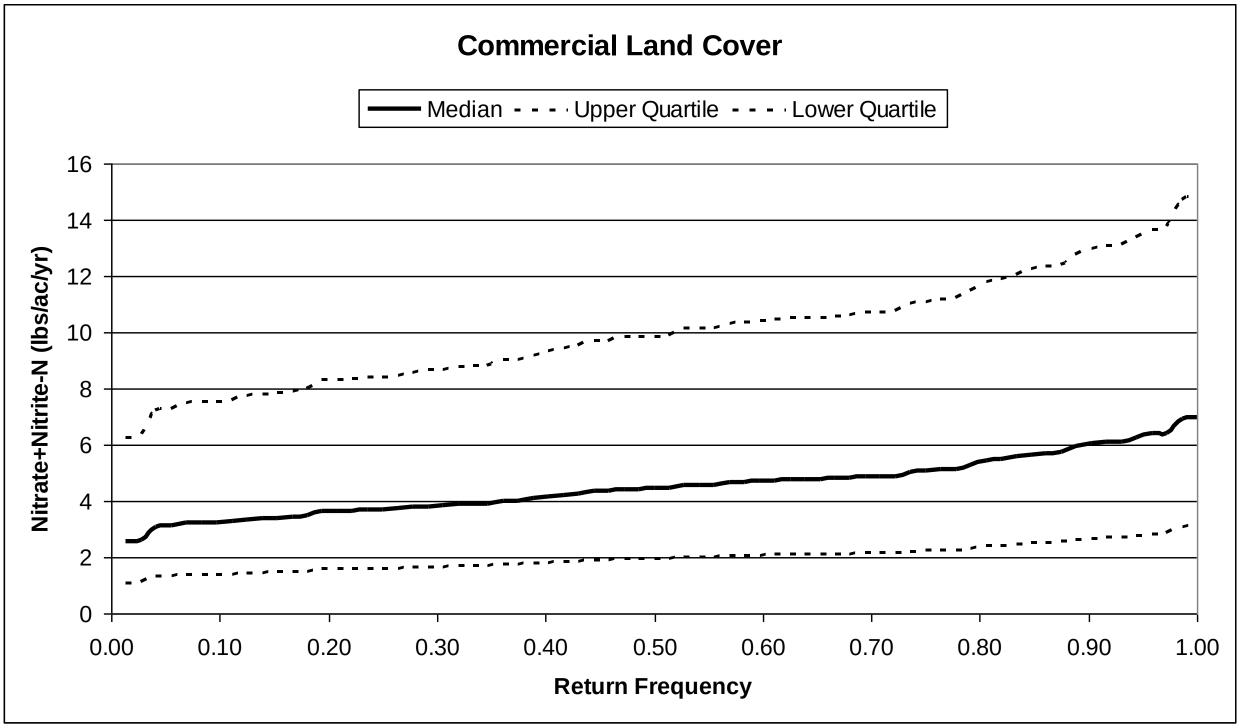

Figure 112. Commercial Land Cover Nitrate+Nitrite-N Load Duration Curve

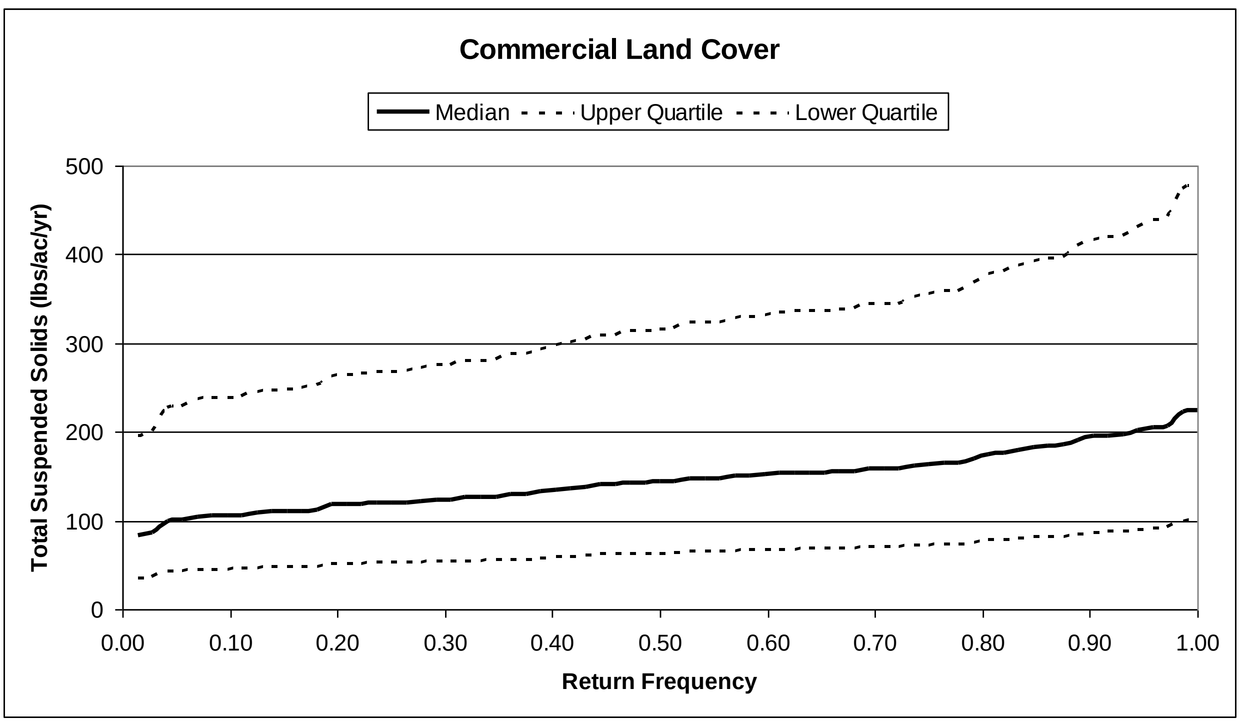

Figure 113. Commercial Land Cover Total Suspended Solids Load Duration Curve

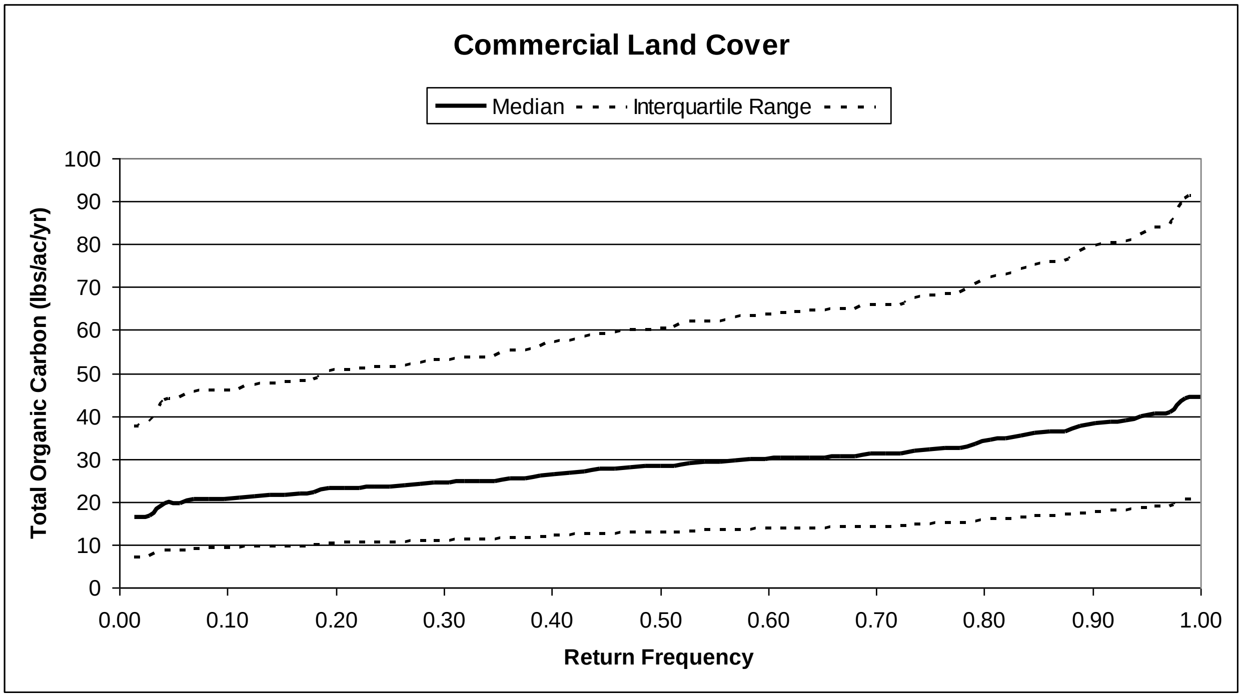

Figure 114. Commercial Land Cover Total Organic Carbon Load Duration Curve

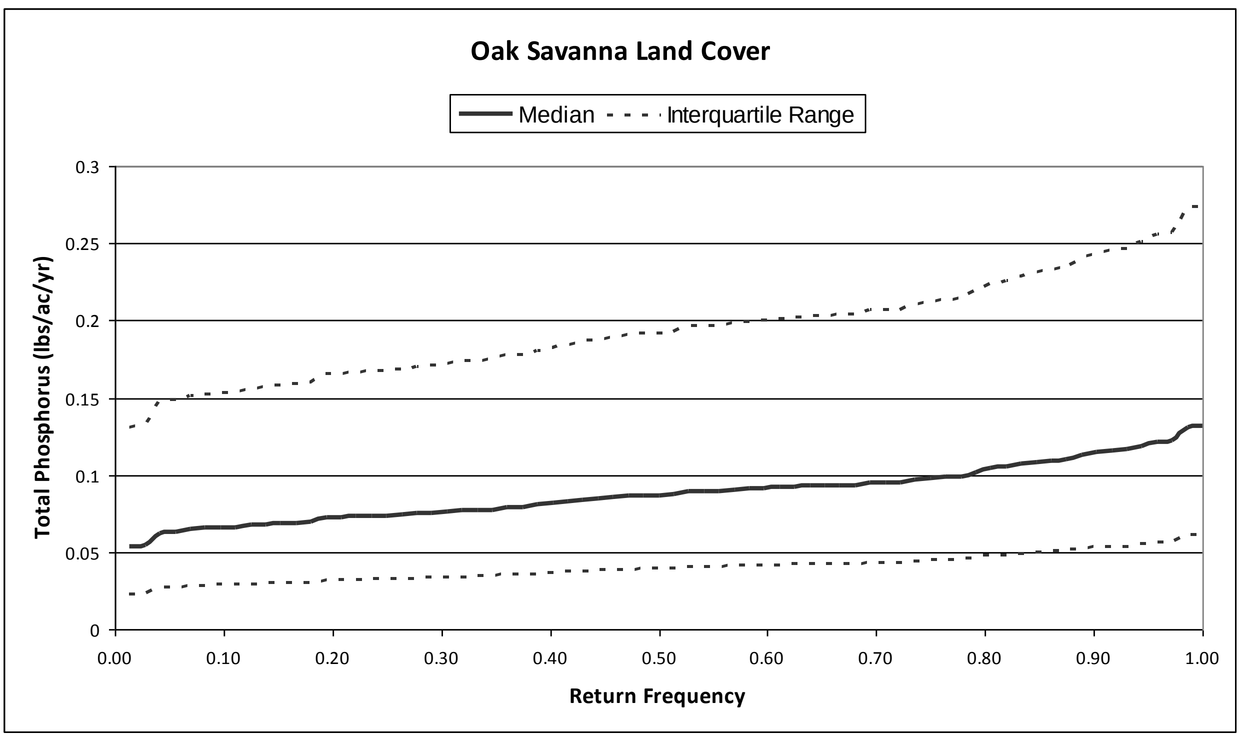

Figure 115. Oak Savanna Cover Total Phosphorus Load Duration Curve

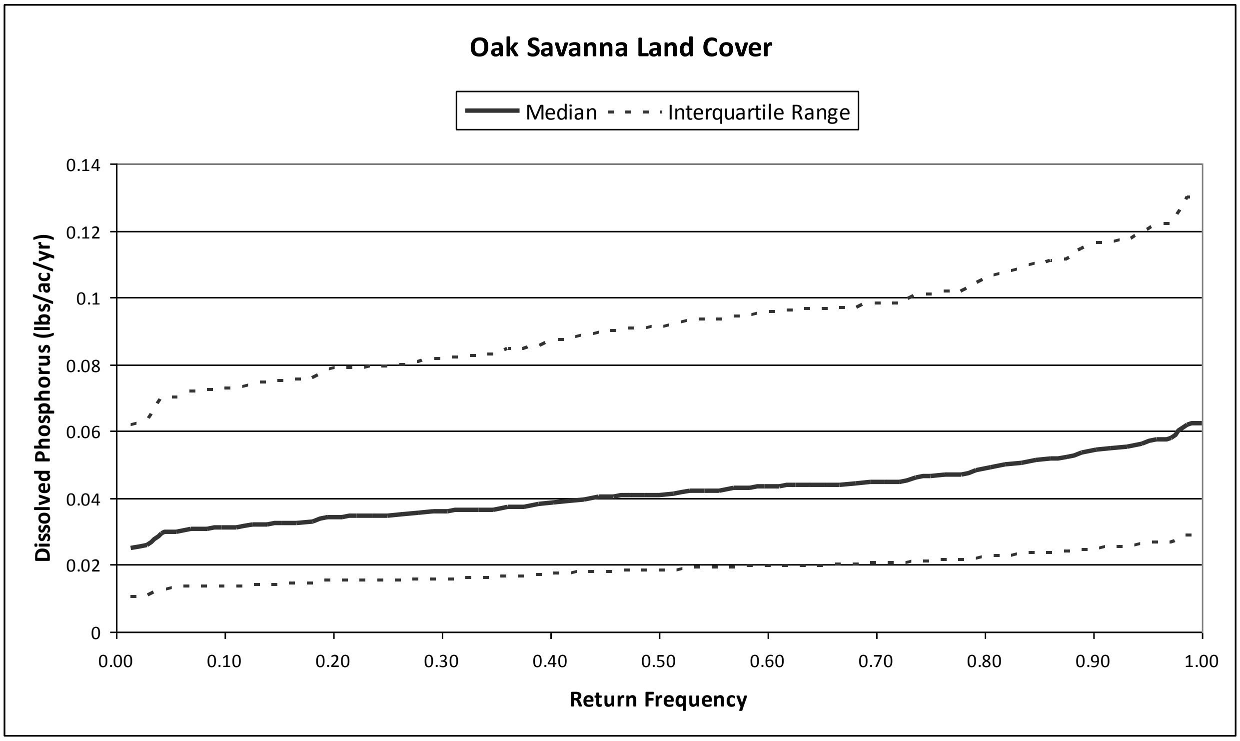

Figure 116. Oak Savanna Cover Dissolved Phosphorus Load Duration Curve

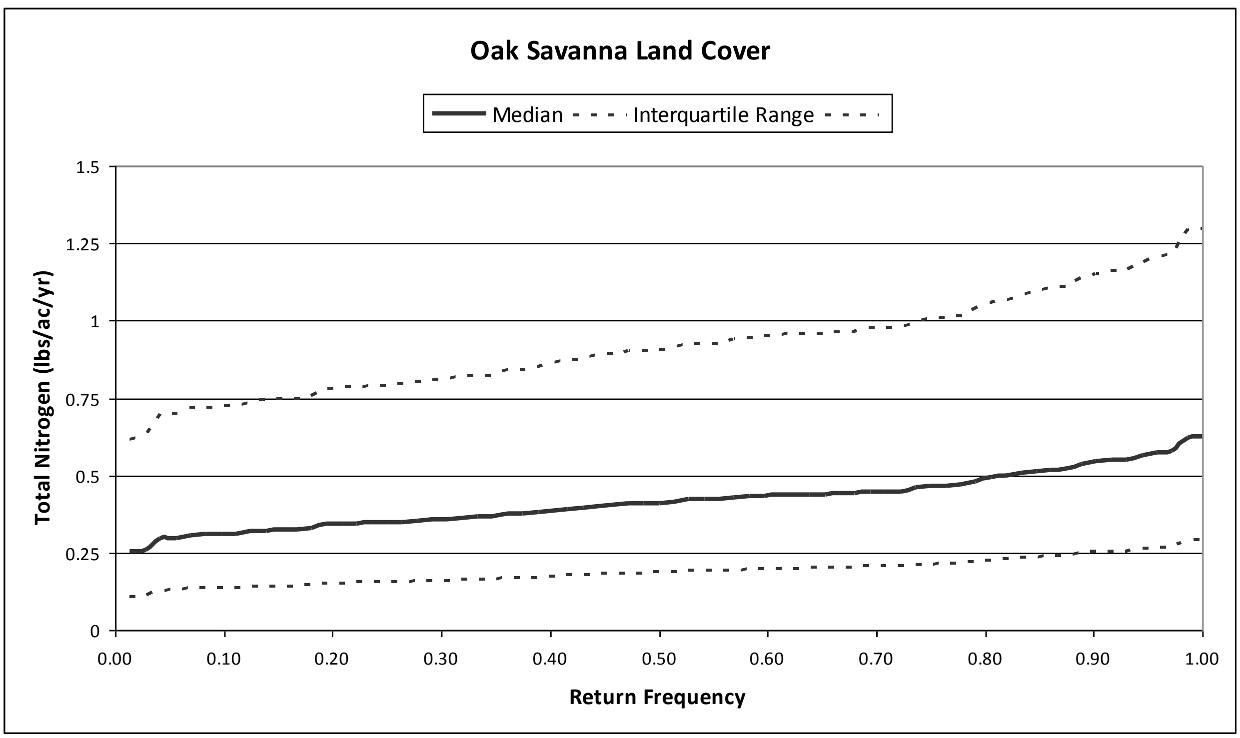

Figure 117. Oak Savanna Cover Total Nitrogen Load Duration Curve

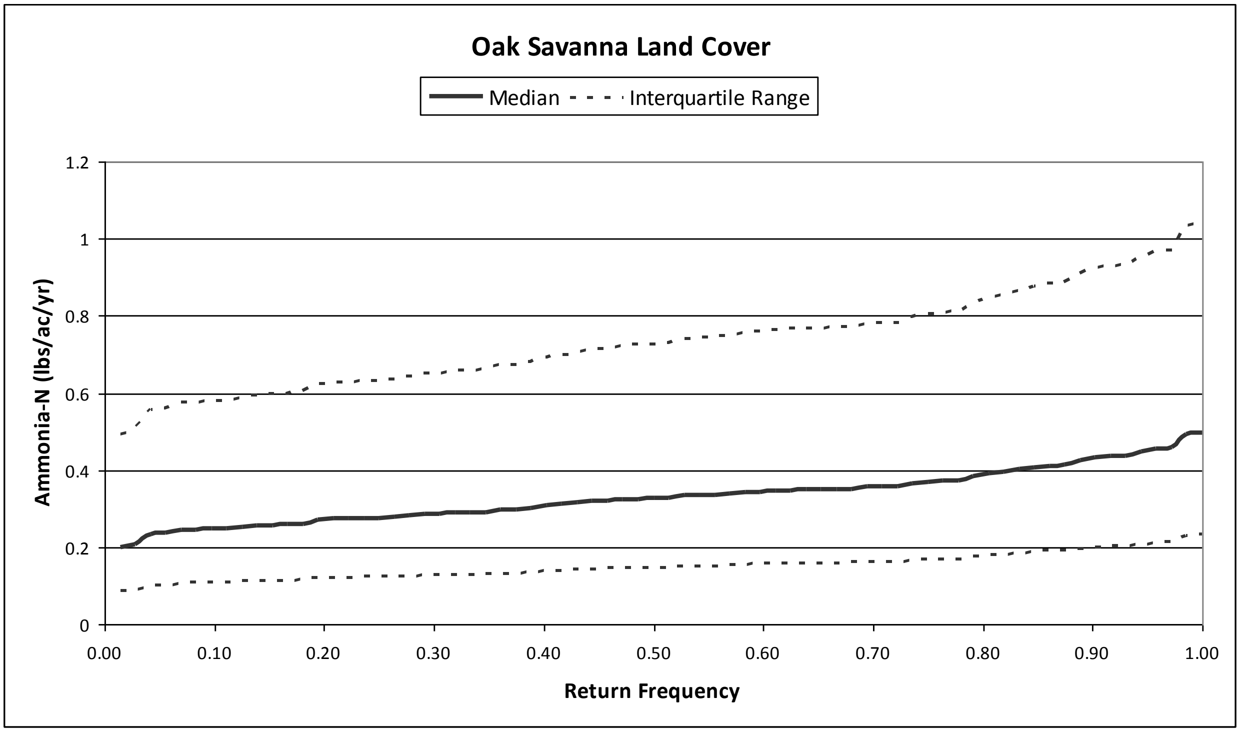

Figure 118. Oak Savanna Cover Ammonia-N Load Duration Curve

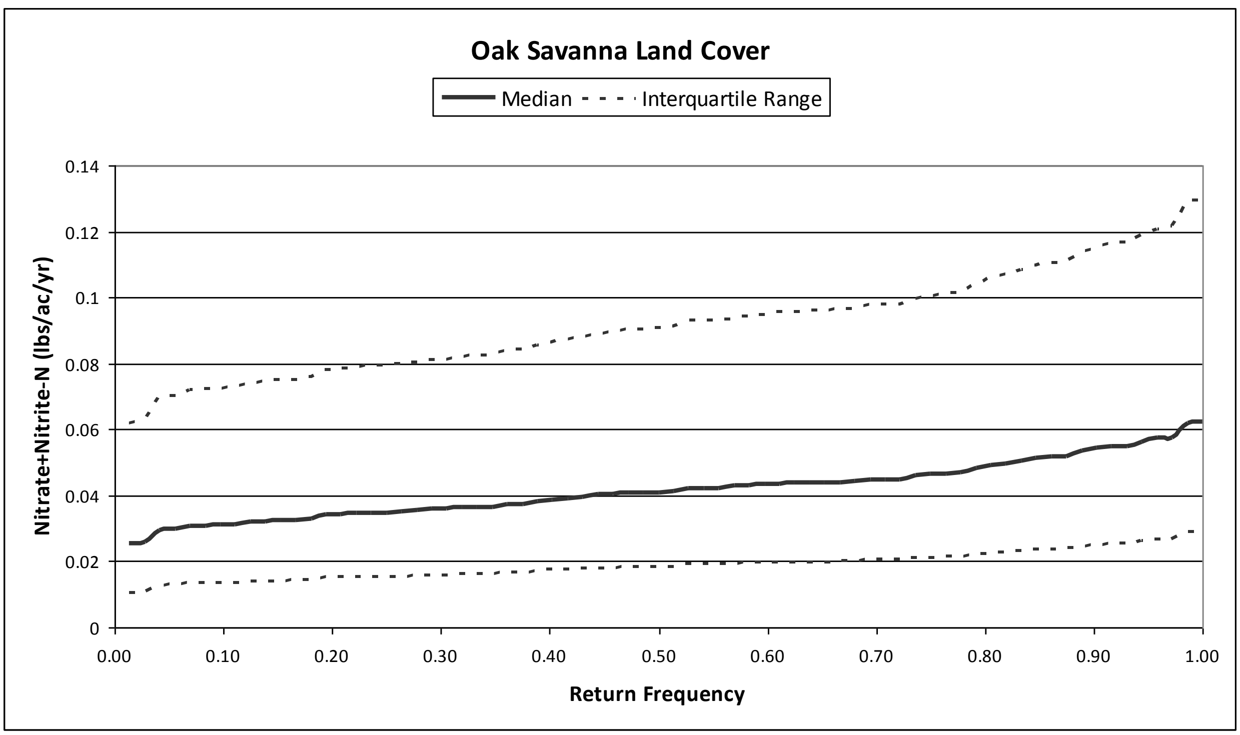

Figure 119. Oak Savanna Cover Nitrate+Nitrite-N Load Duration Curve

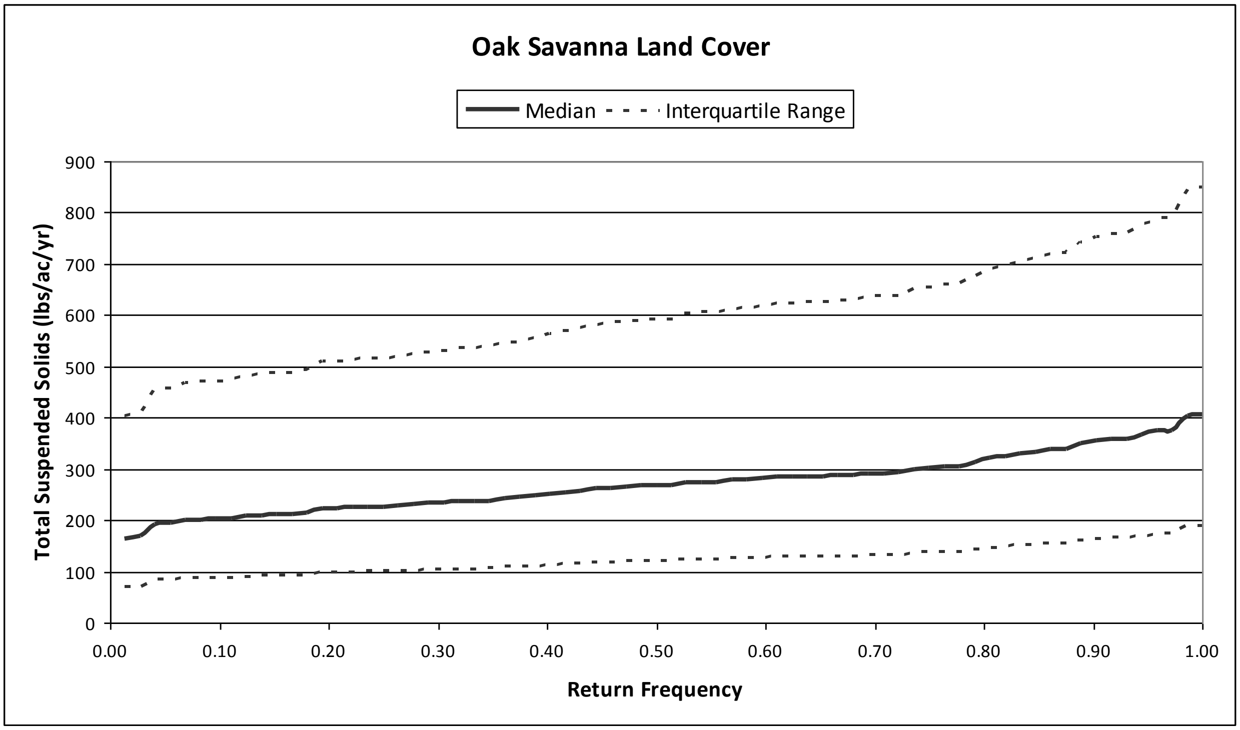

Figure 120. Oak Savanna Cover Total Suspended Solids Load Duration Curve

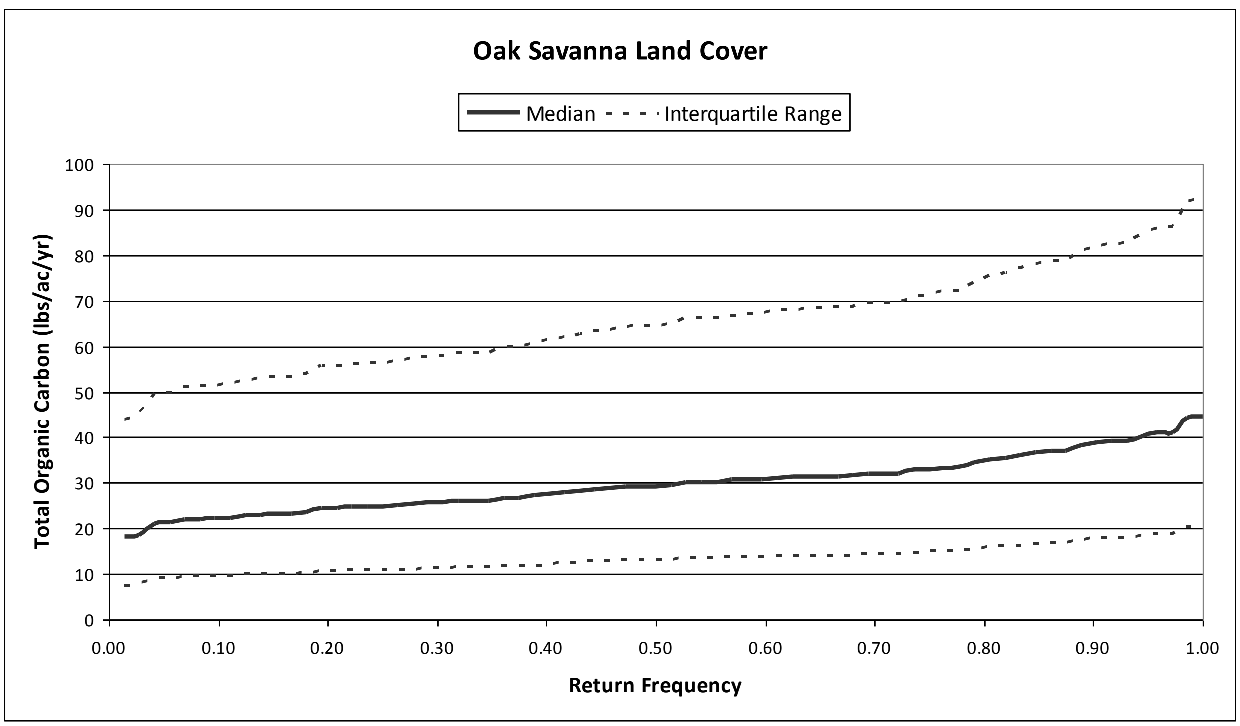

Figure 121. Oak Savanna Cover Total Organic Carbon Load Duration Curve

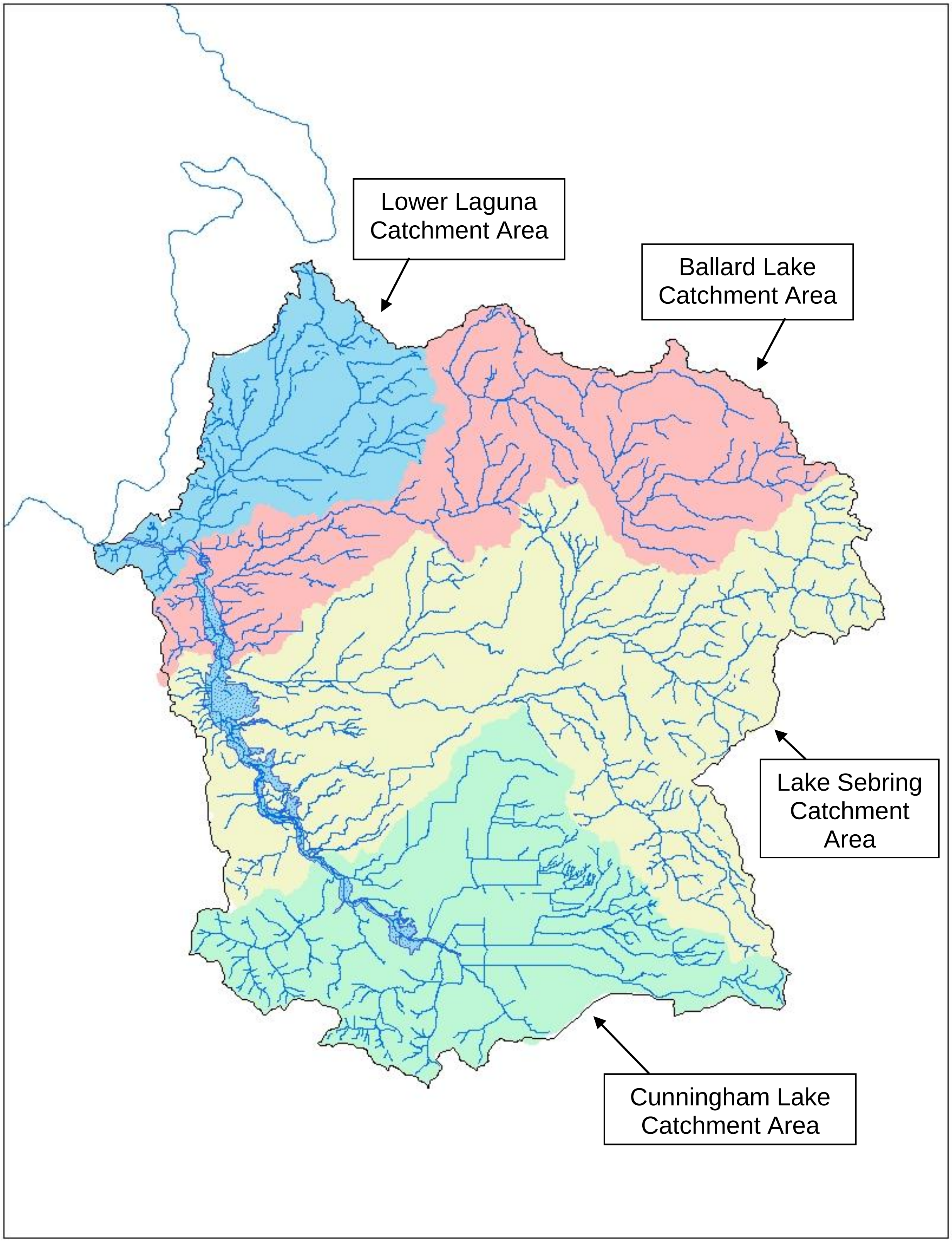

Figure 122. Laguna Watershed Historical Lake Catchment Areas

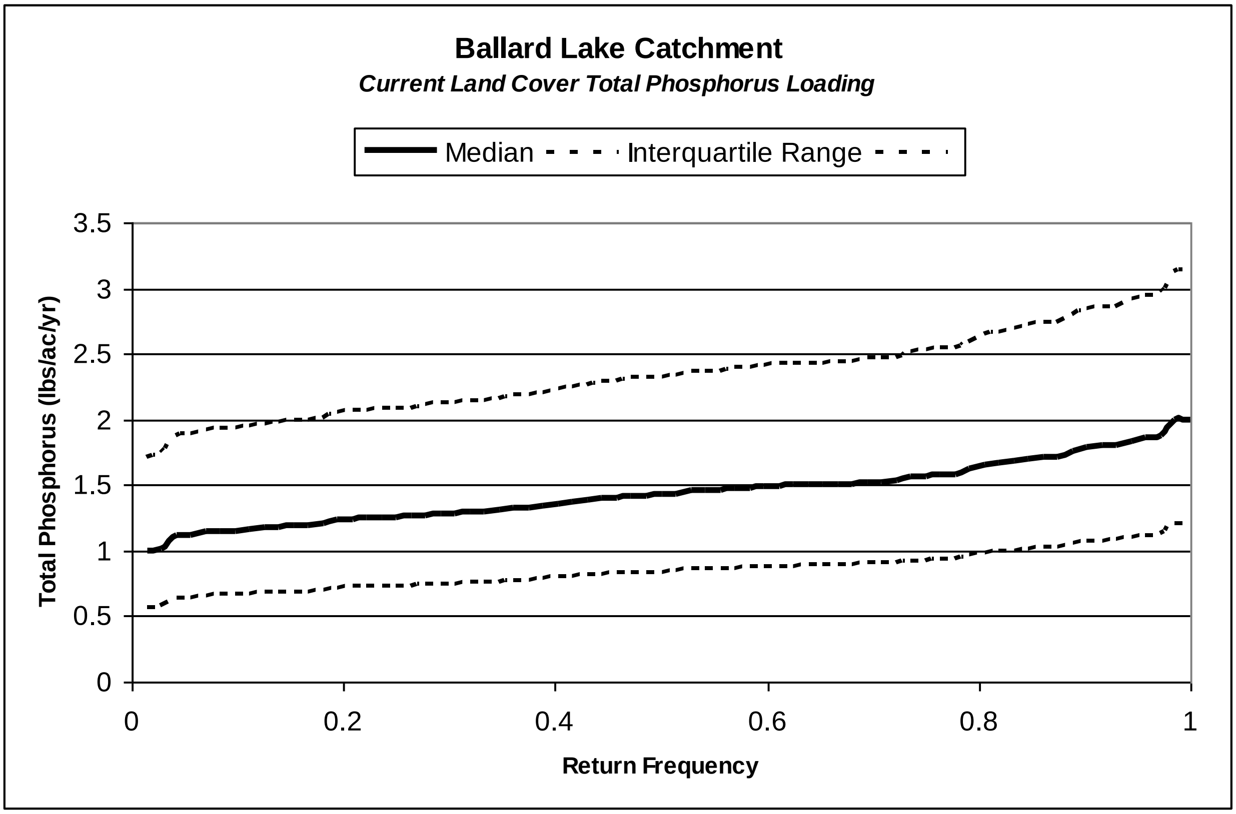

Figure 123. Current Ballard Lake Catchment Total Phosphorus Load Duration Curve

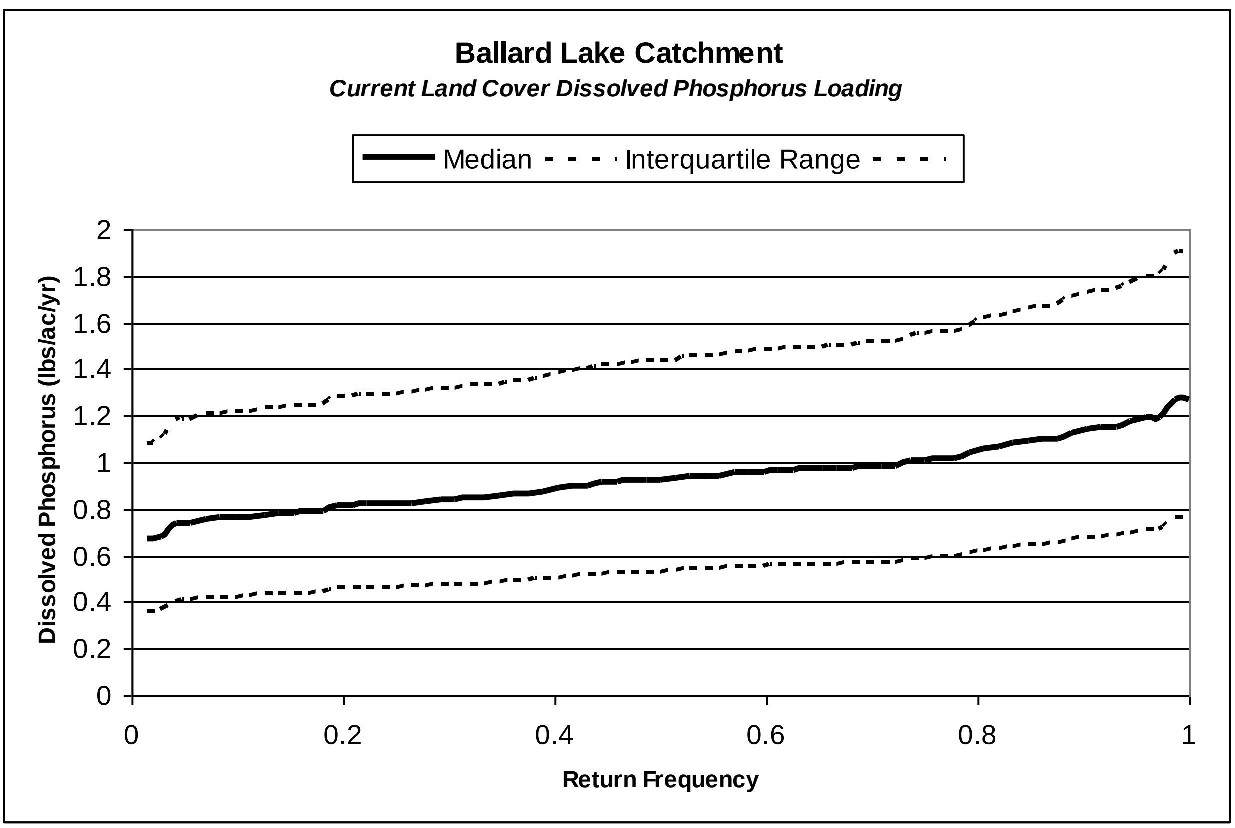

Figure 124. Current Ballard Lake Catchment Dissolved Phosphorus Load Duration Curve

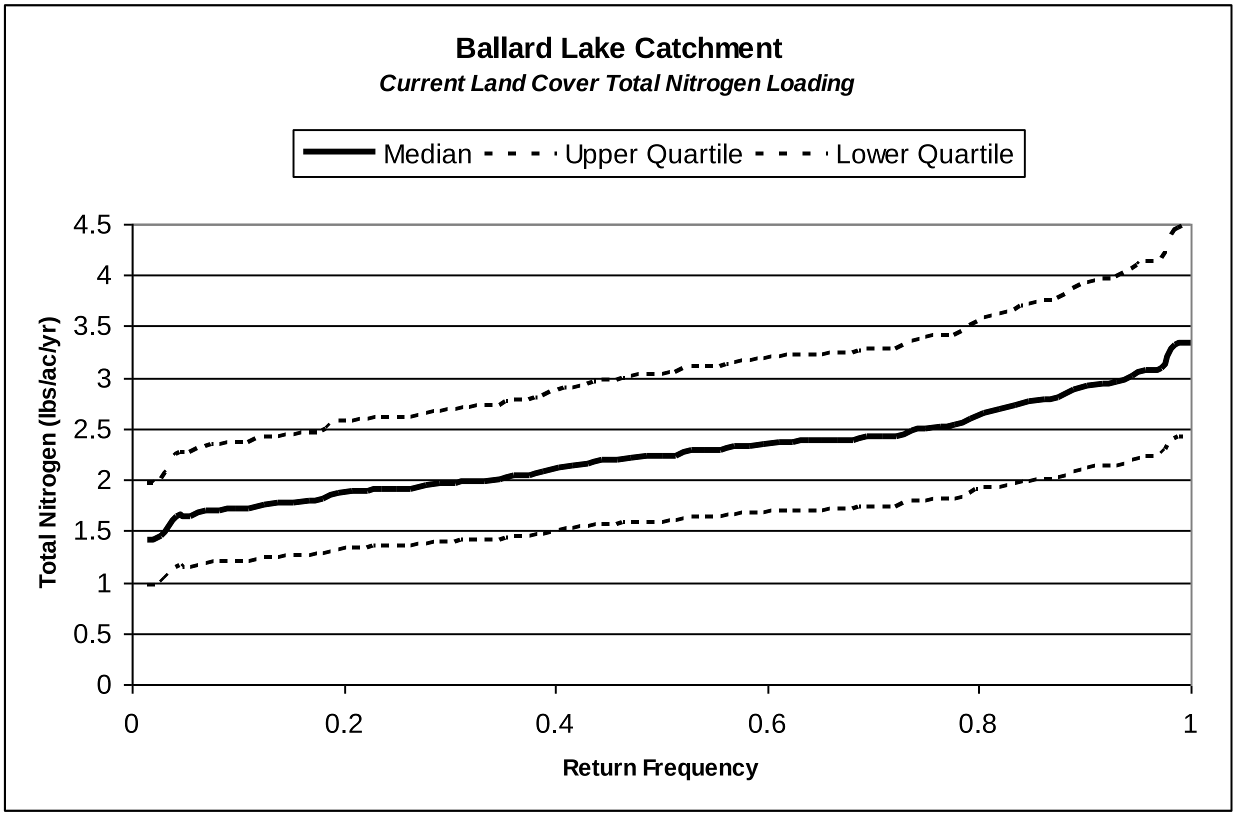

Figure 125. Current Ballard Lake Catchment Total Nitrogen Load Duration Curve

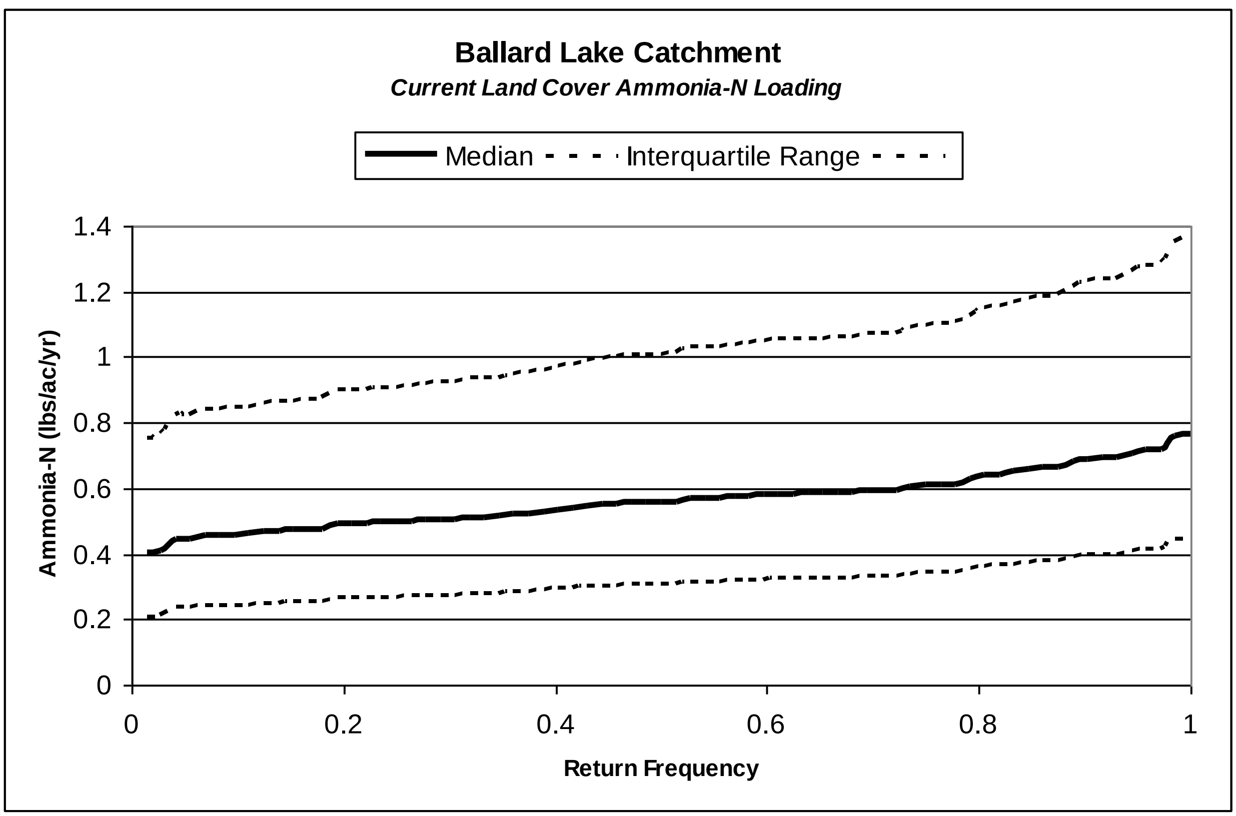

Figure 126. Current Ballard Lake Catchment Ammonia-N Load Duration Curve

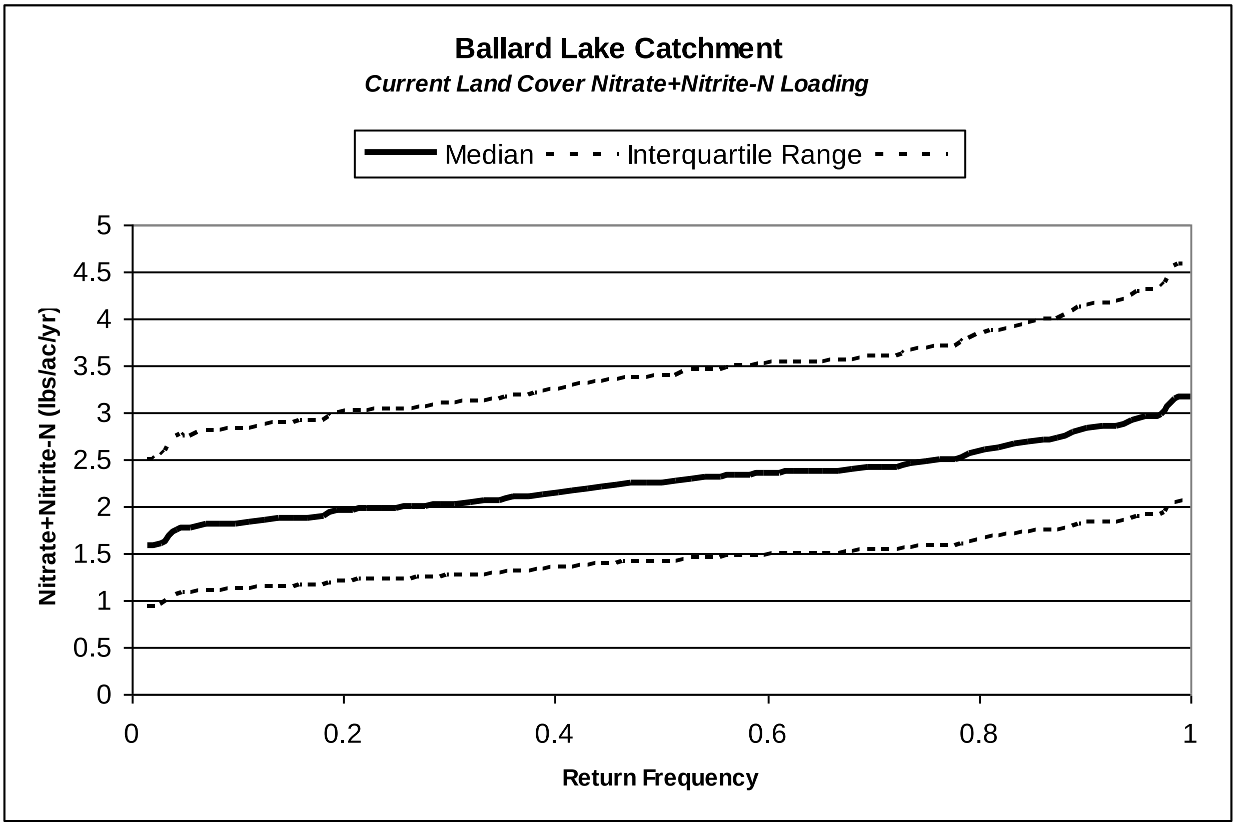

Figure 127. Current Ballard Lake Catchment Nitrate+Nitrite-N Load Duration Curve

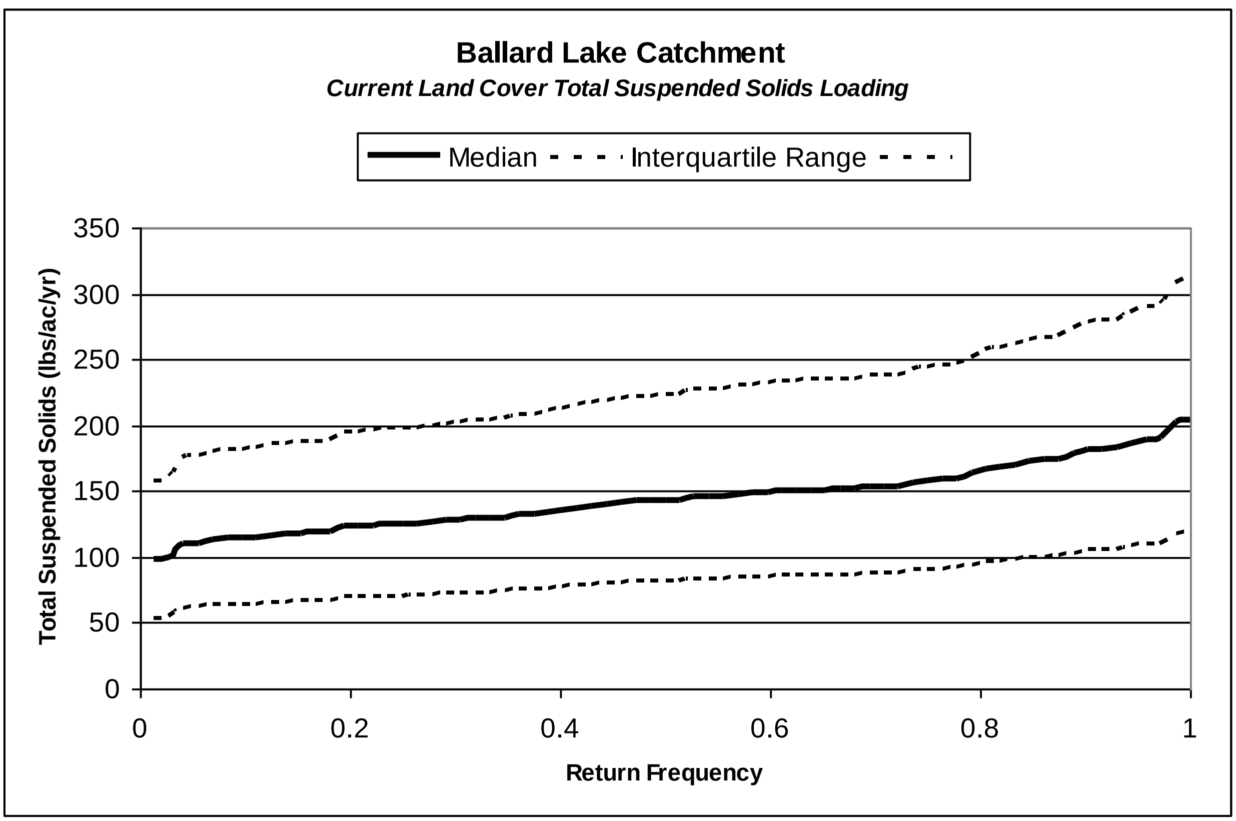

Figure 128. Current Ballard Lake Catchment Total Suspended Solids Load Duration Curve

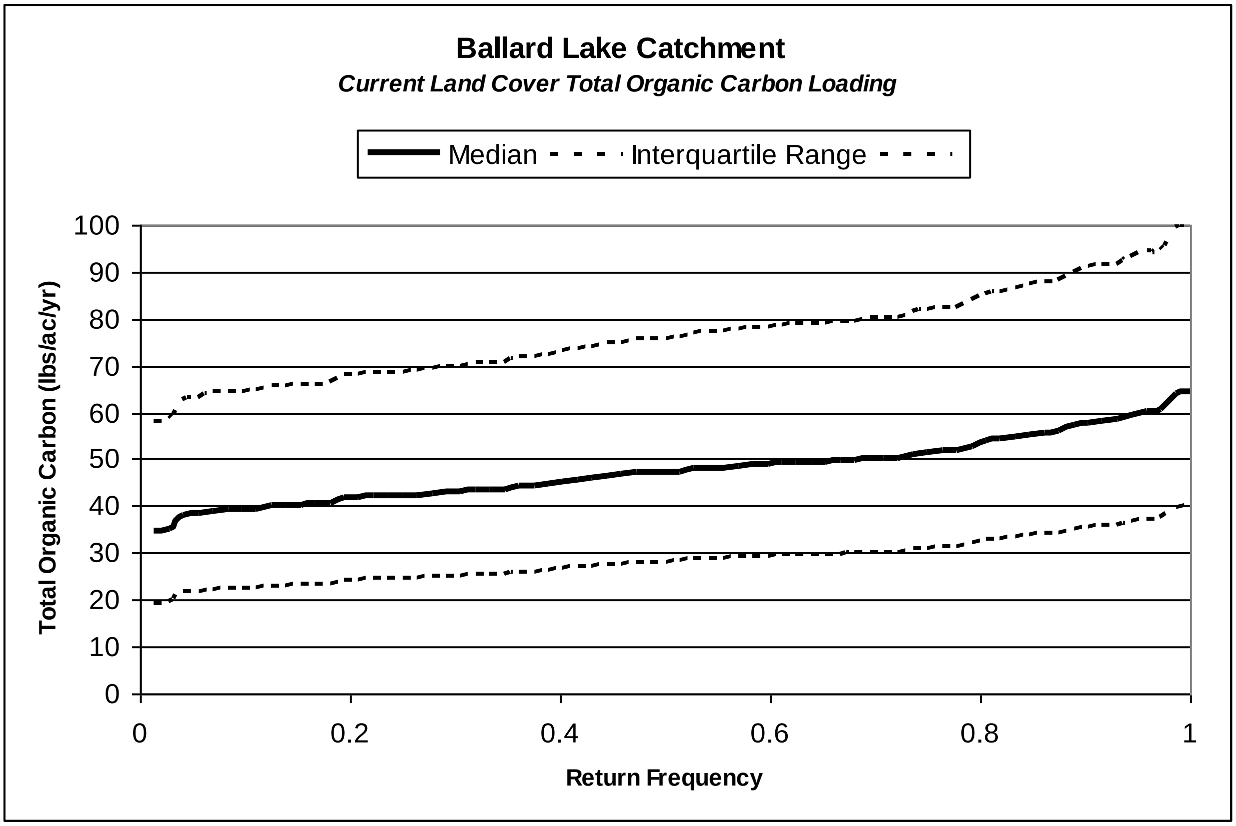

Figure 129. Current Ballard Lake Catchment Total Organic Carbon Load Duration Curve

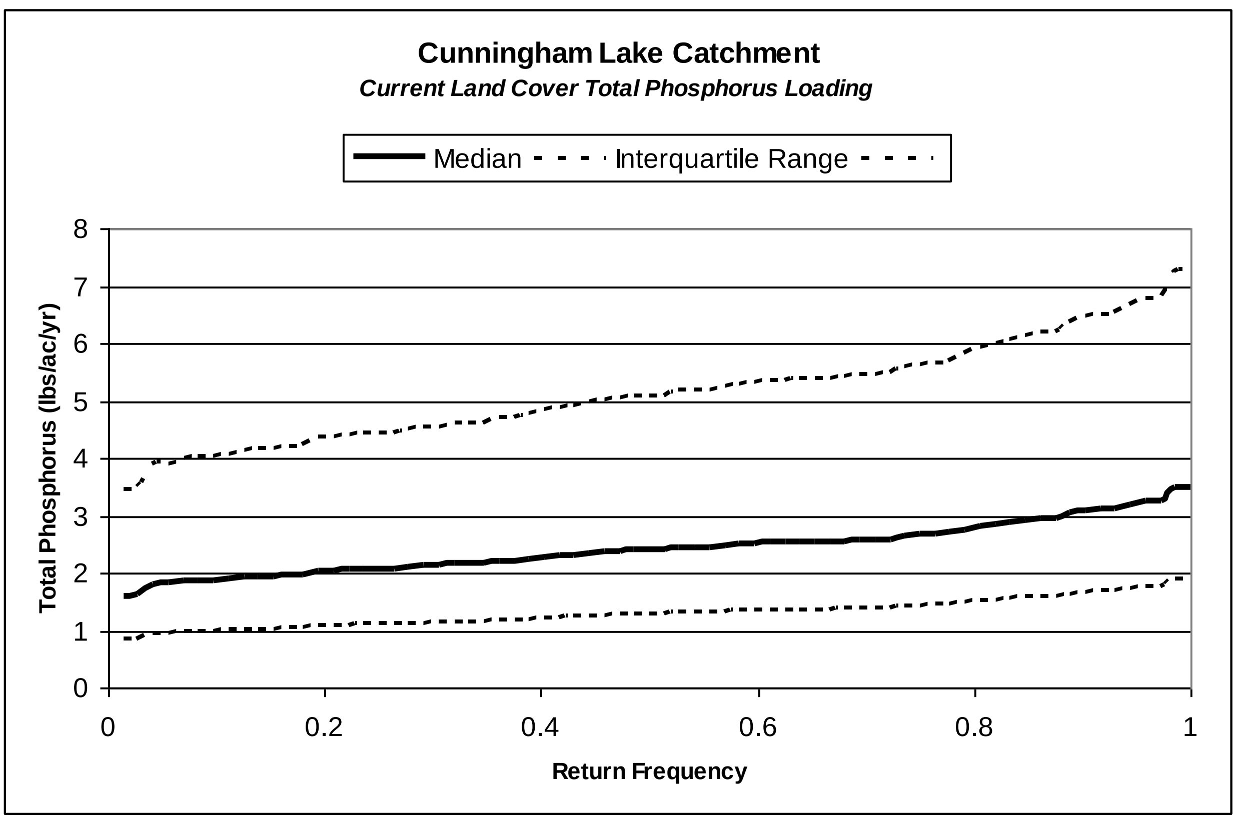

Figure 130. Current Cunningham Lake Catchment Total Phosphorus Load Duration Curve

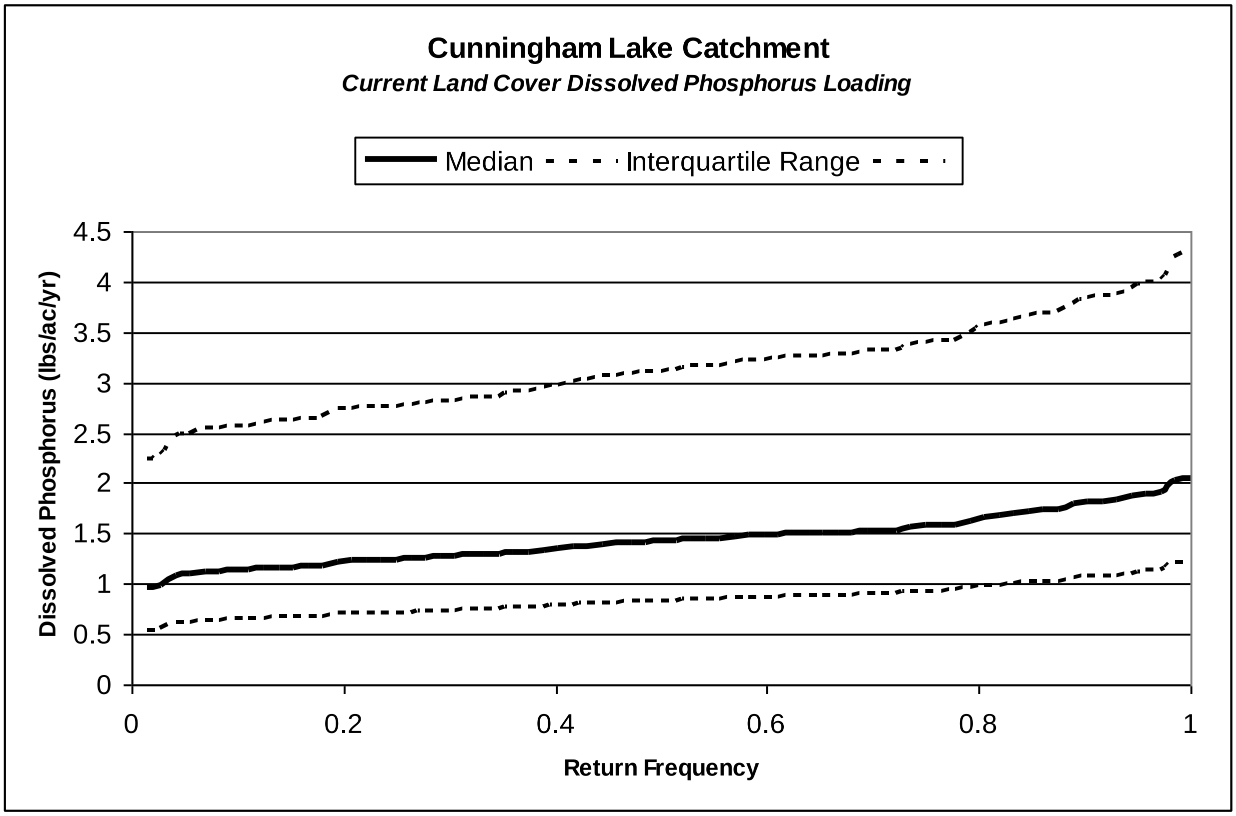

Figure 131. Current Cunningham Lake Catchment Dissolved Phosphorus Load Duration Curve

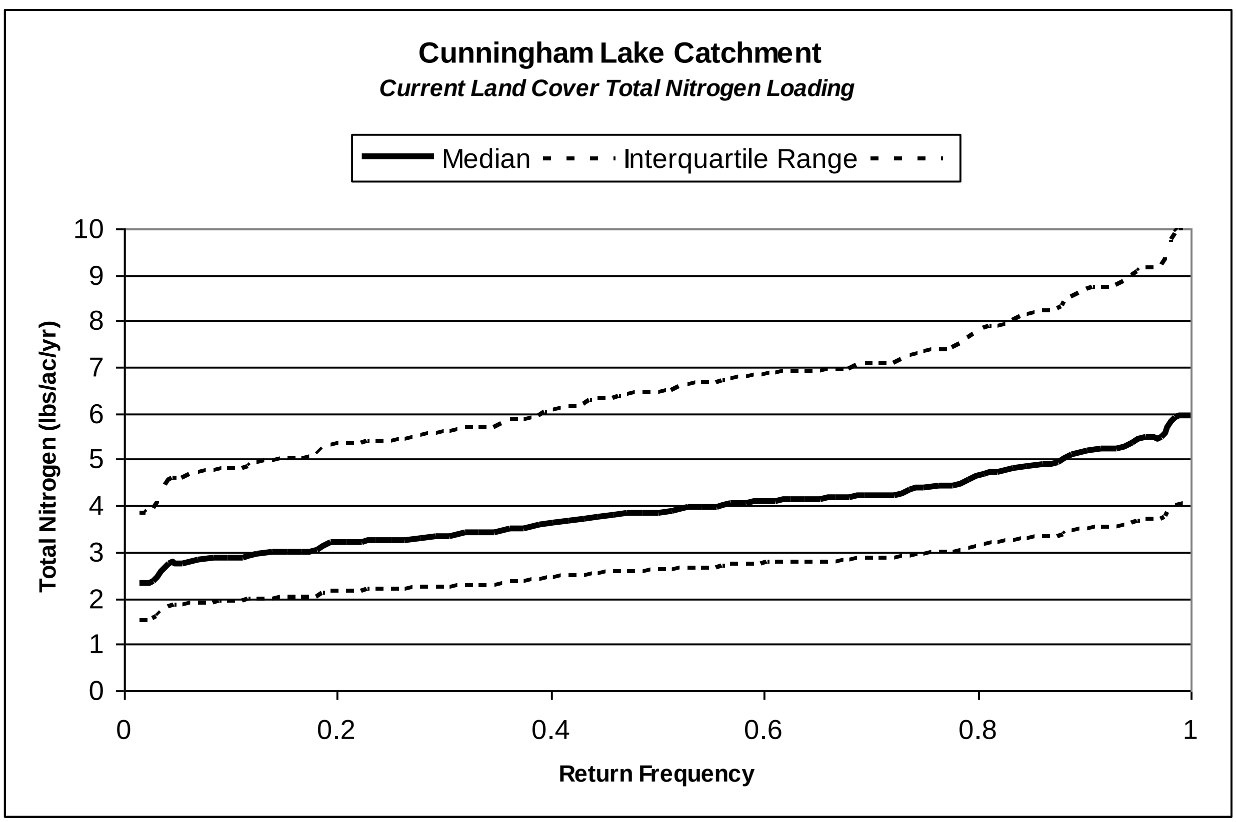

Figure 132. Current Cunningham Lake Catchment Total Nitrogen Load Duration Curve

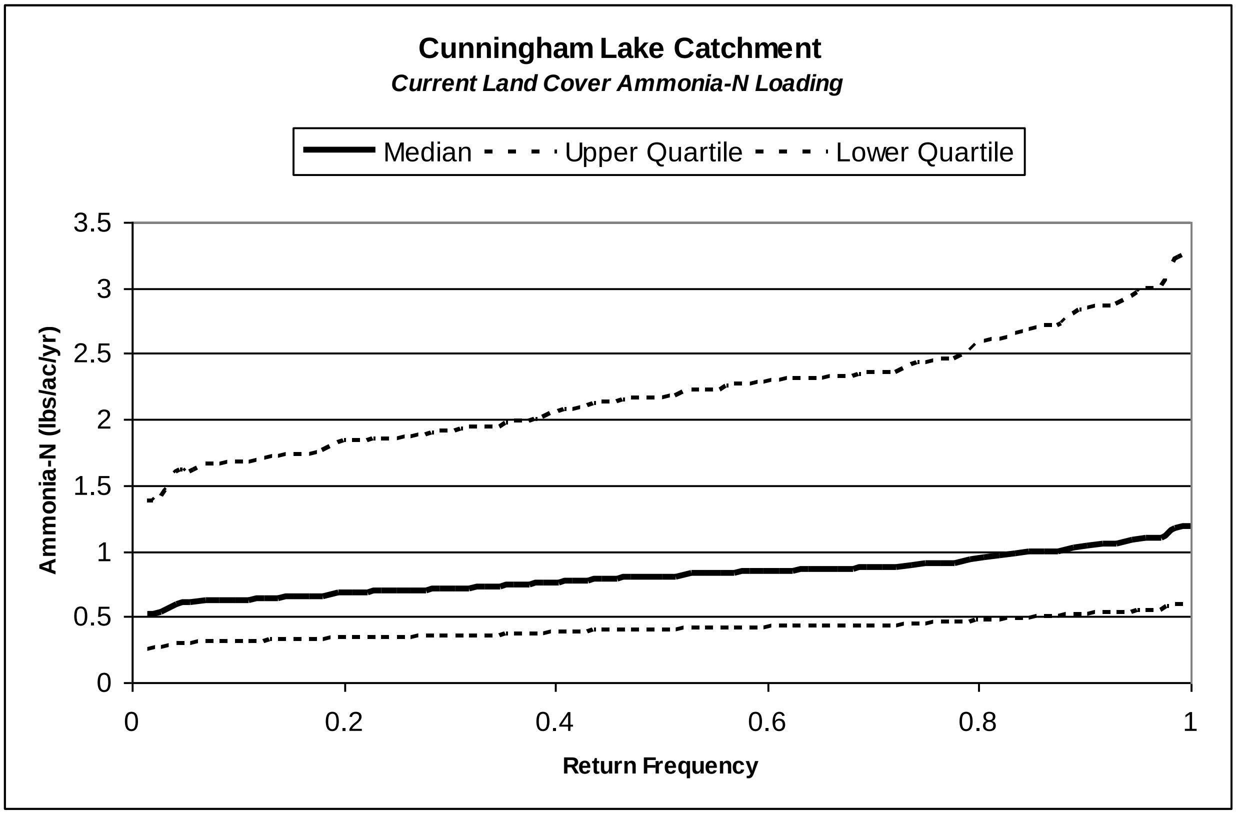

Figure 133. Current Cunningham Lake Catchment Ammonia-N Load Duration Curve

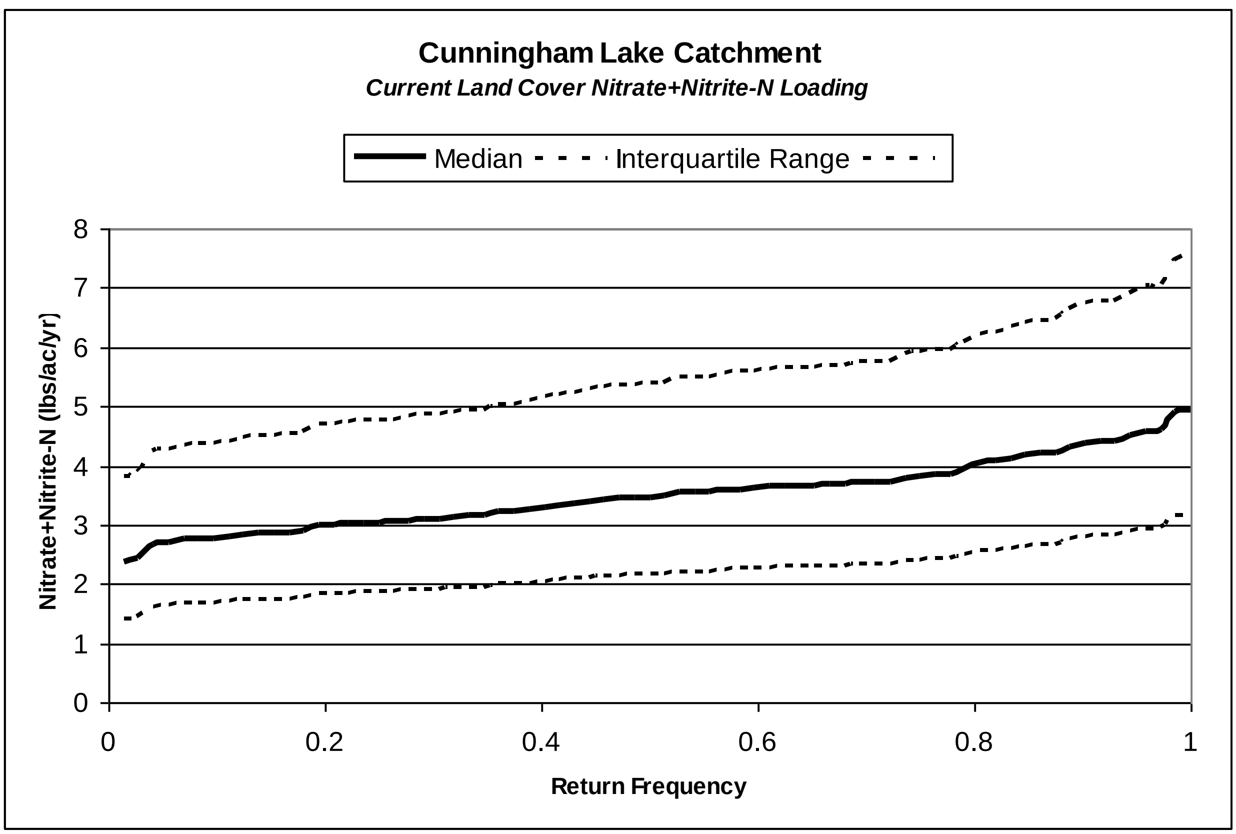

Figure 134. Current Cunningham Lake Catchment Nitrate+Nitrite-N Load Duration Curve

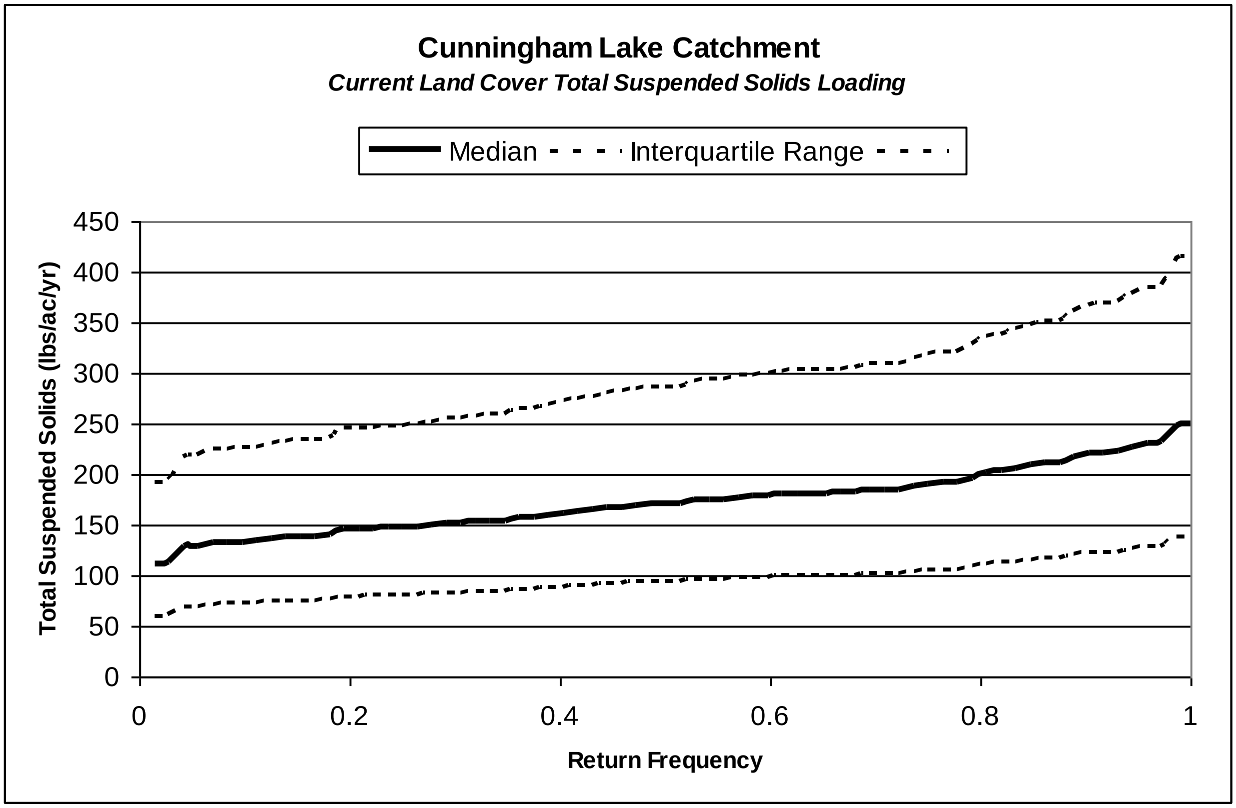

Figure 135. Current Cunningham Lake Catchment Total Suspended Solids Load Duration Curve

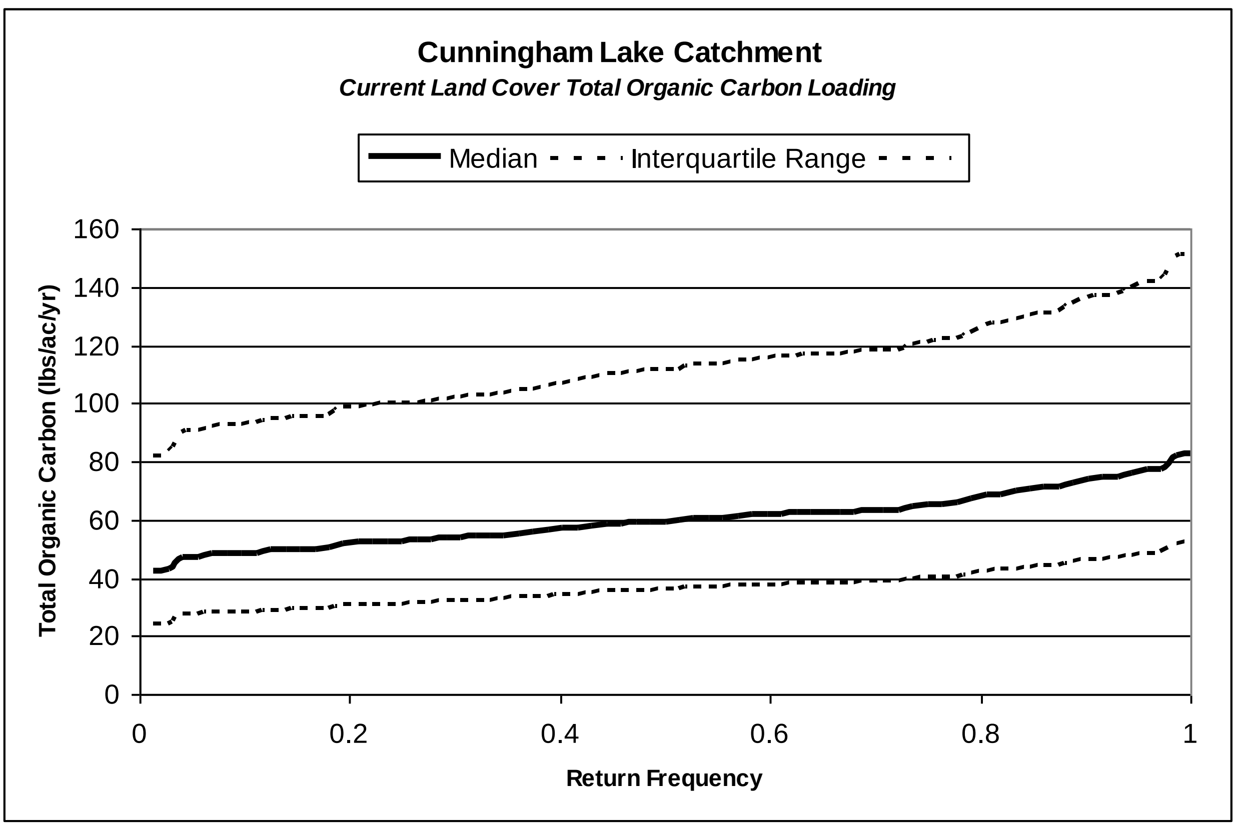

Figure 136. Current Cunningham Lake Catchment Total Organic Carbon Load Duration Curve

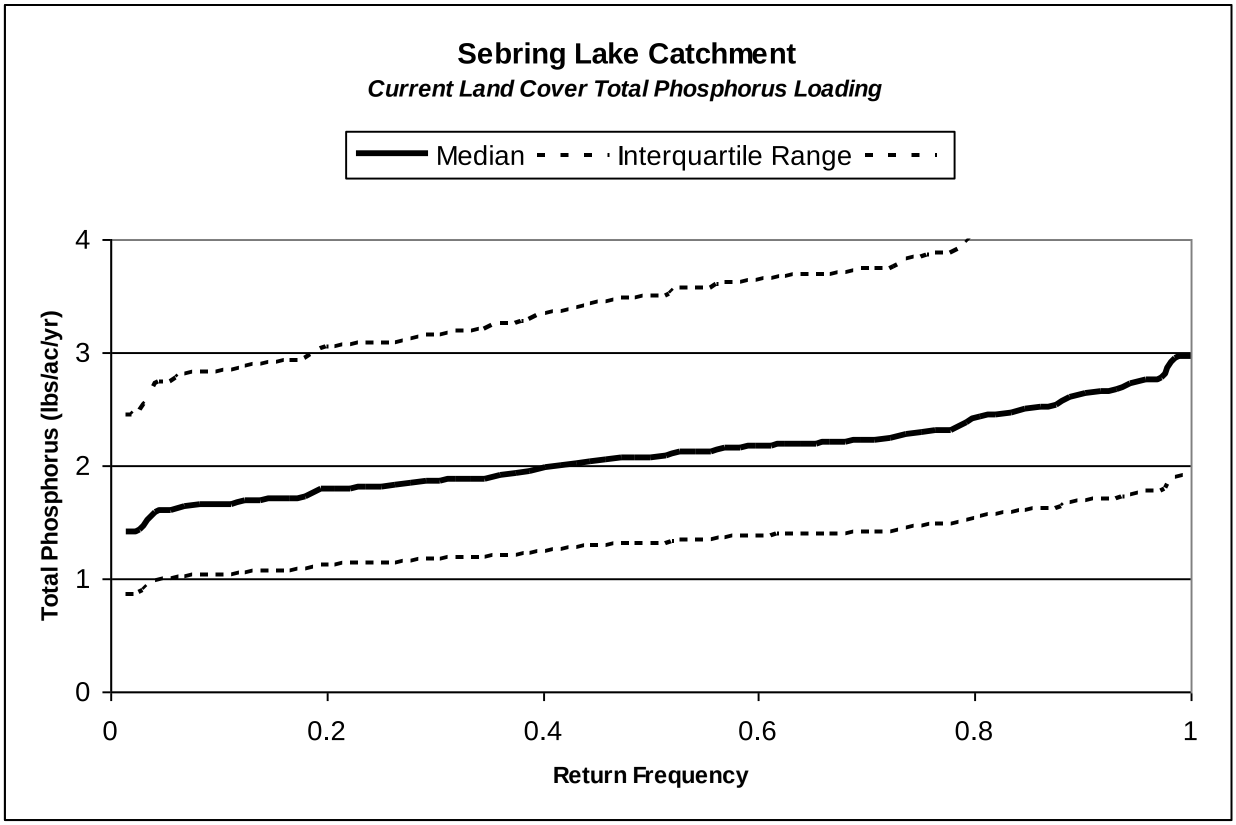

Figure 137. Current Sebring Lake Catchment Total Phosphorus Load Duration Curve

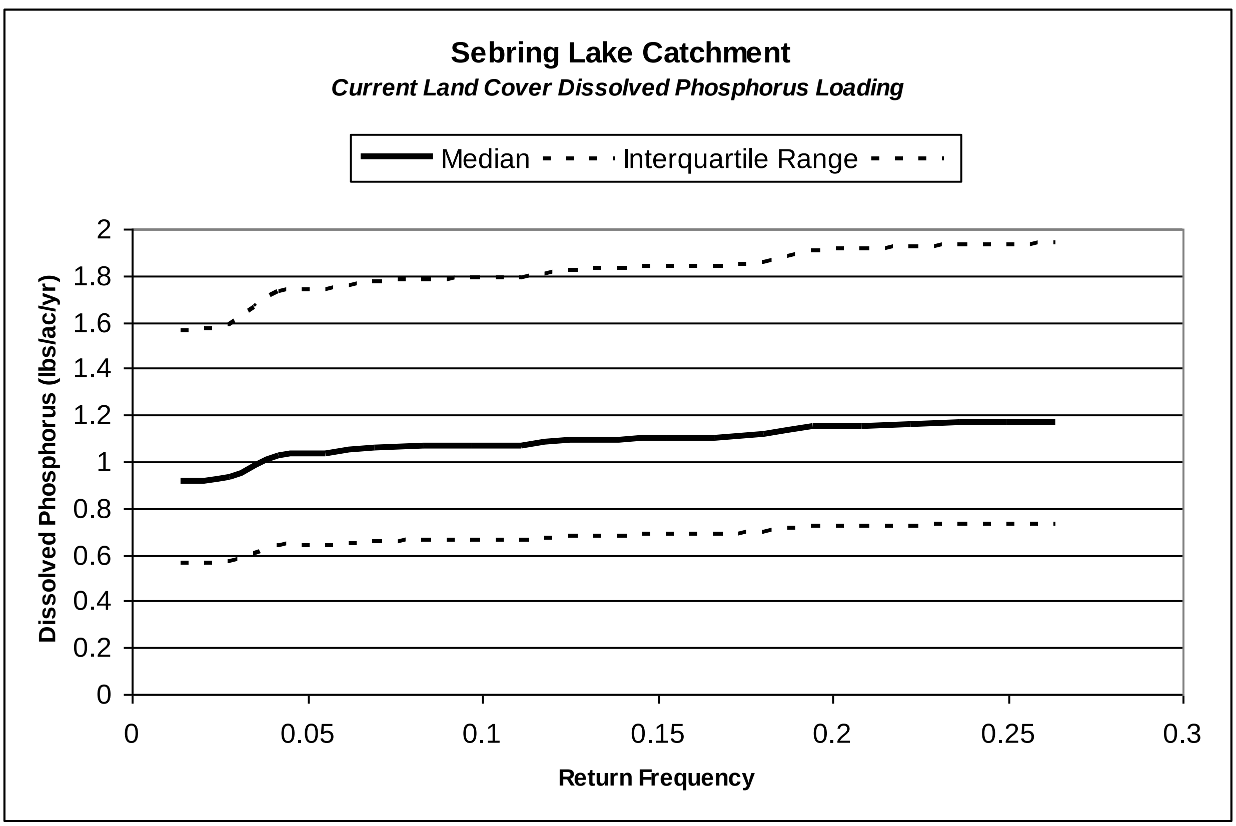

Figure 138. Current Sebring Lake Catchment Dissolved Phosphorus Load Duration Curve

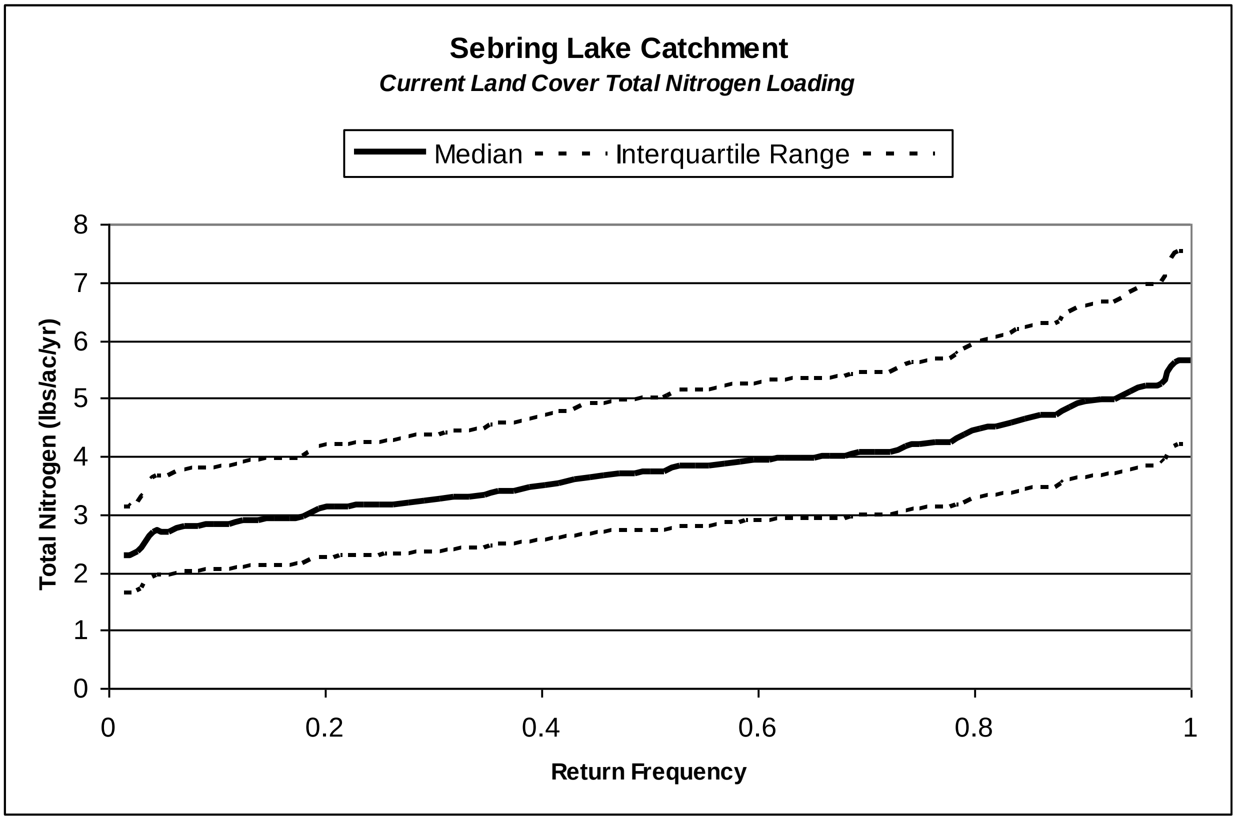

Figure 139. Current Sebring Lake Catchment Total Nitrogen Load Duration Curve

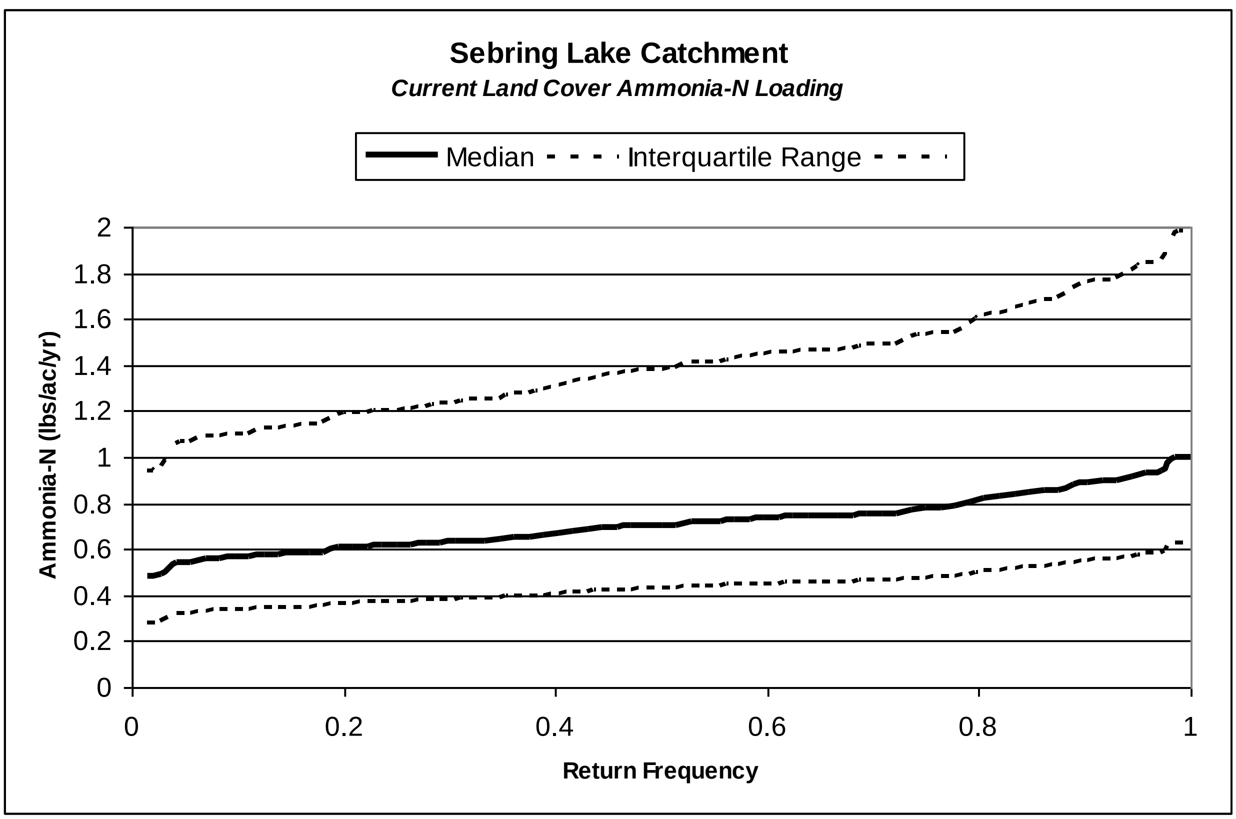

Figure 140. Current Sebring Lake Catchment Ammonia-N Load Duration Curve

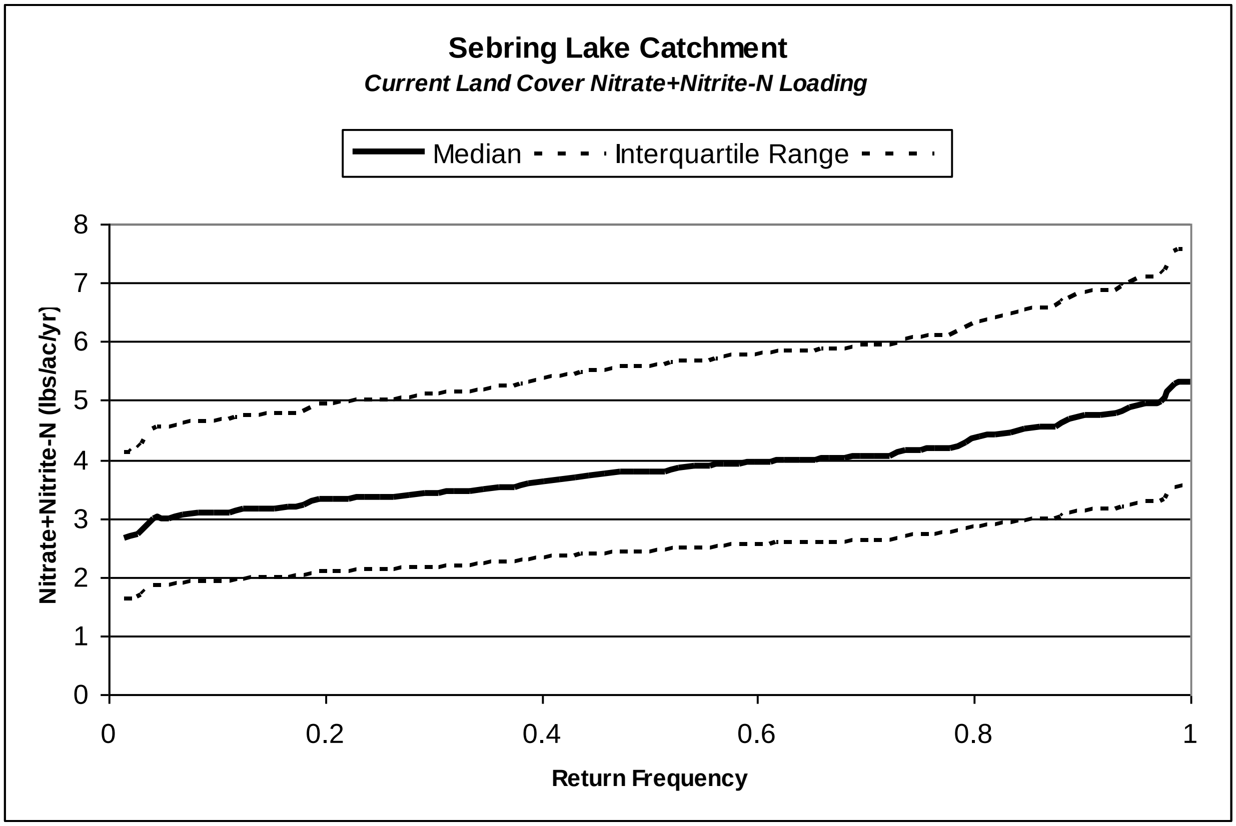

Figure 141. Current Sebring Lake Catchment Nitrate+Nitrite-N Load Duration Curve

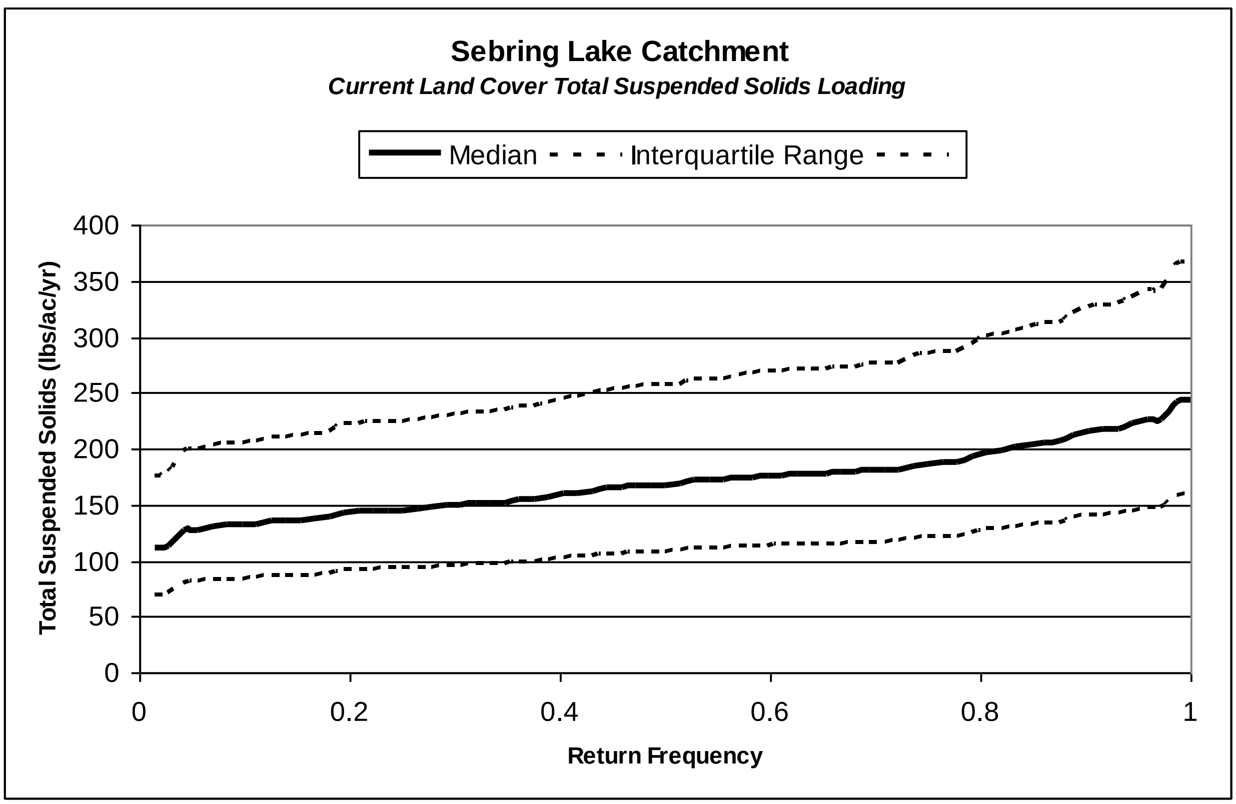

Figure 142. Current Sebring Lake Catchment Total Suspended Solids Load Duration Curve

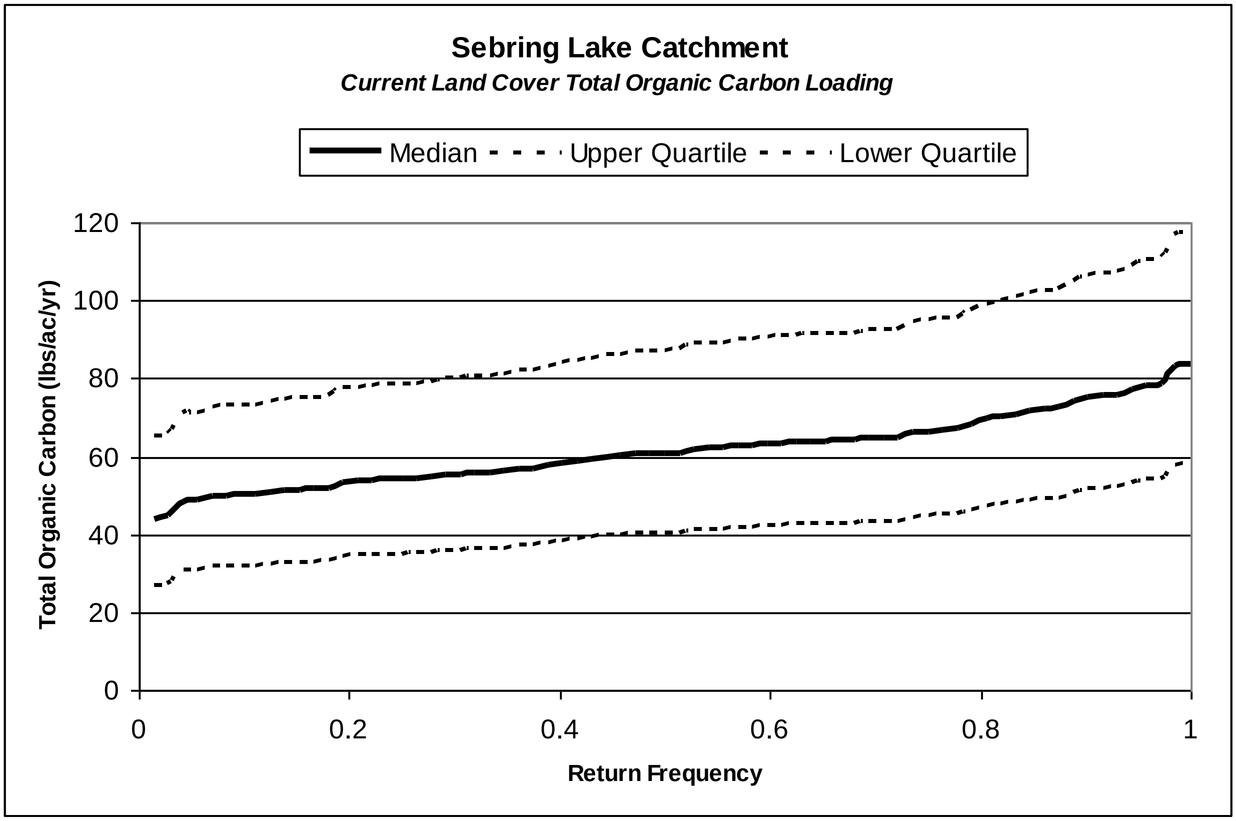

Figure 143. Current Sebring Lake Catchment Total Organic Carbon Load Duration Curve

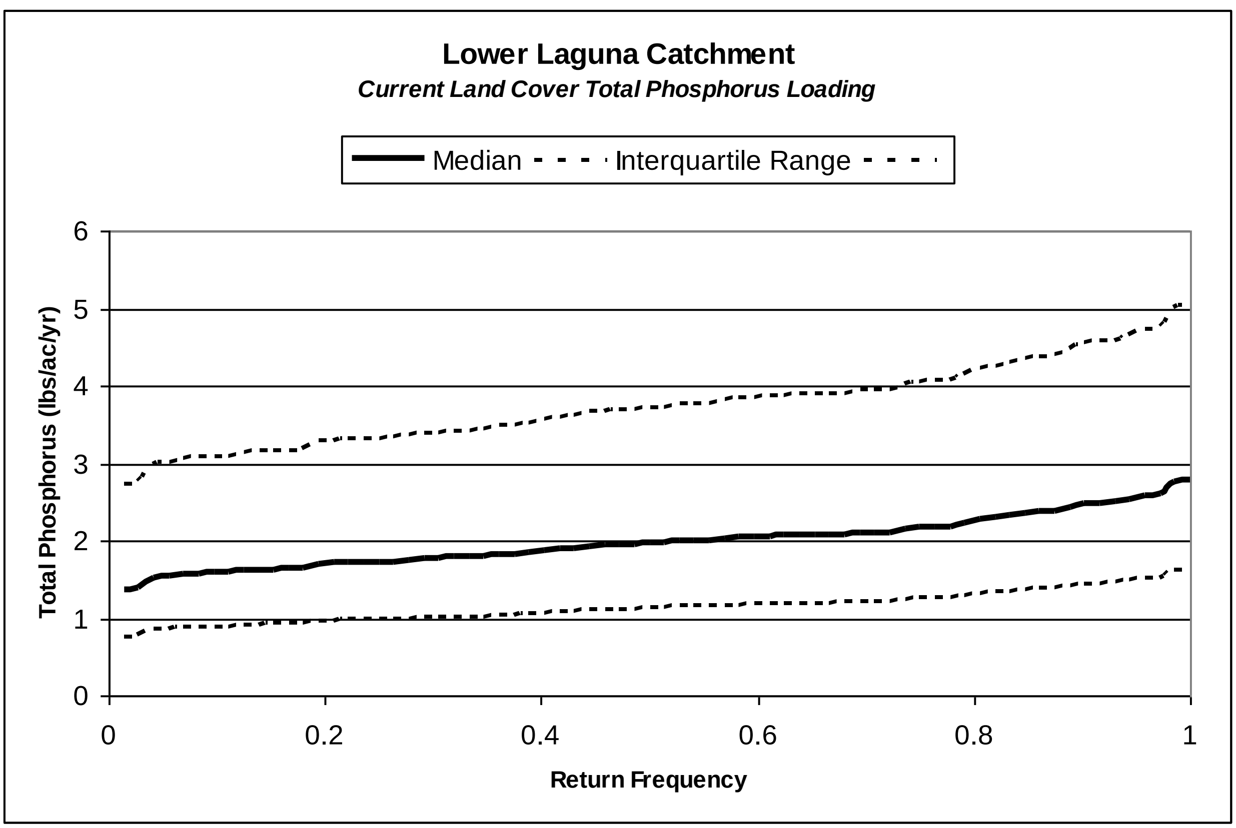

Figure 144. Current Lower Laguna Catchment Total Phosphorus Load Duration Curve

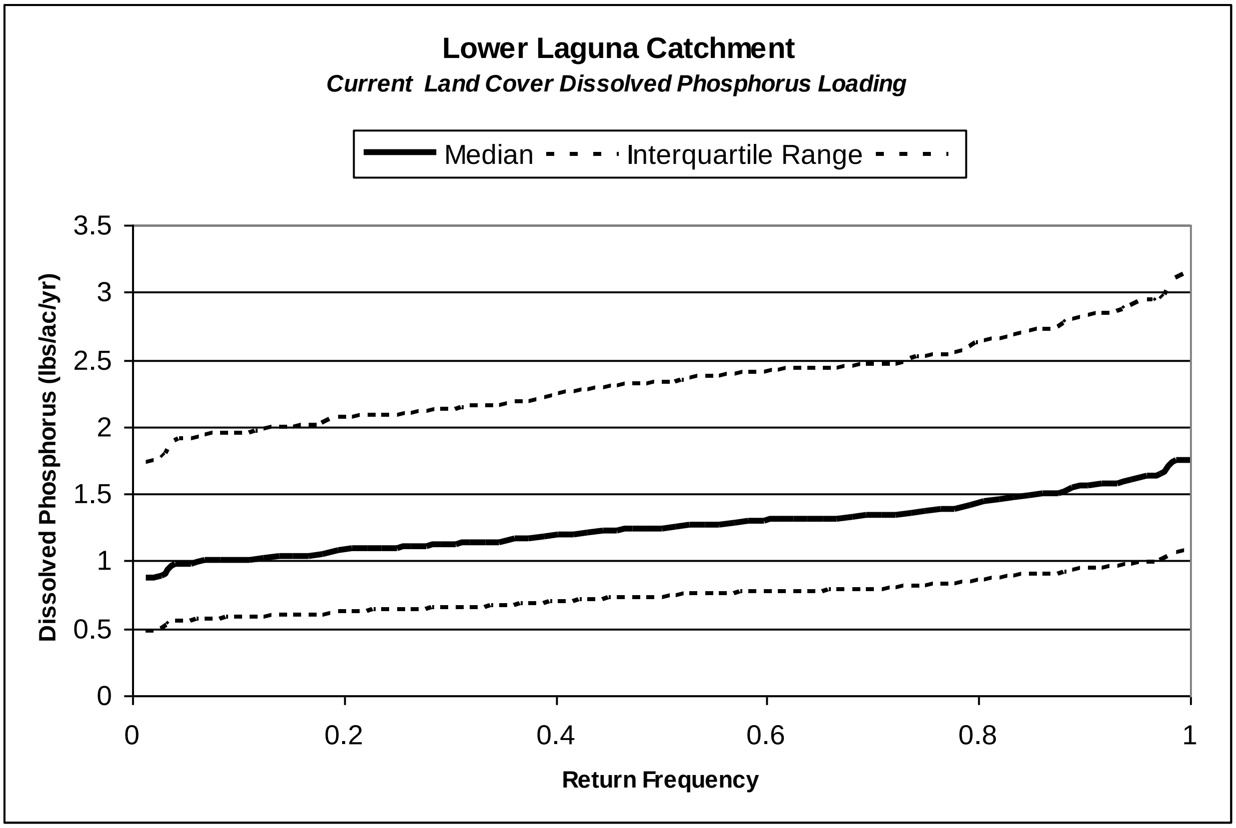

Figure 145. Current Lower Laguna Catchment Dissolved Phosphorus Load Duration Curve

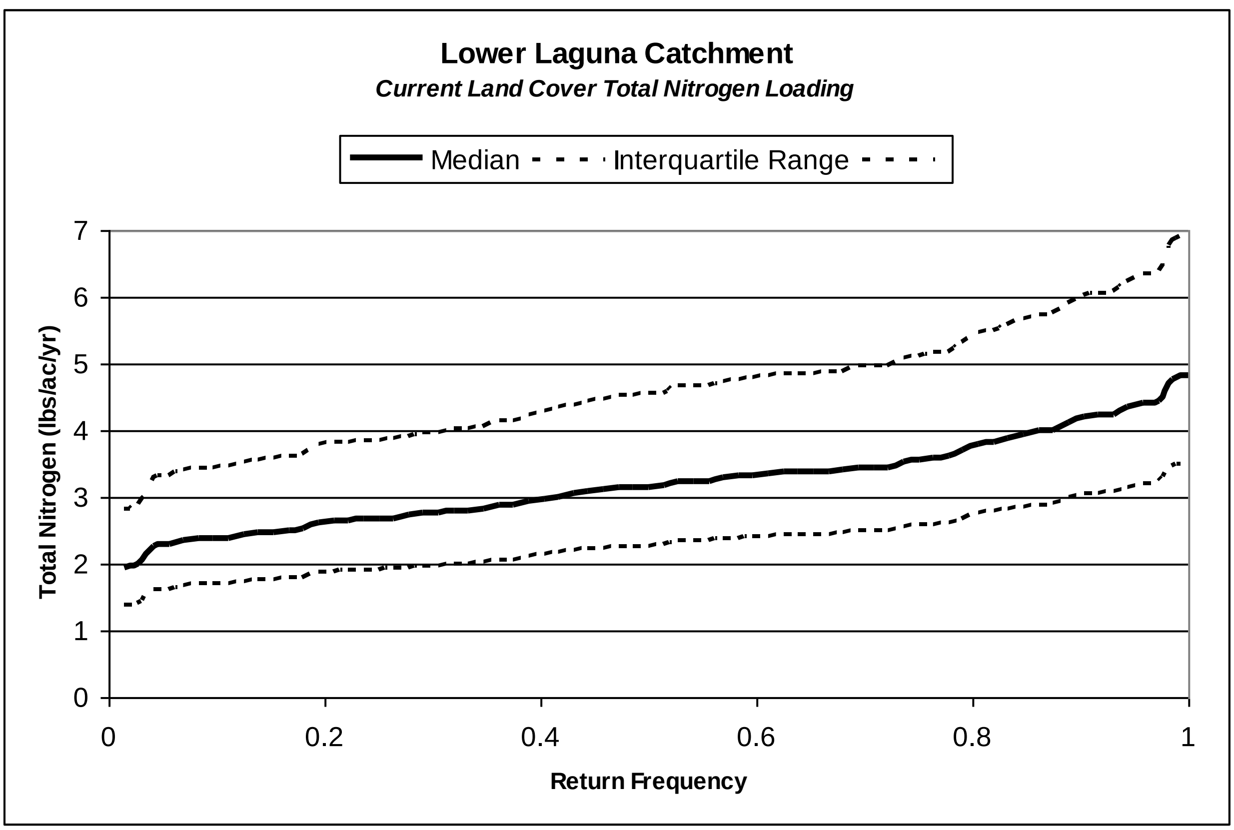

Figure 146. Current Lower Laguna Catchment Total Nitrogen Load Duration Curve

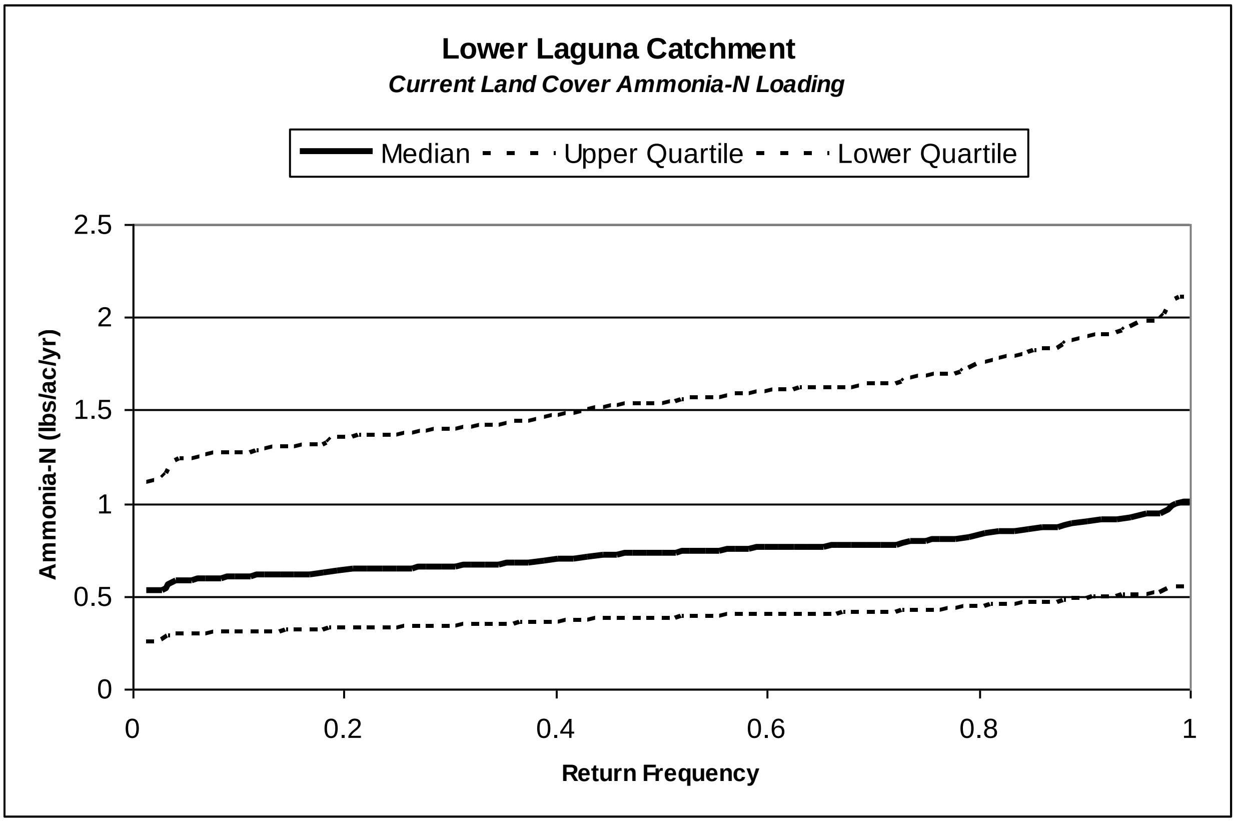

Figure 147. Current Lower Laguna Catchment Ammonia-N Load Duration Curve

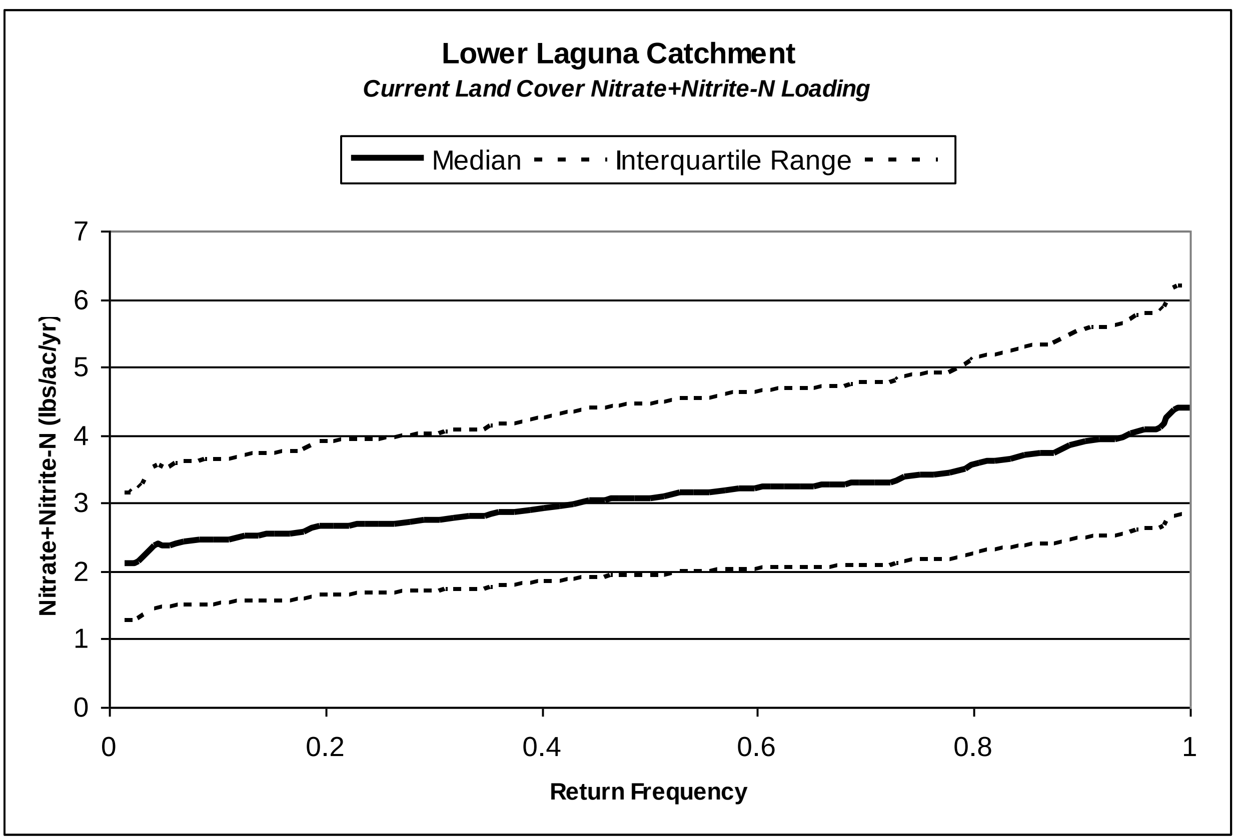

Figure 148. Current Lower Laguna Catchment Nitrate+Nitrite-N Load Duration Curve

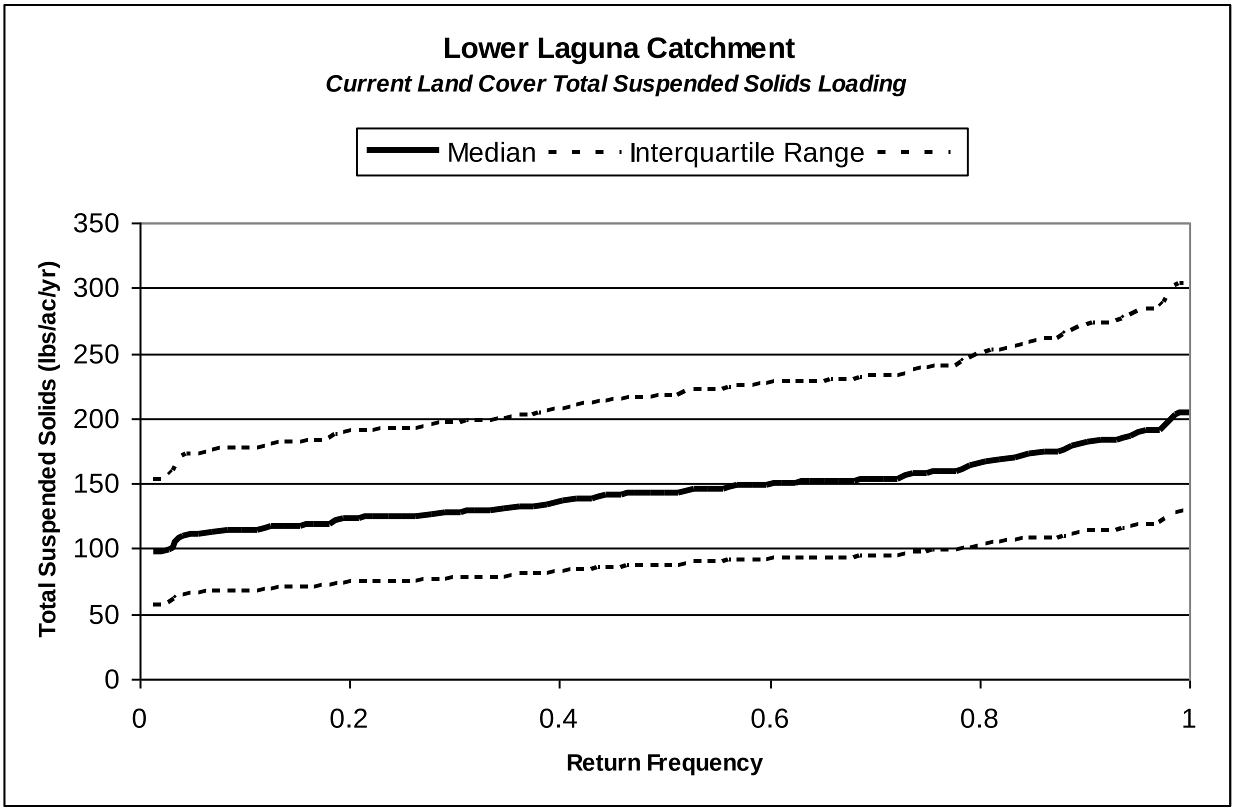

Figure 149. Current Lower Laguna Catchment Total Suspended Solids Load Duration Curve

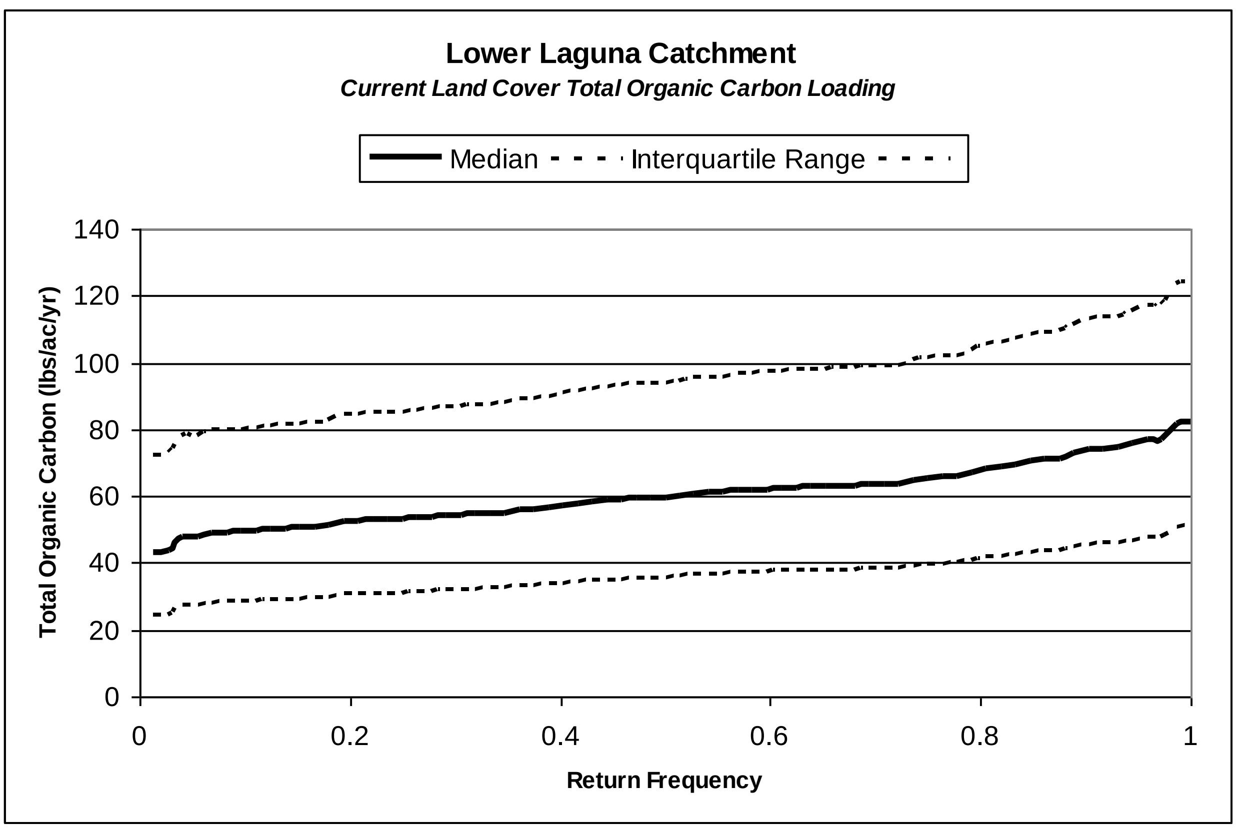

Figure 150. Current Lower Laguna Catchment Total Organic Carbon Load Duration Curve

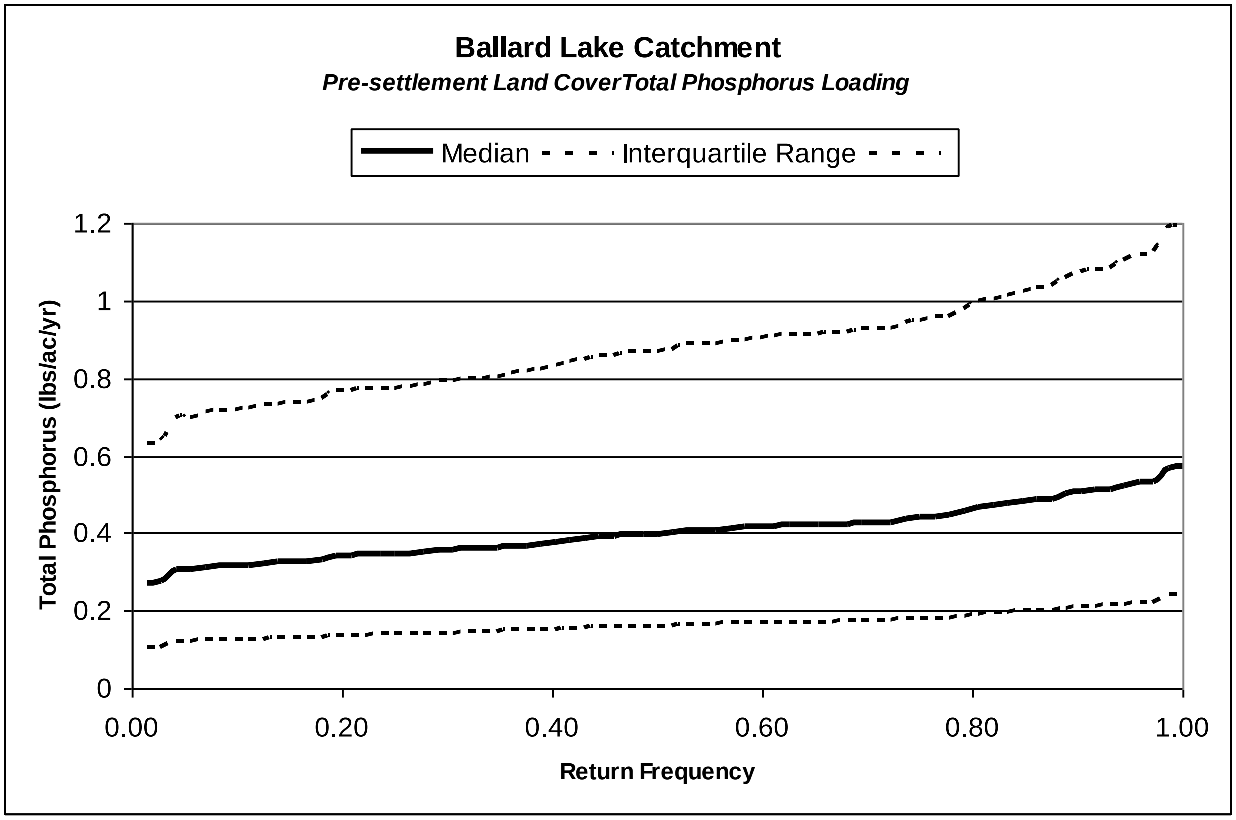

Figure 151. Pre-settlement Ballard Lake Catchment Total Phosphorus Load Duration Curve

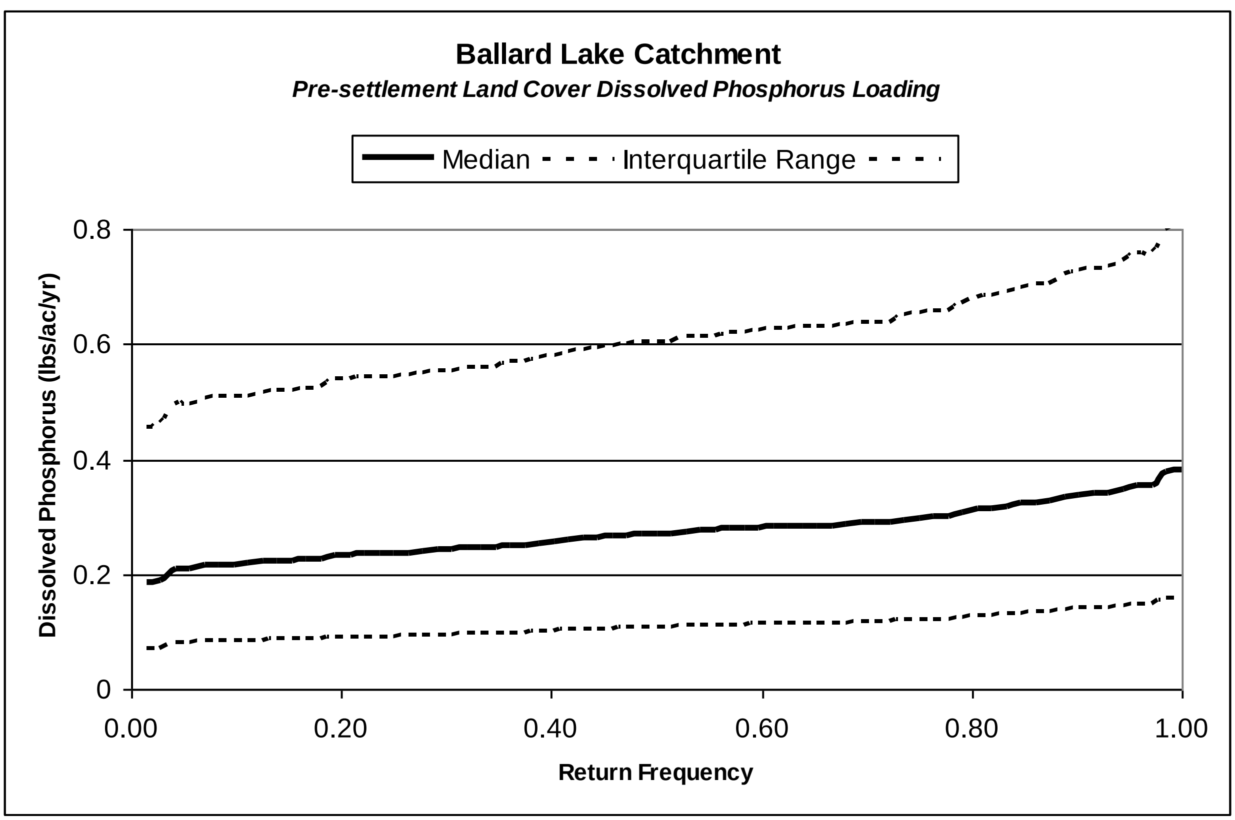

Figure 152. Pre-settlement Ballard Lake Catchment Dissolved Phosphorus Load Duration Curve

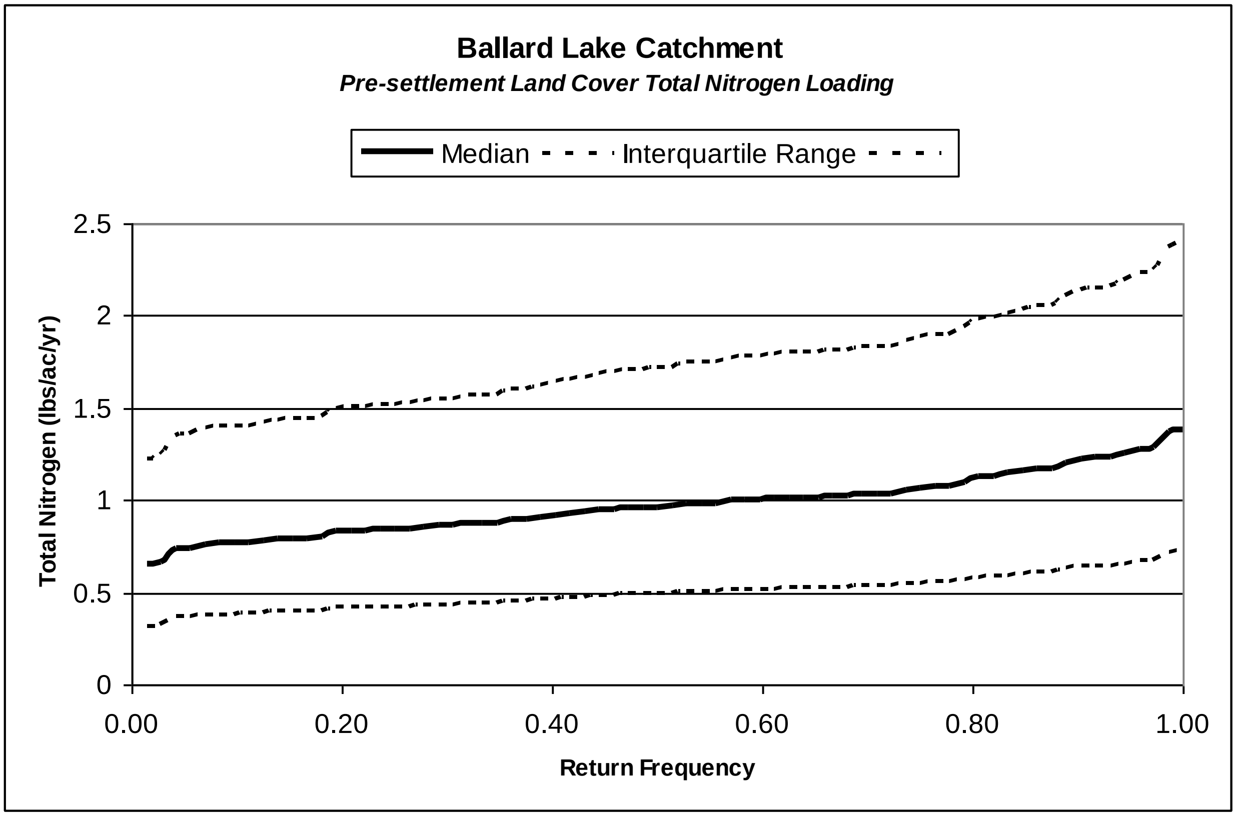

Figure 153. Pre-settlement Ballard Lake Catchment Total Nitrogen Load Duration Curve

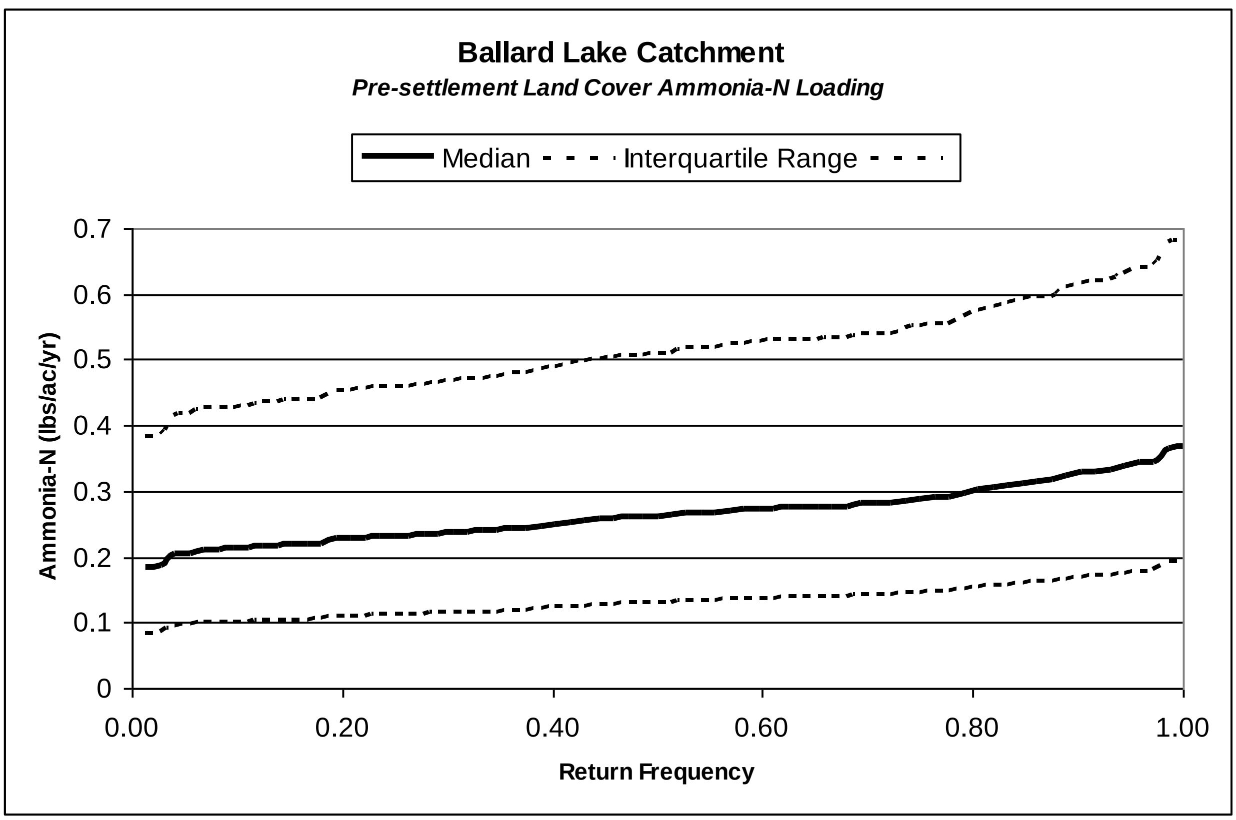

Figure 154. Pre-settlement Ballard Lake Catchment Ammonia-N Load Duration Curve

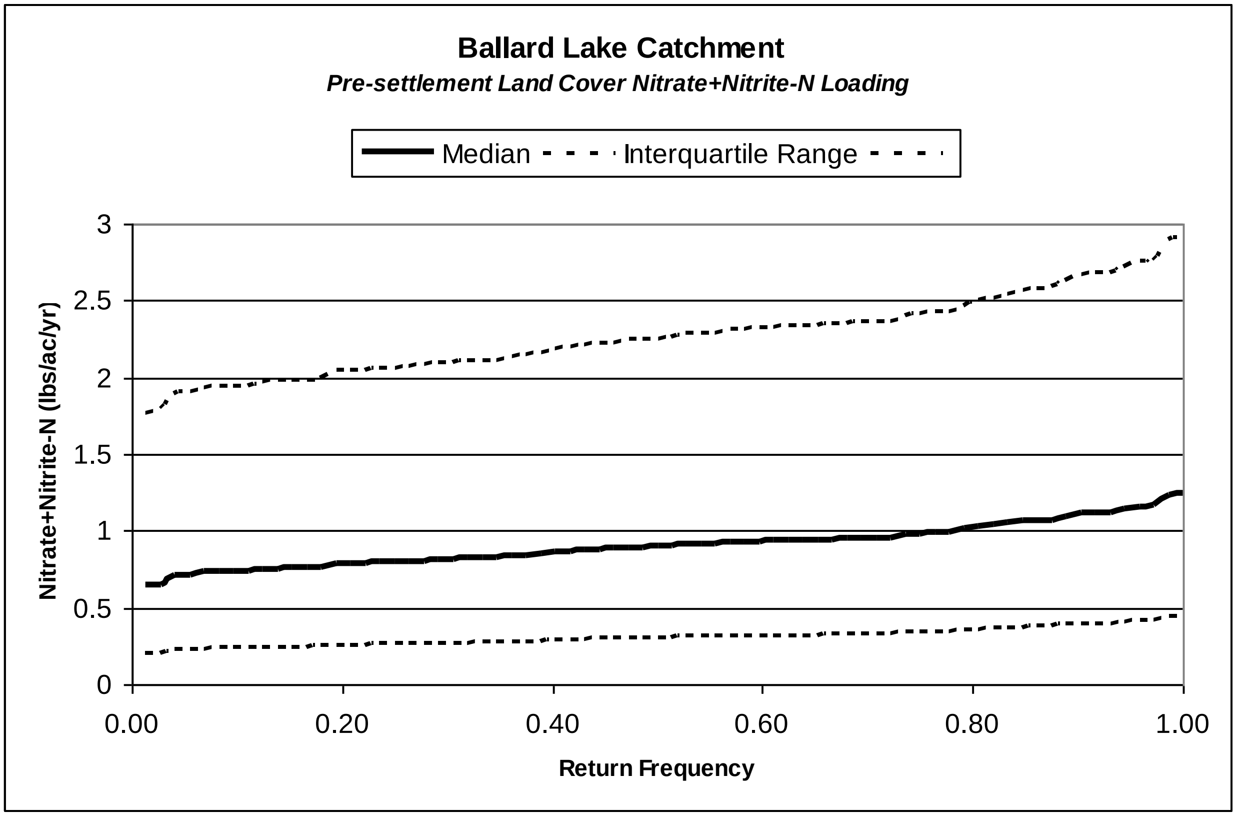

Figure 155. Pre-settlement Ballard Lake Catchment Nitrate+Nitrite-N Load Duration Curve

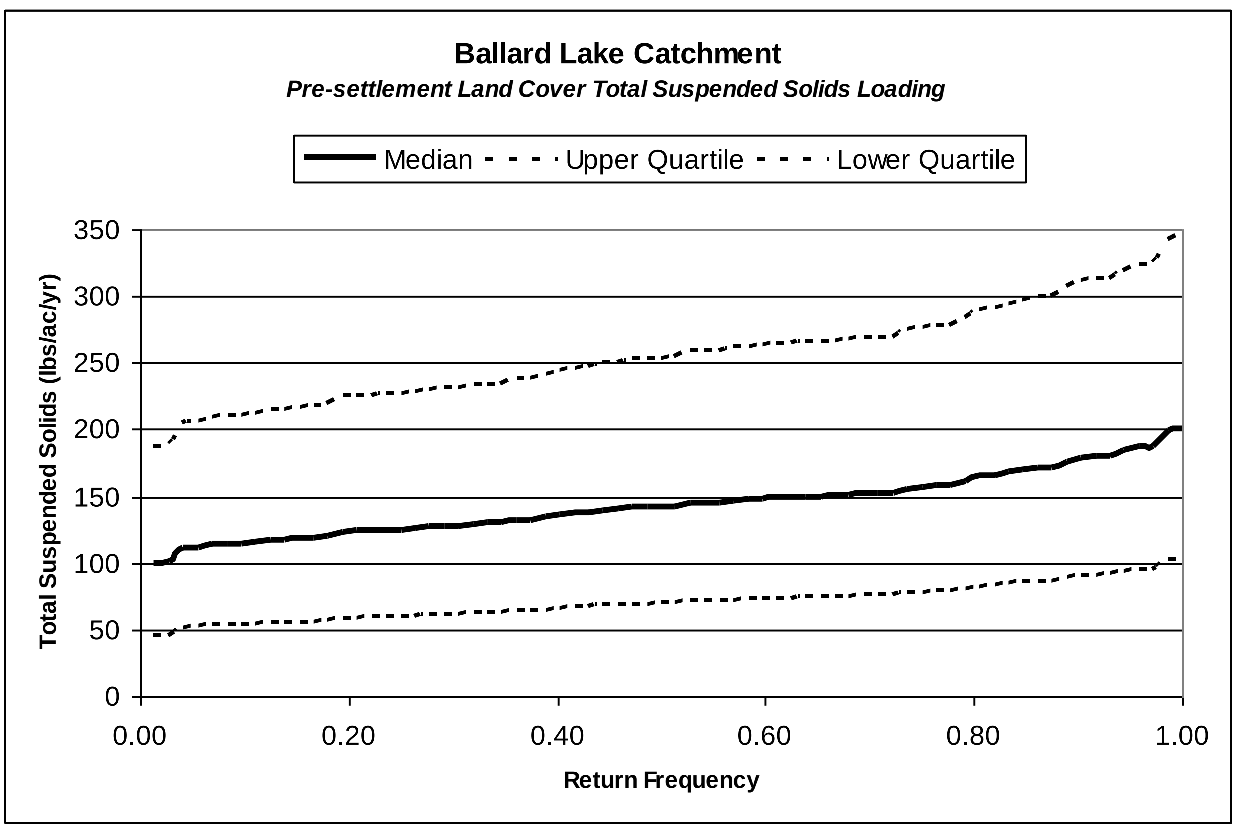

Figure 156. Pre-settlement Ballard Lake Catchment Total Suspended Solids Load Duration Curve

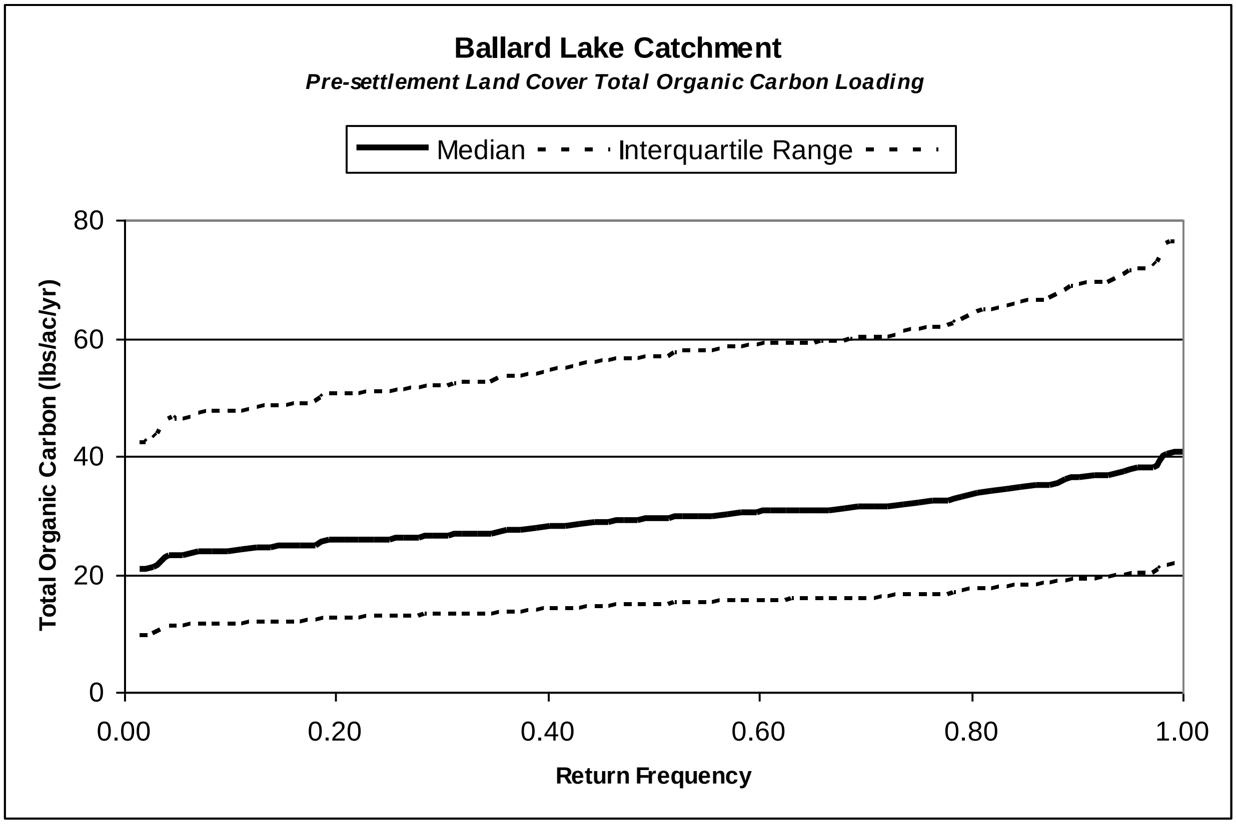

Figure 157. Pre-settlement Ballard Lake Catchment Total Organic Carbon Load Duration Curve

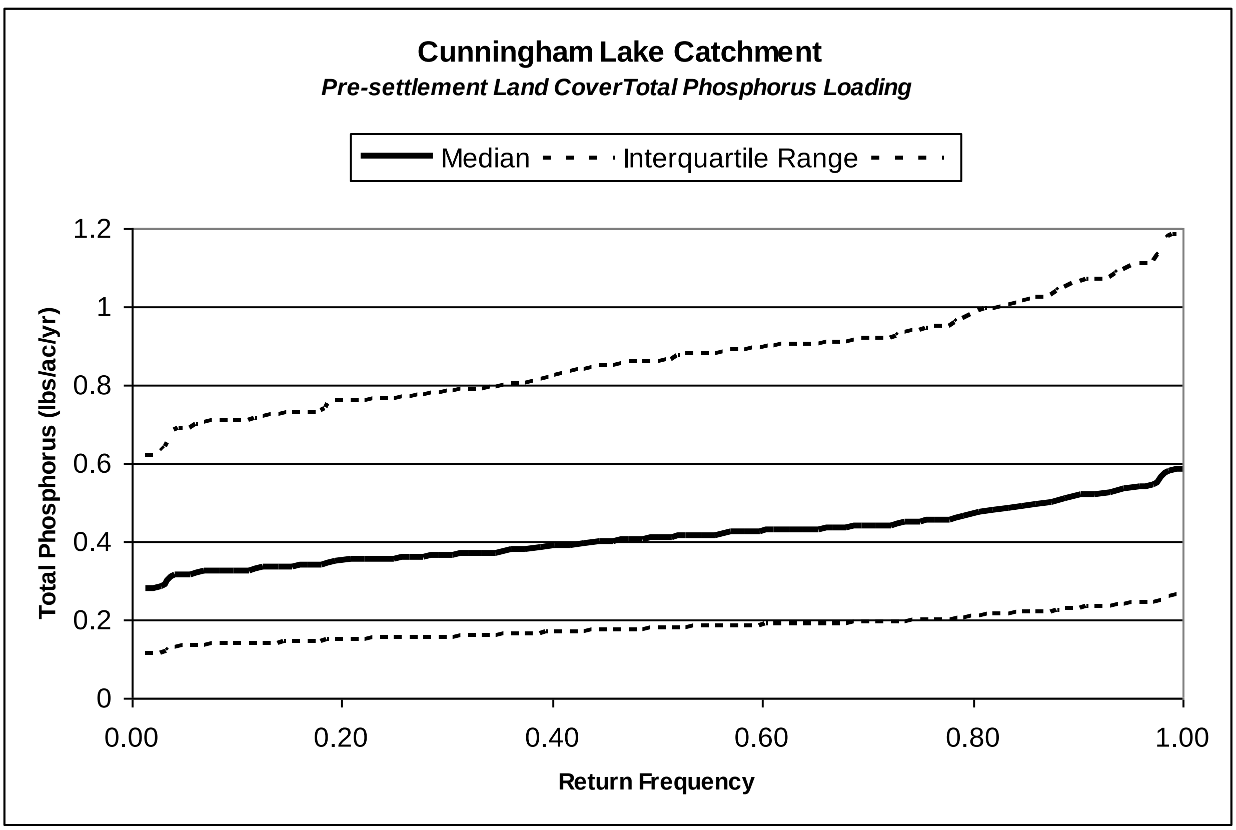

Figure 158. Pre-settlement Cunningham Lake Catchment Total Phosphorus Load Duration Curve

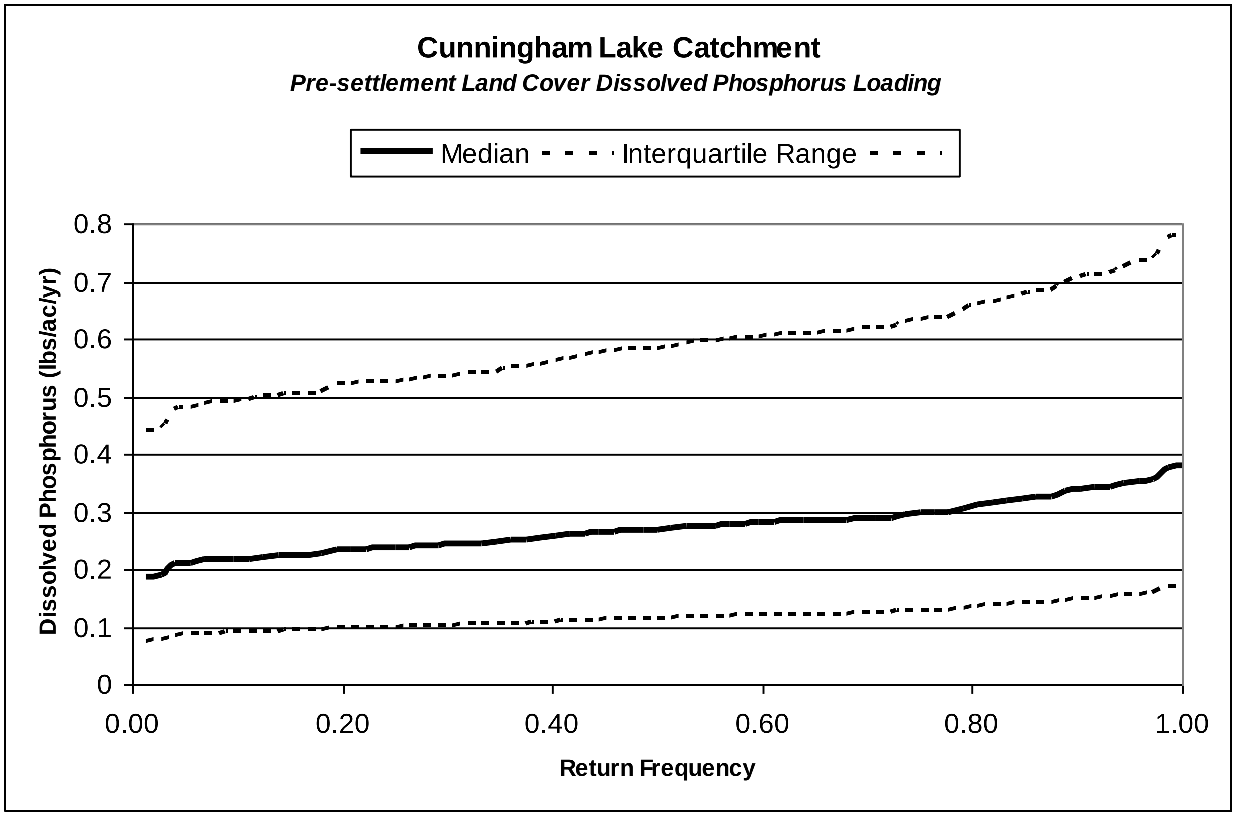

Figure 159. Pre-settlement Cunningham Lake Catchment Dissolved Phosphorus Load Duration Curve

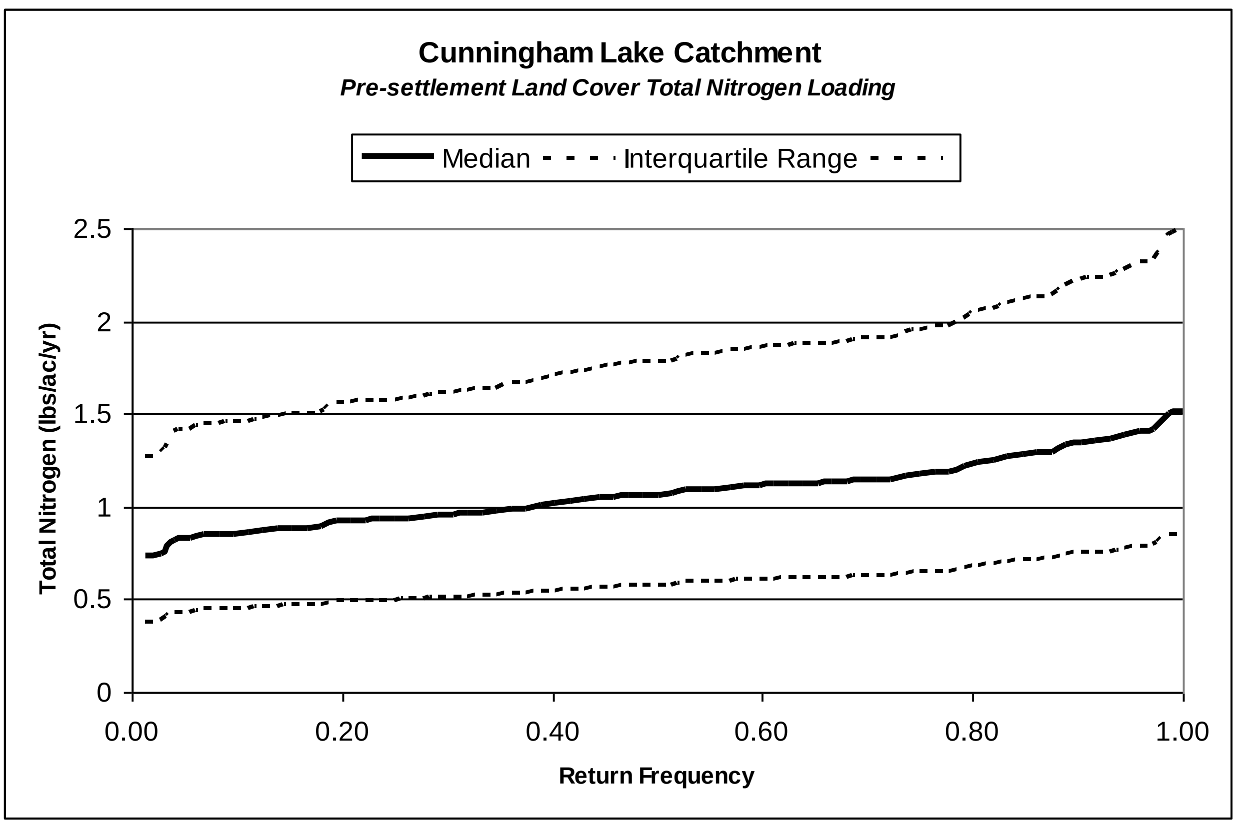

Figure 160. Pre-settlement Cunningham Lake Catchment Total Nitrogen Load Duration Curve

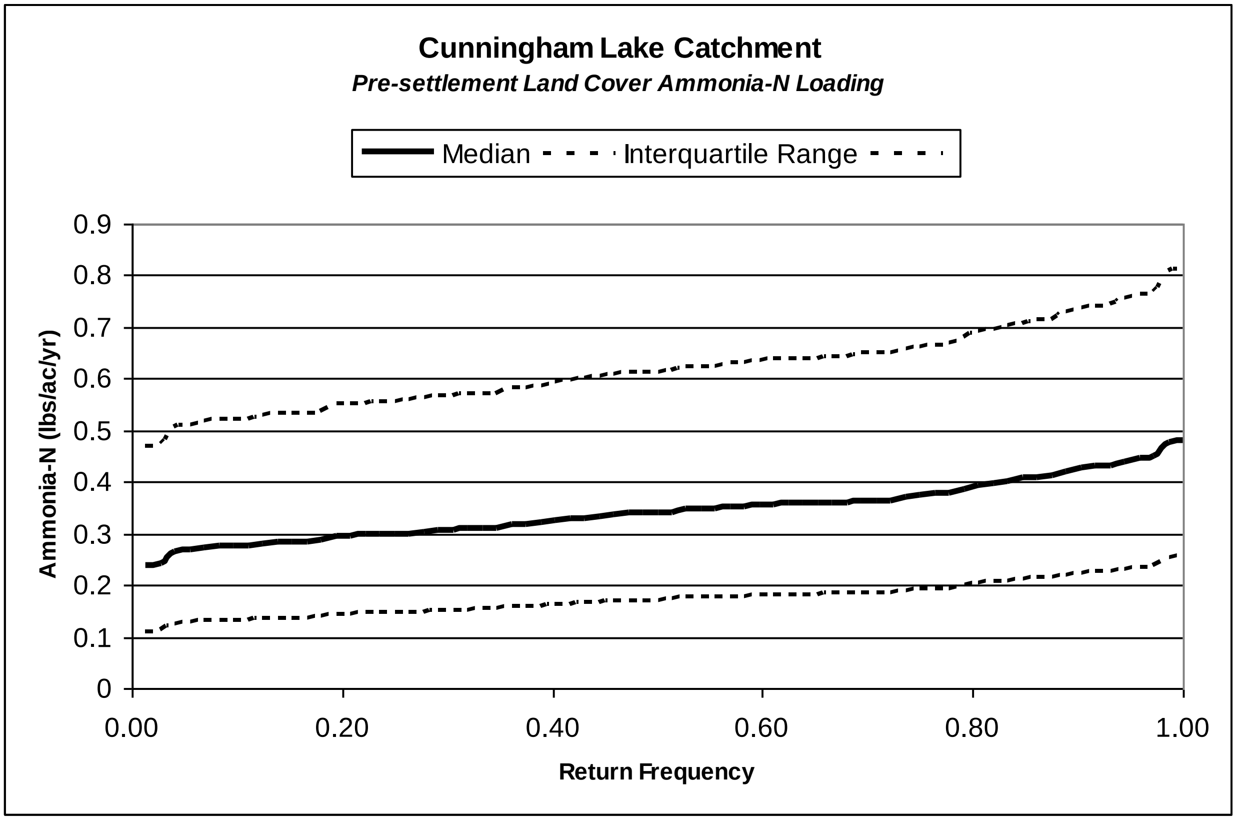

Figure 161. Pre-settlement Cunningham Lake Catchment Ammonia-N Load Duration Curve

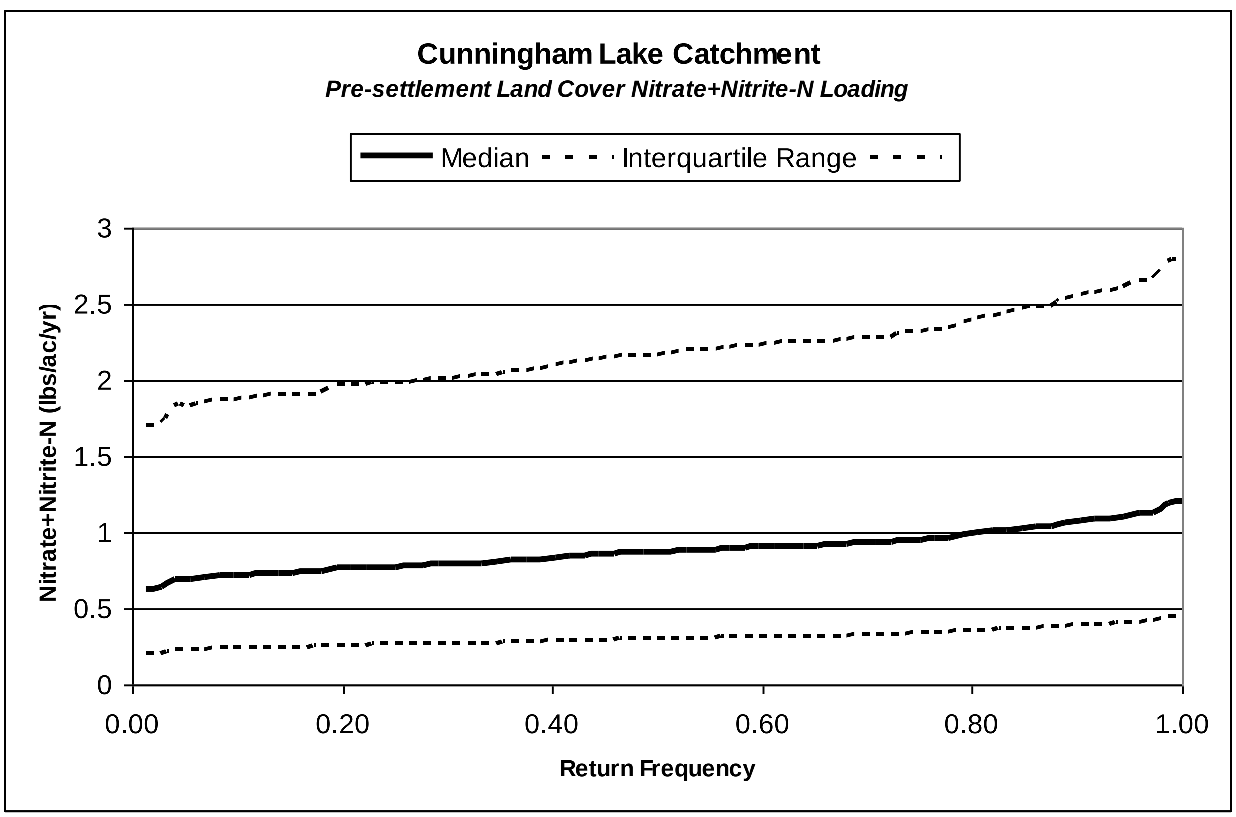

Figure 162. Pre-settlement Cunningham Lake Catchment Nitrate+Nitrite-N Load Duration Curve

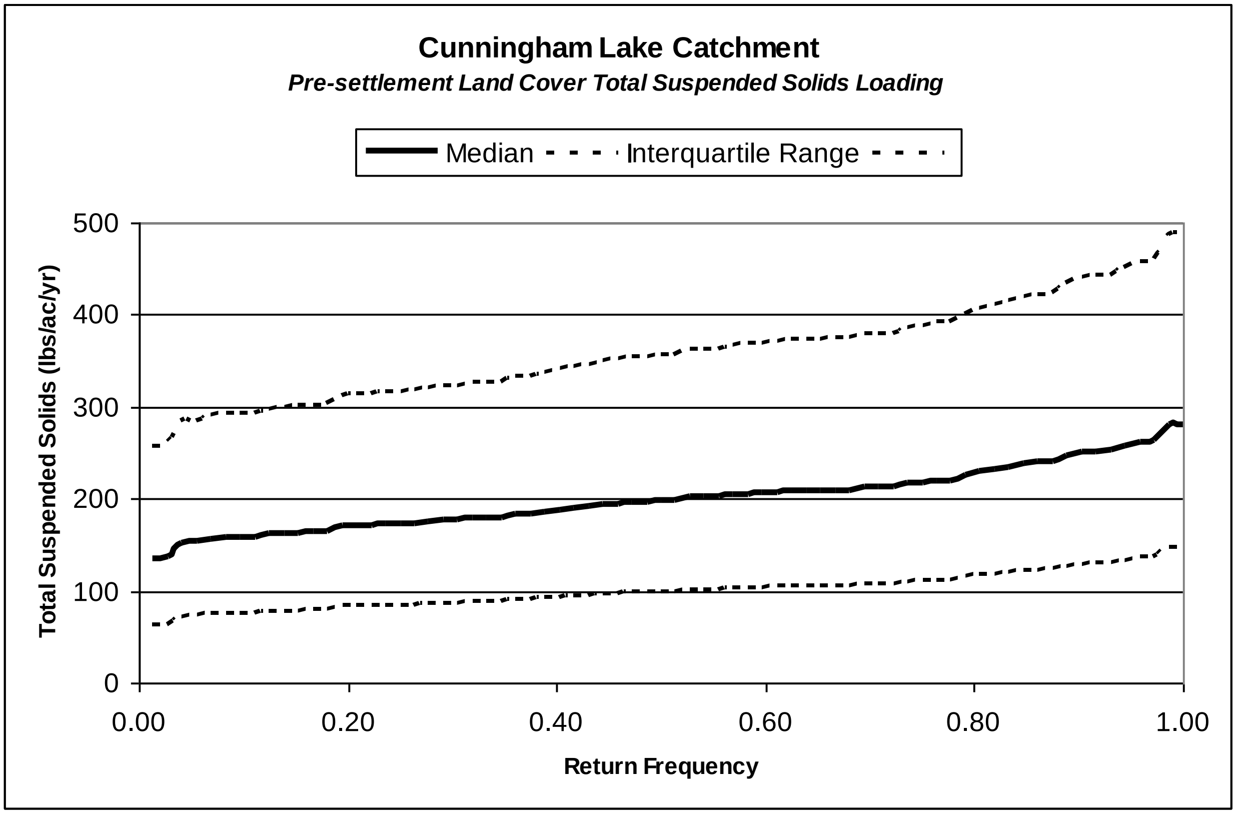

Figure 163. Pre-settlement Cunningham Lake Catchment Total Suspended Solids Load Duration Curve

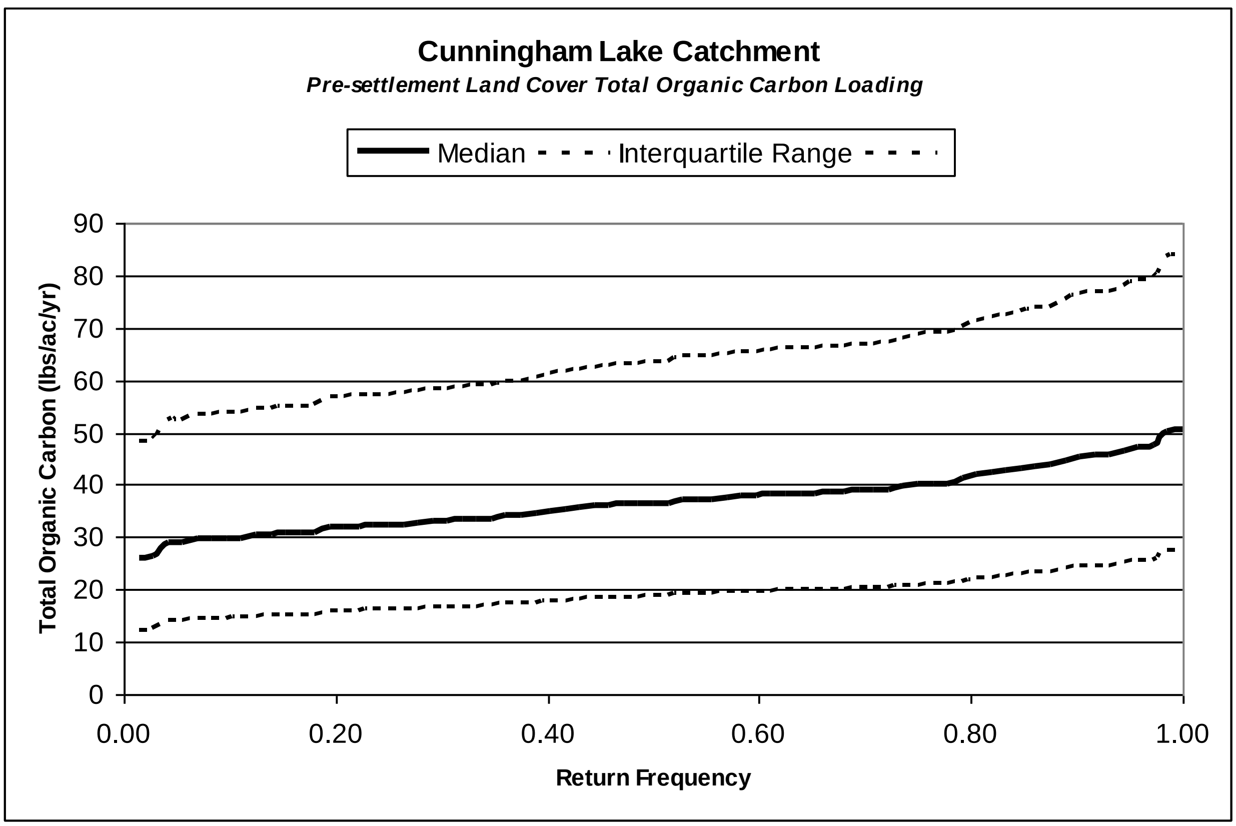

Figure 164. Pre-settlement Cunningham Lake Catchment Total Organic Carbon Load Duration Curve

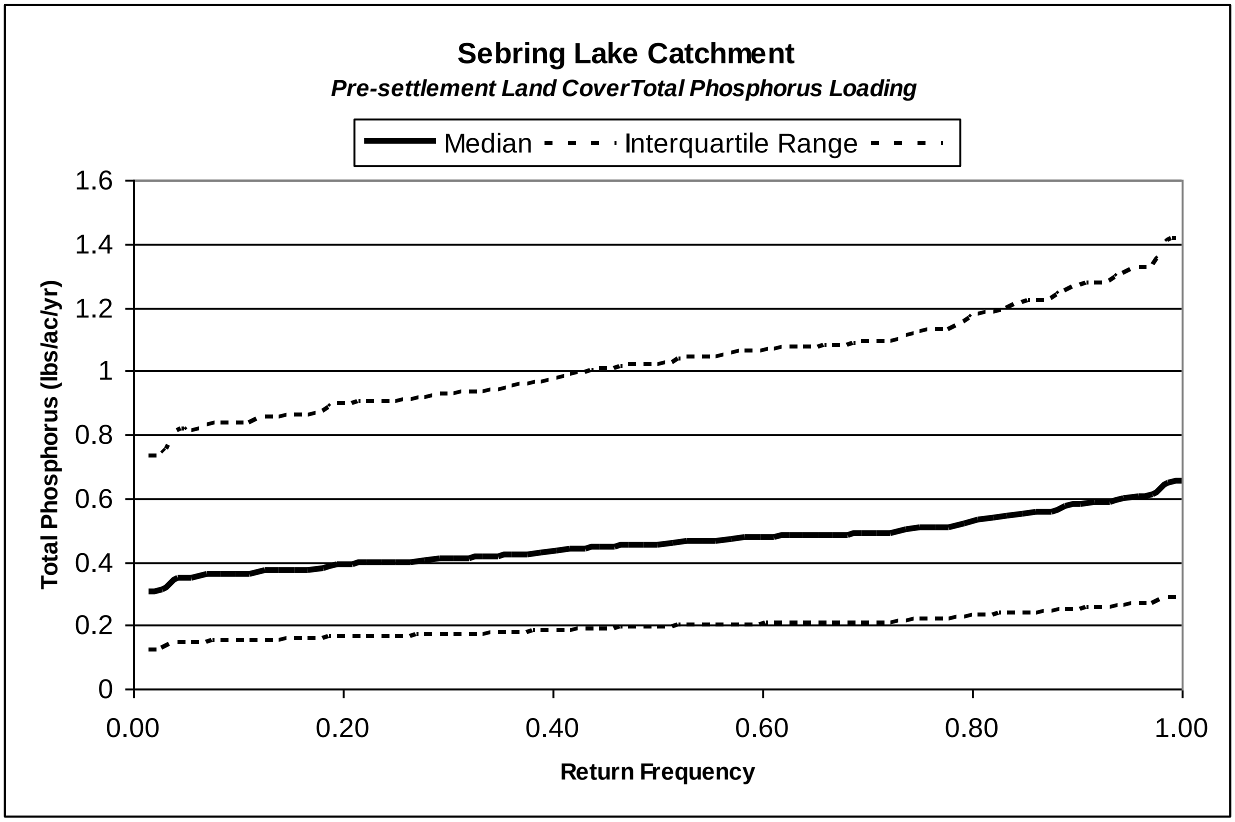

Figure 165. Pre-settlement Sebring Lake Catchment Total Phosphorus Load Duration Curve

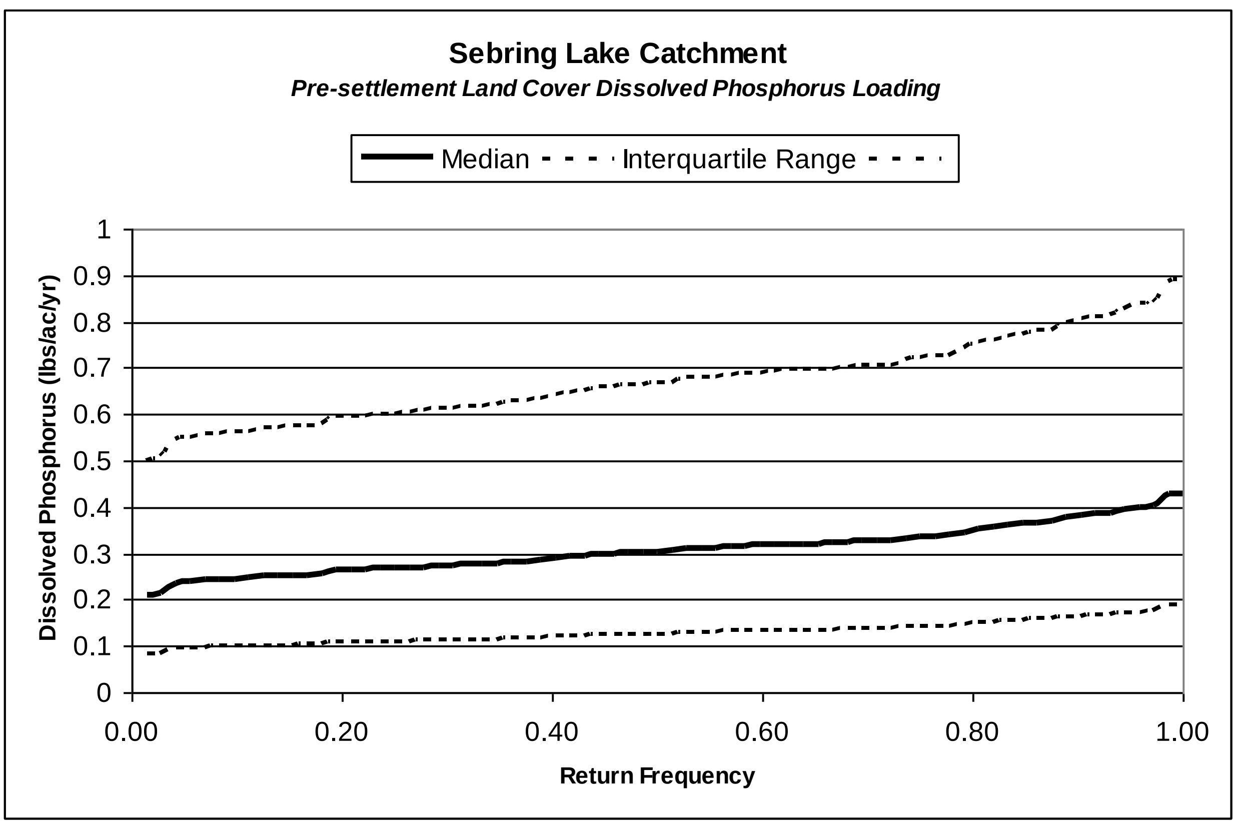

Figure 166. Pre-settlement Sebring Lake Catchment Dissolved Phosphorus Load Duration Curve

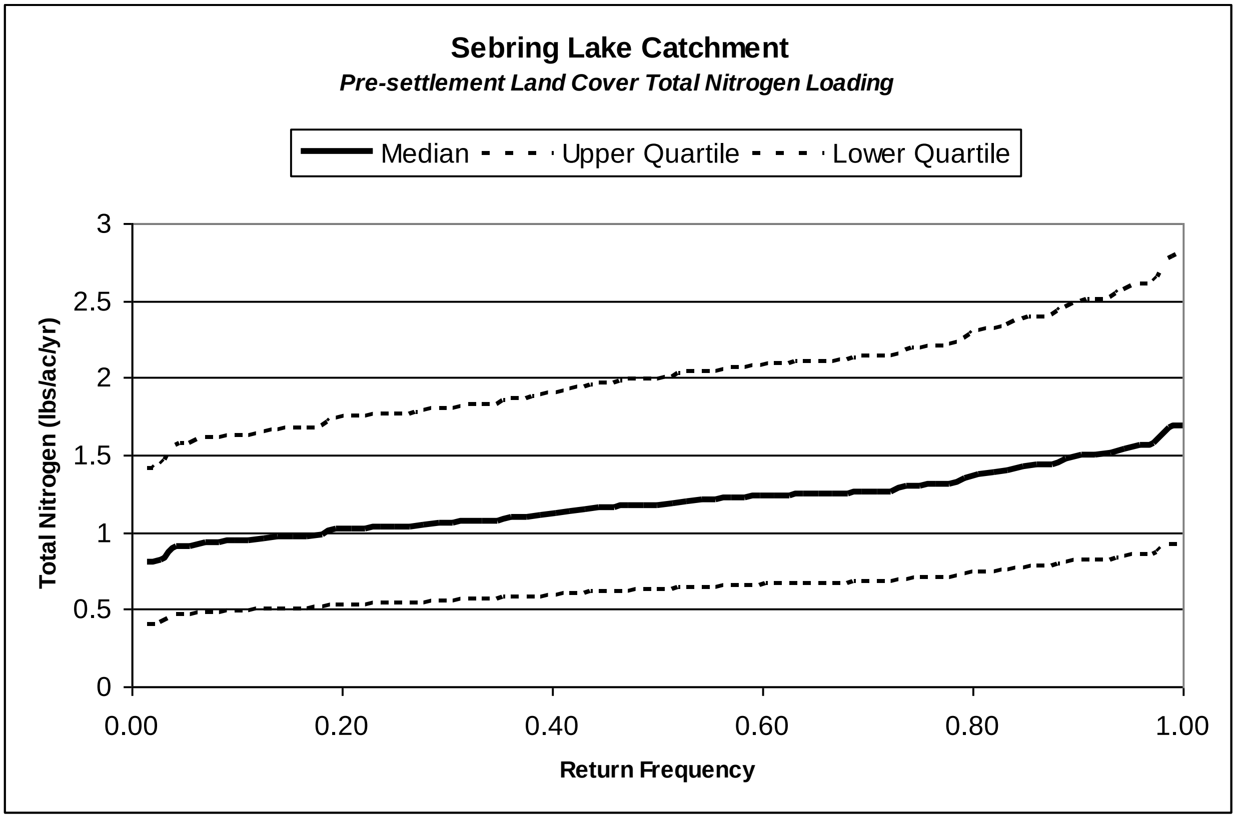

Figure 167. Pre-settlement Sebring Lake Catchment Total Nitrogen Load Duration Curve

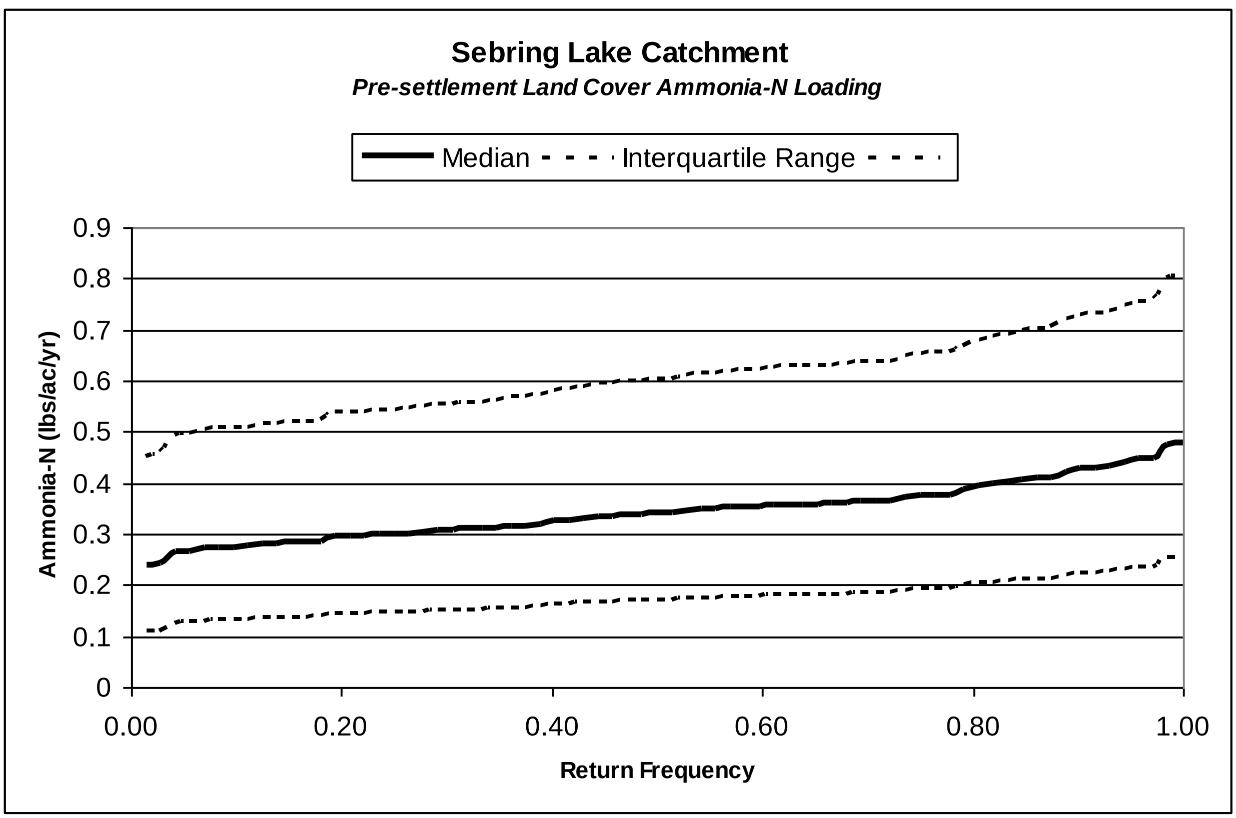

Figure 168. Pre-settlement Sebring Lake Catchment Ammonia-N Load Duration Curve

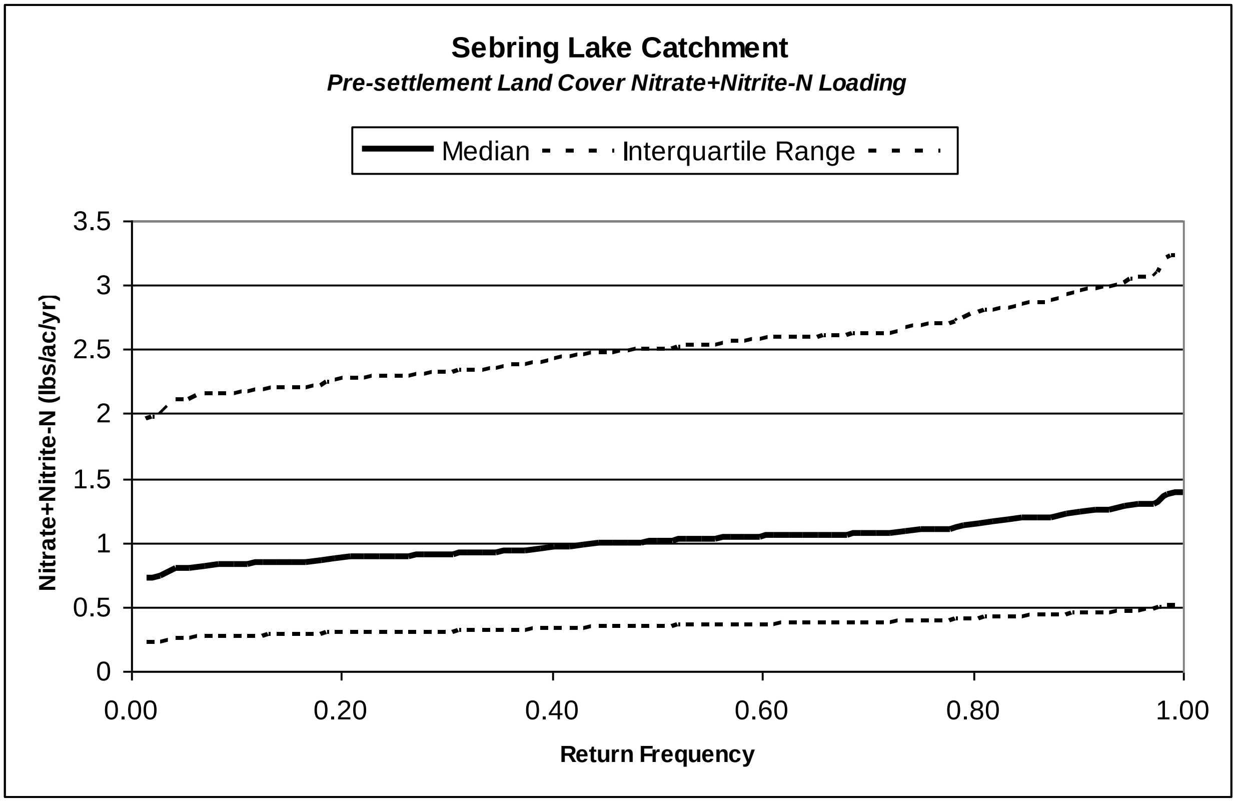

Figure 169. Pre-settlement Sebring Lake Catchment Nitrate+Nitrite-N Load Duration Curve

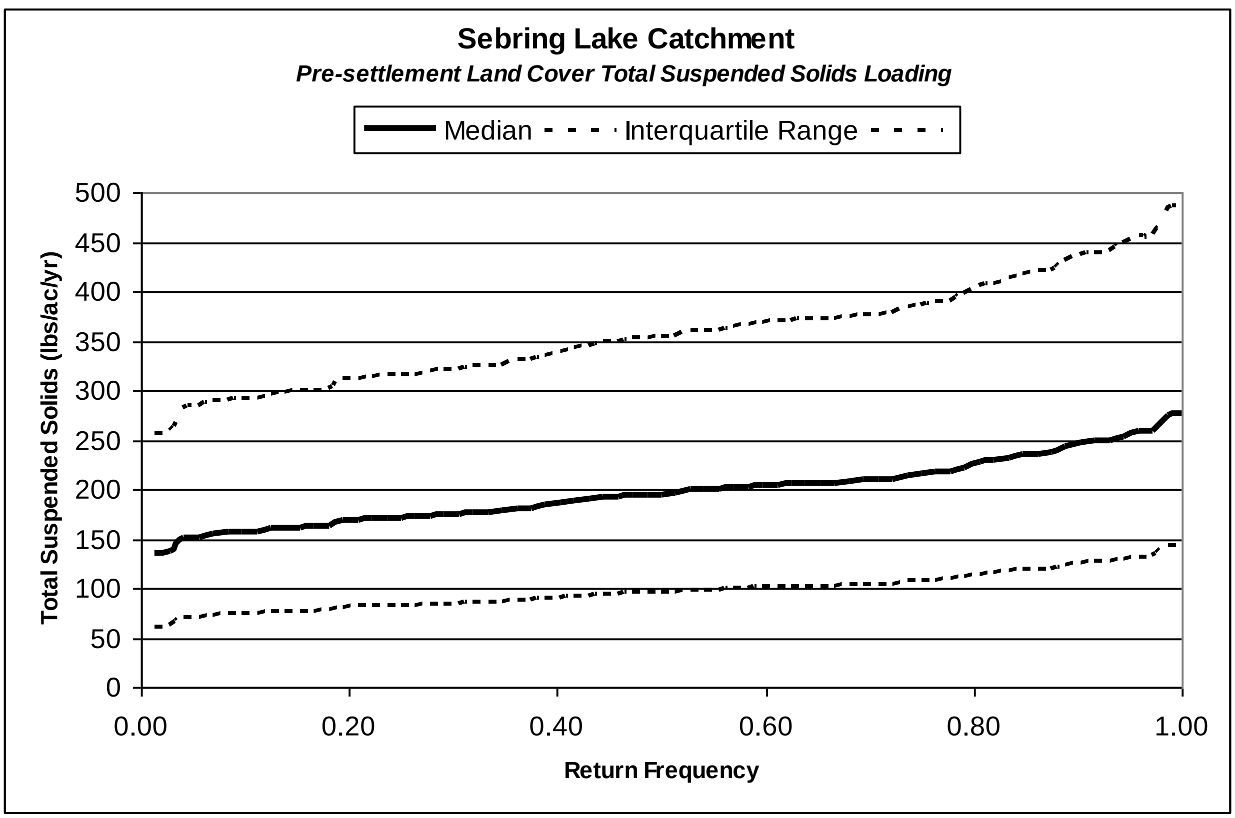

Figure 170. Pre-settlement Sebring Lake Catchment Total Suspended Solids Load Duration Curve

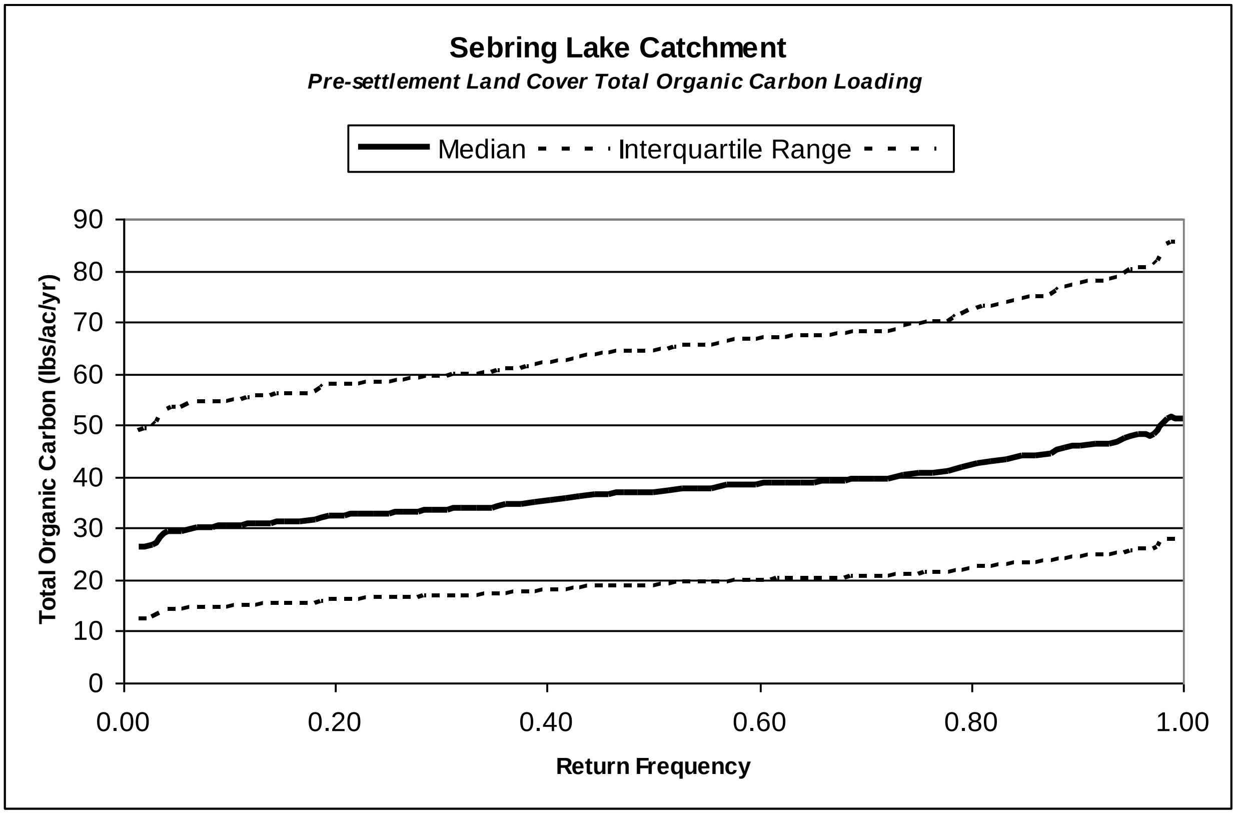

Figure 171. Pre-settlement Sebring Lake Catchment Total Organic Carbon Load Duration Curve

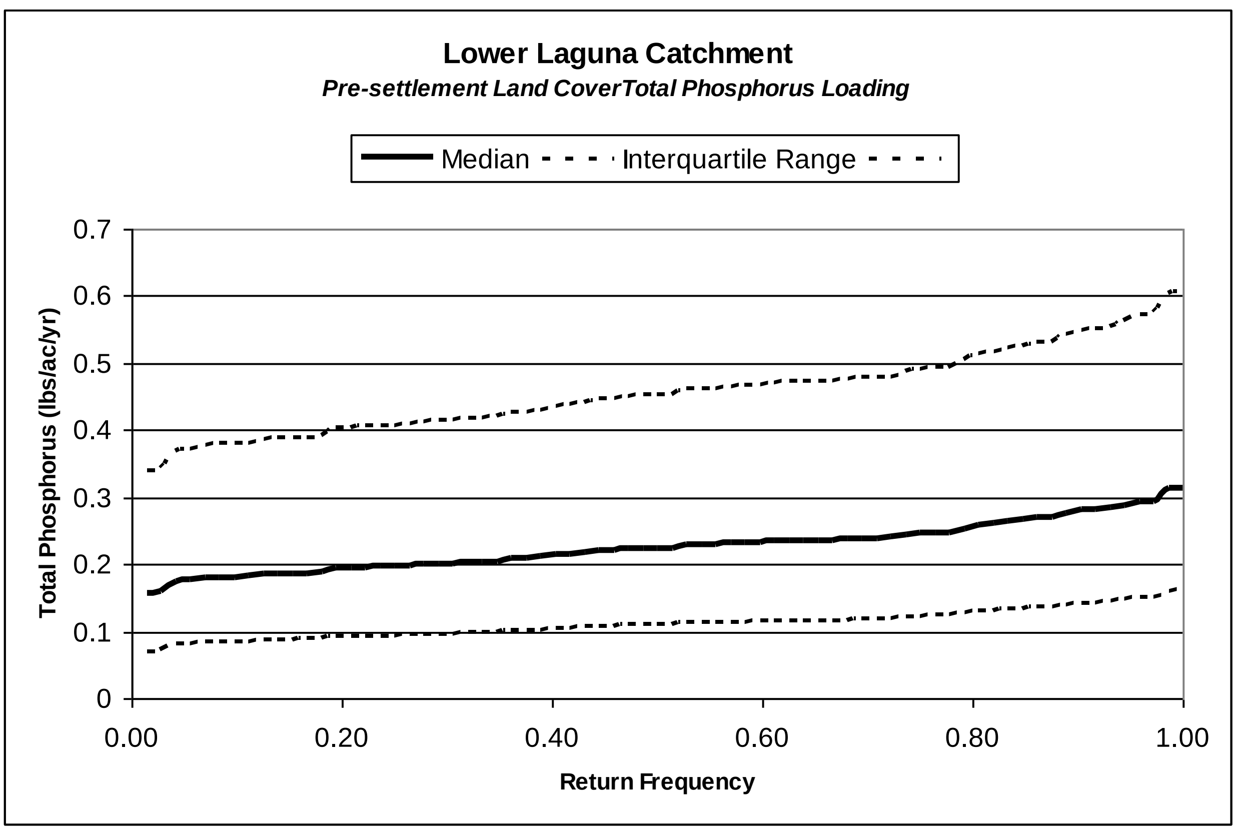

Figure 172. Pre-settlement Lower Laguna Catchment Total Phosphorus Load Duration Curve

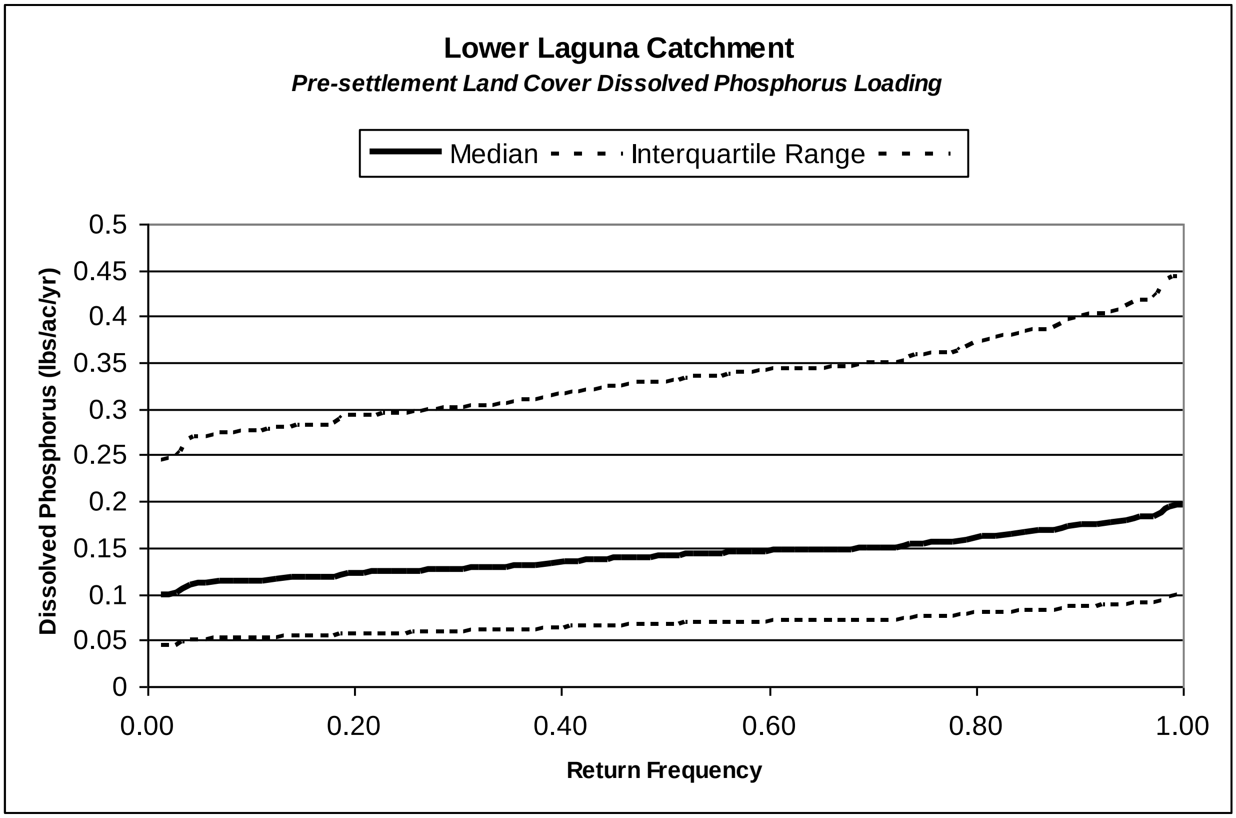

Figure 173. Pre-settlement Lower Laguna Catchment Dissolved Phosphorus Load Duration Curve

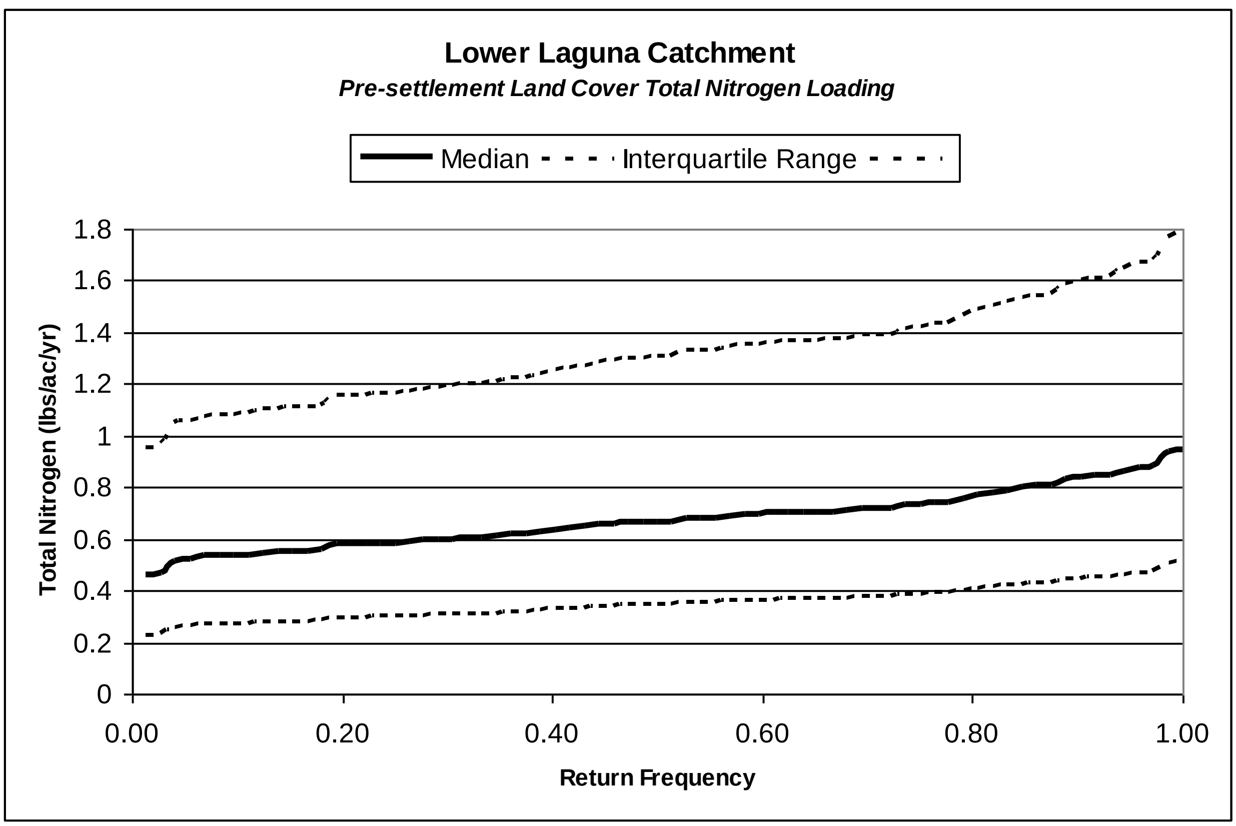

Figure 174. Pre-settlement Lower Laguna Catchment Total Nitrogen Load Duration Curve

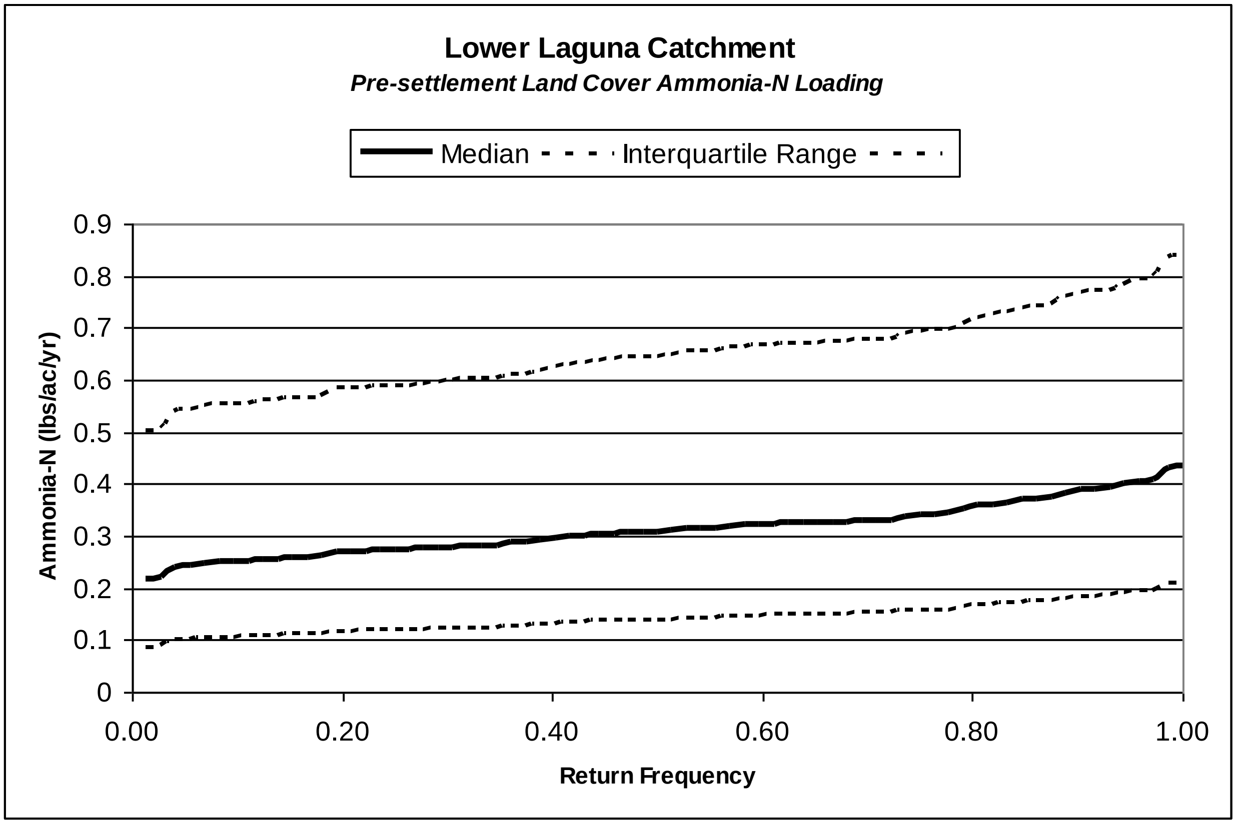

Figure 175. Pre-settlement Lower Laguna Catchment Ammonia-N Load Duration Curve

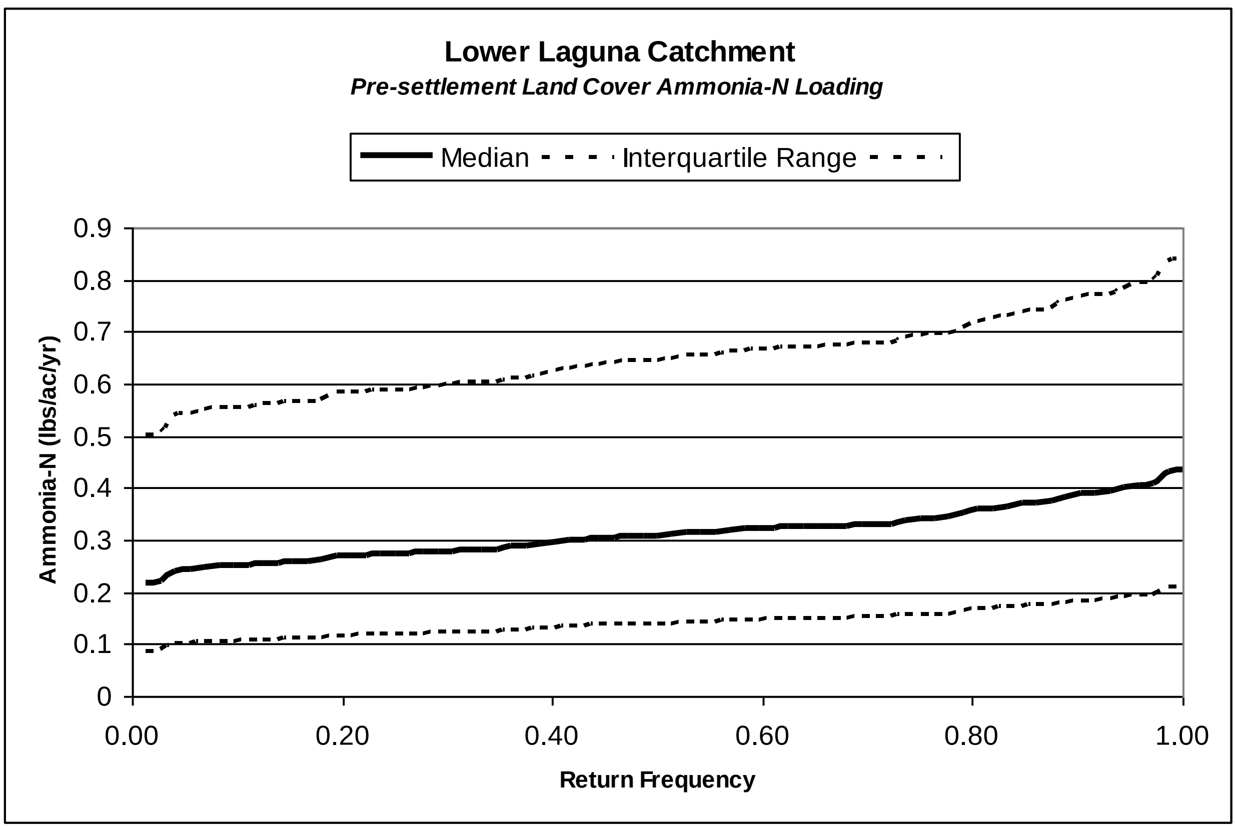

Figure 176. Pre-settlement Lower Laguna Catchment Nitrate+Nitrite-N Load Duration Curve

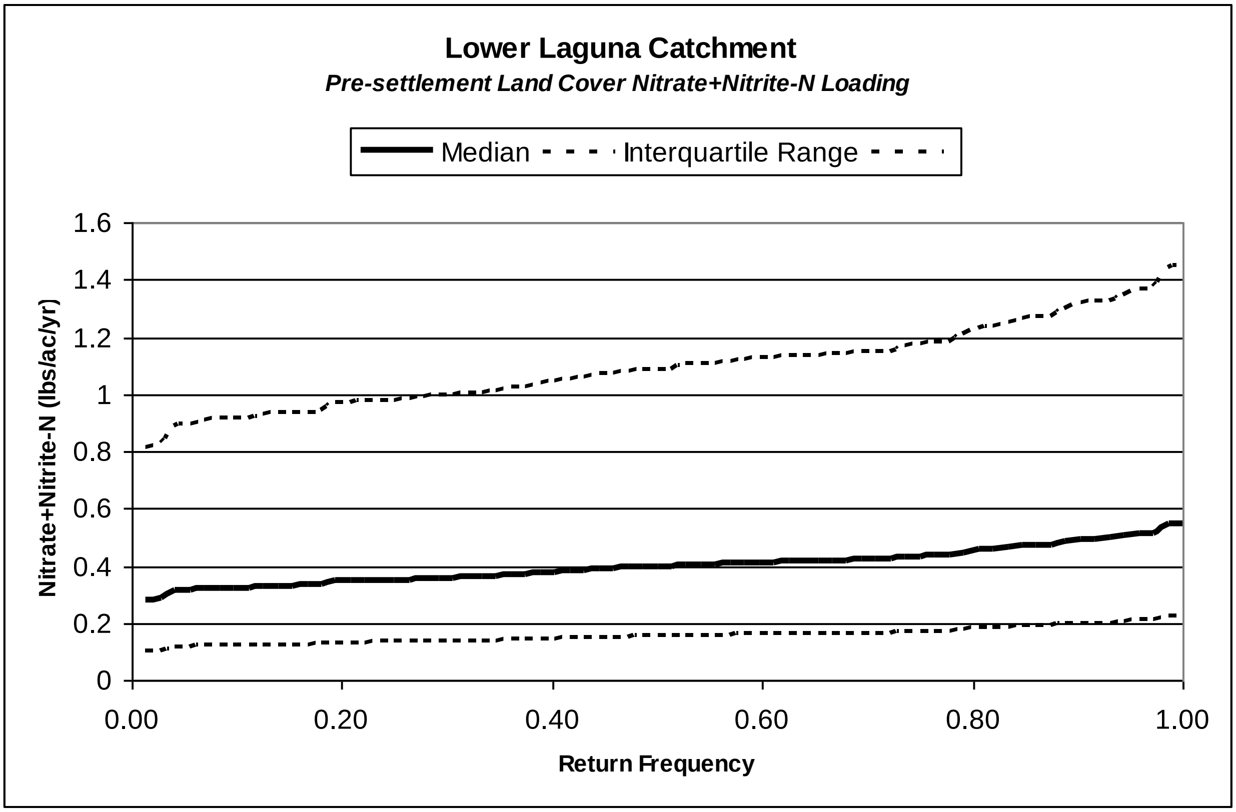

Figure 177. Pre-settlement Lower Laguna Catchment Total Suspended Solids Load Duration Curve

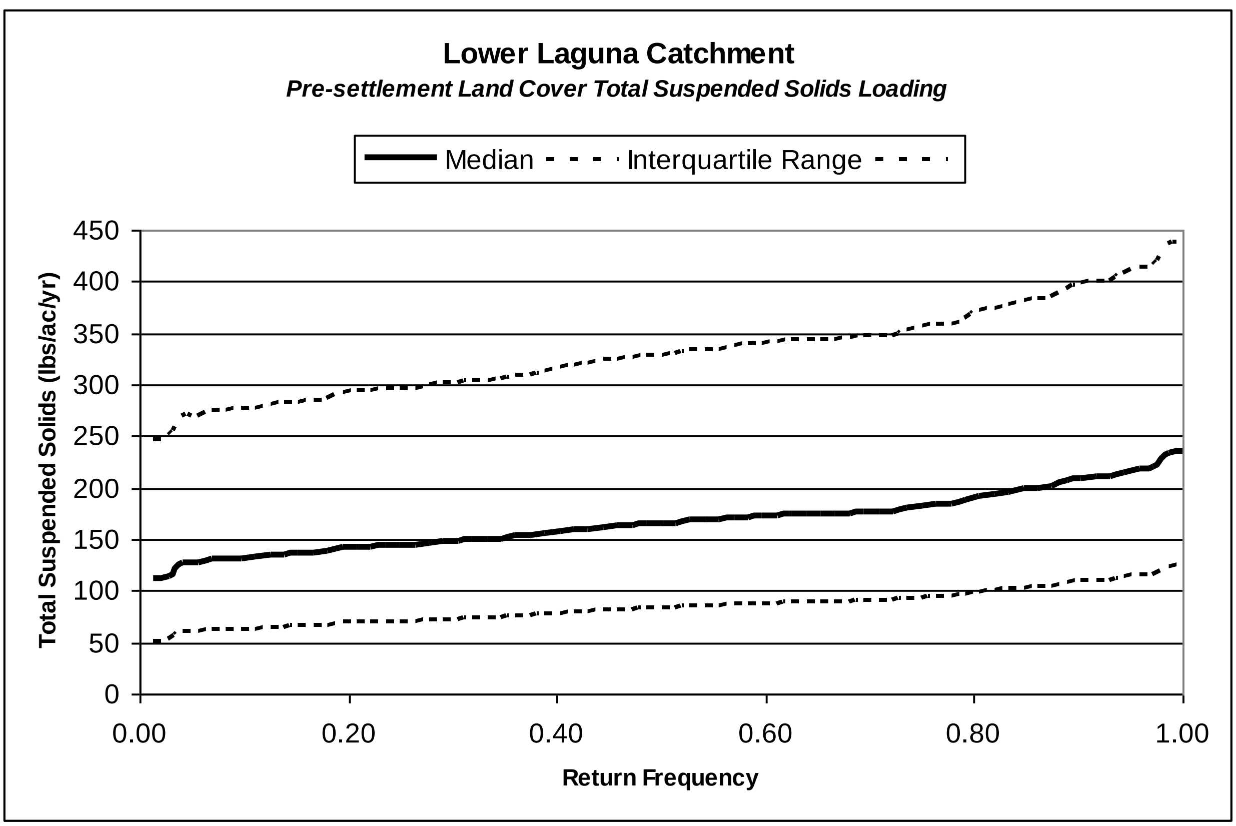

Figure 178. Pre-settlement Lower Laguna Catchment Total Organic Carbon Load Duration Curve

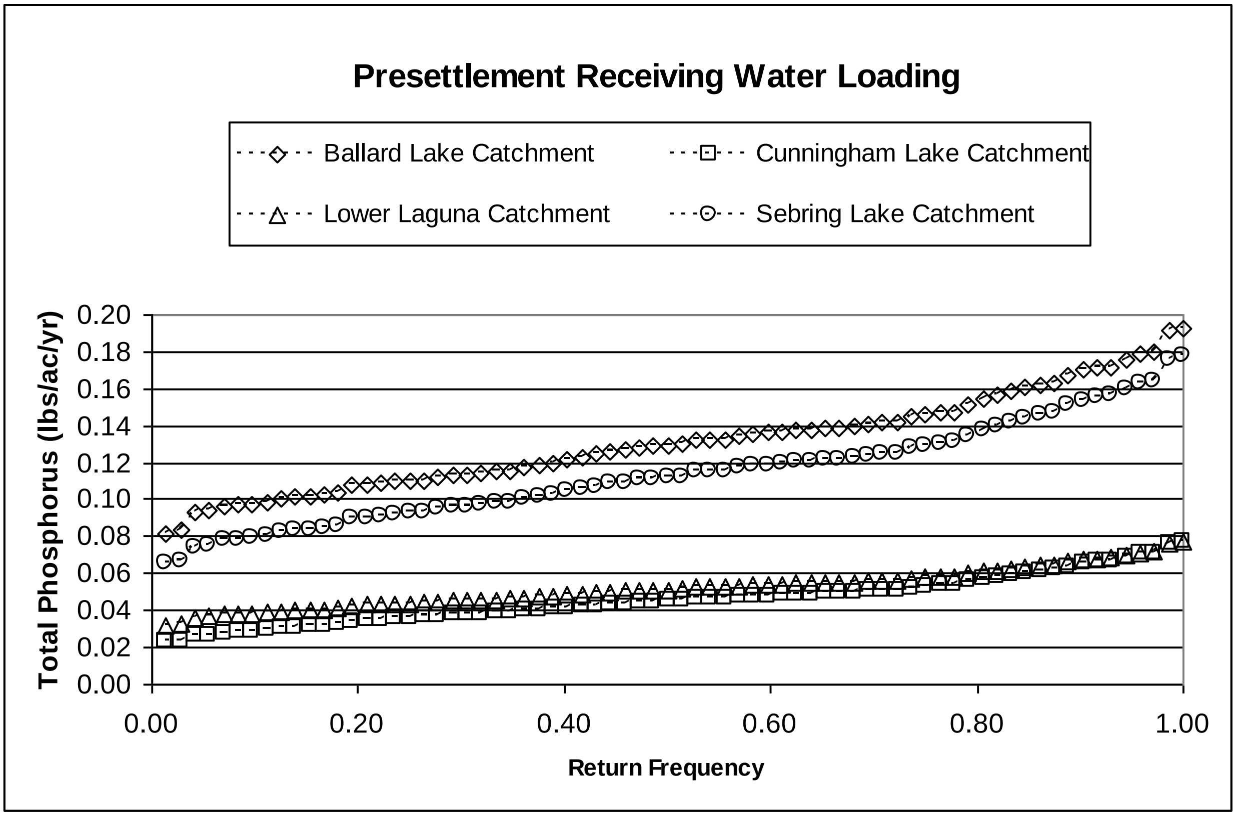

Figure 179. Comparison of Pre-Settlement Laguna Watershed Total Phosphorus Load Duration Curves

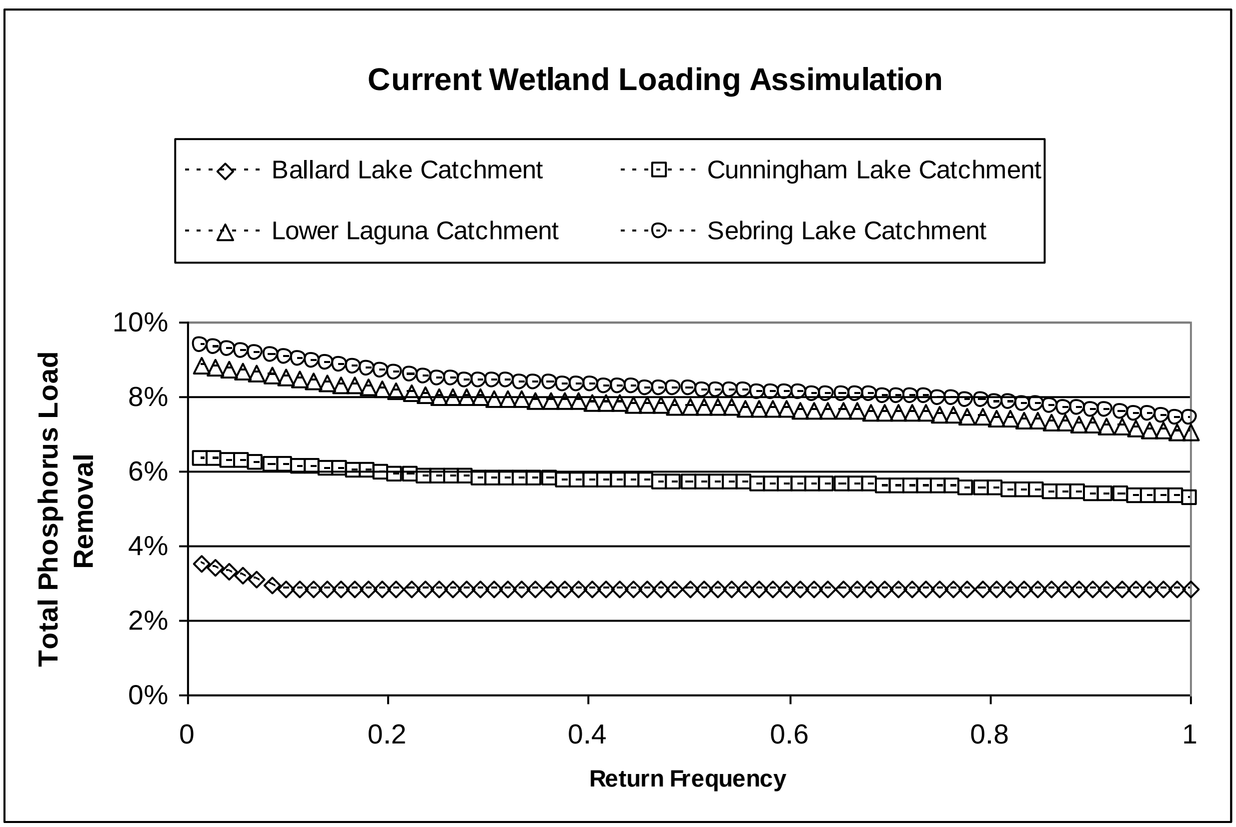

Figure 180. Comparison of Current Laguna Watershed Total Phosphorus Load Duration Curves

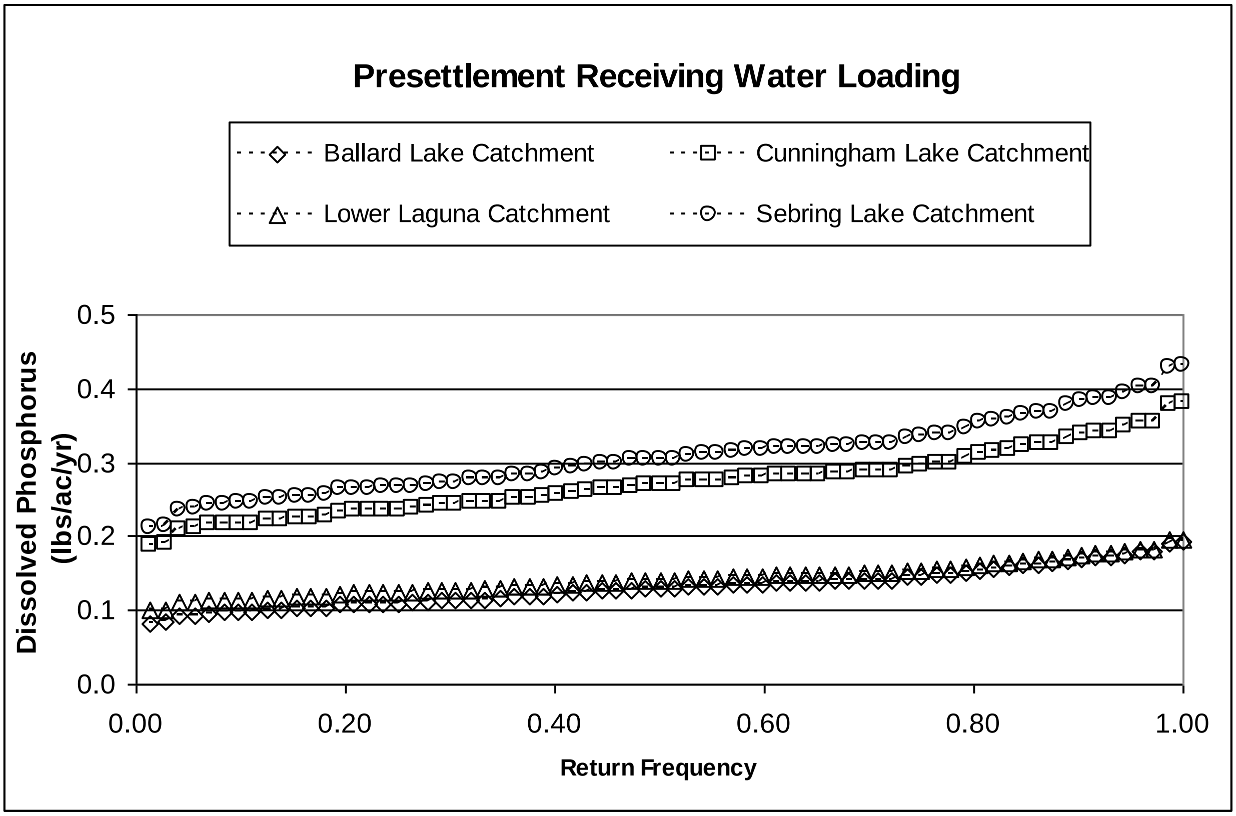

Figure 181. Comparison of Pre-Settlement Laguna Watershed Dissolved Phosphorus Load Duration Curves

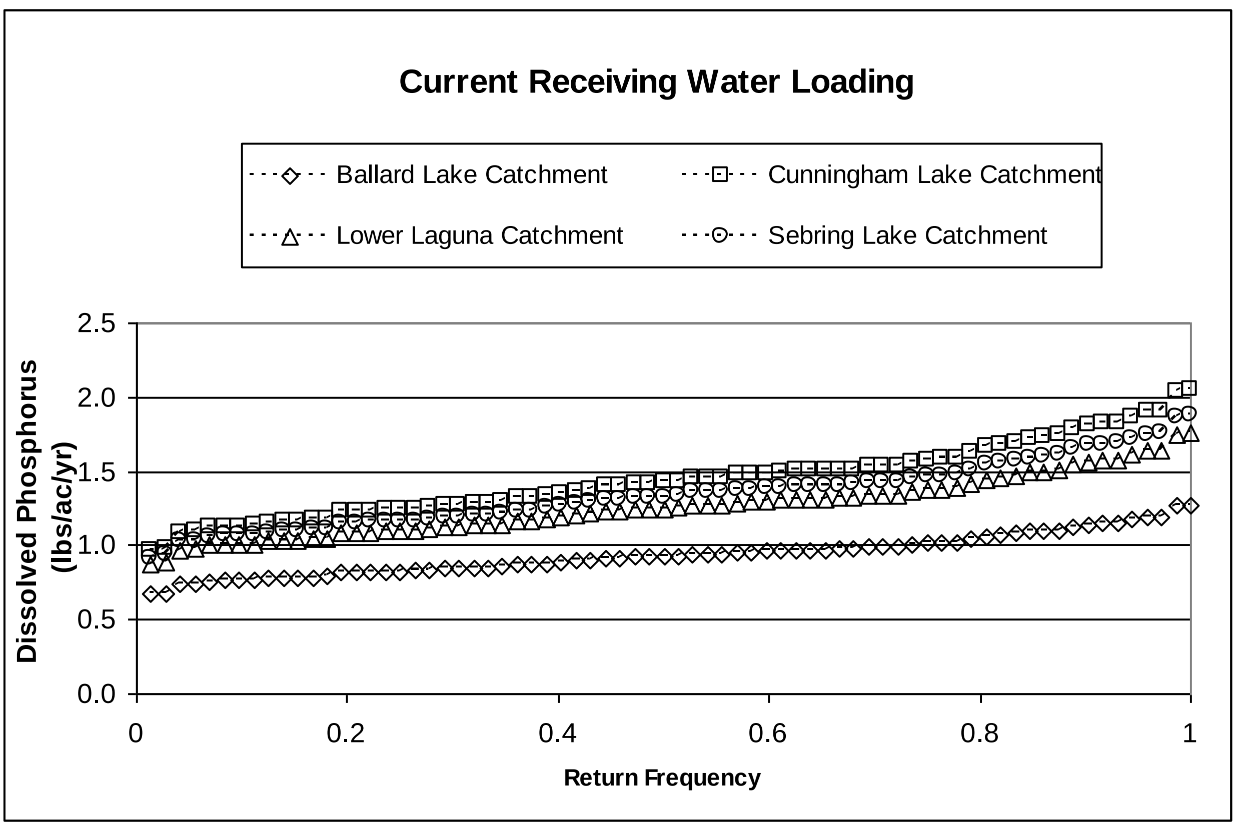

Figure 182. Comparison of Current Laguna Watershed Dissolved Phosphorus Load Duration Curves

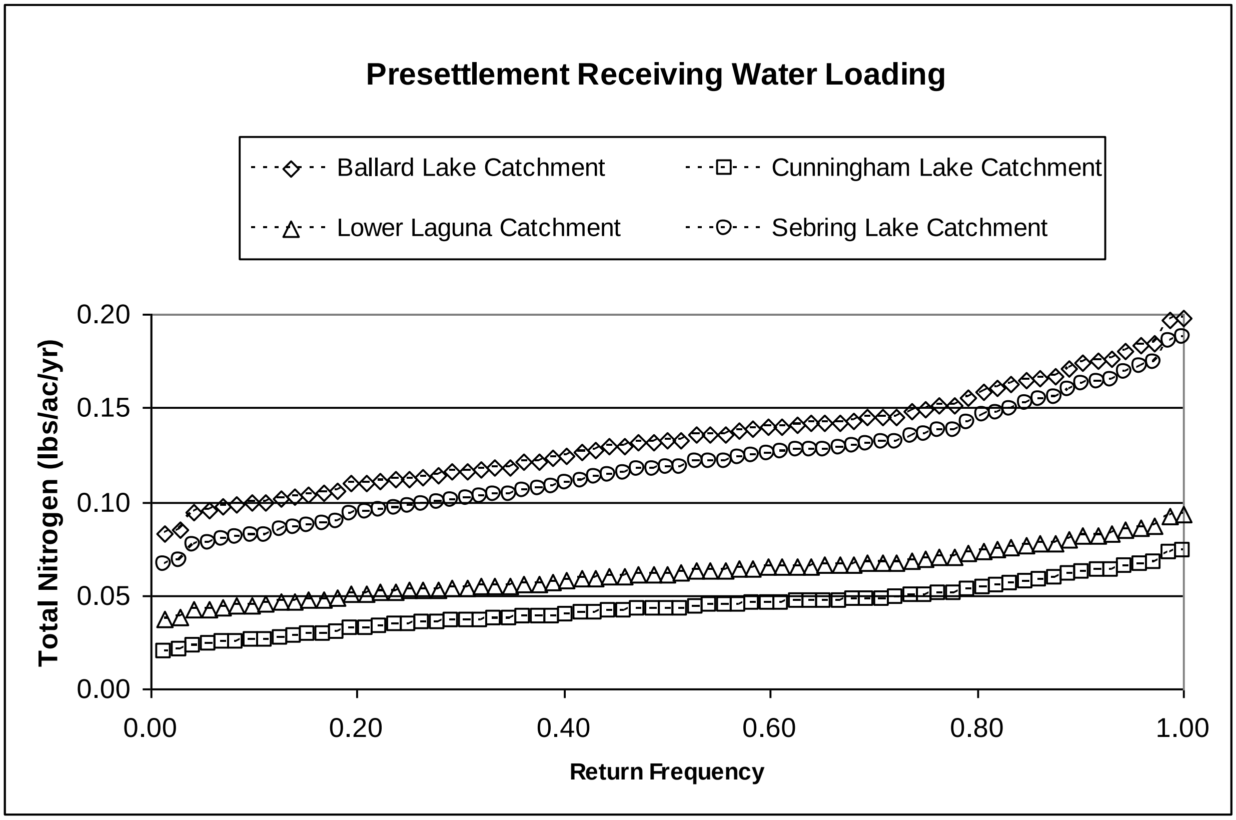

Figure 183. Comparison of Pre-Settlement Laguna Watershed Total Nitrogen Load Duration Curves

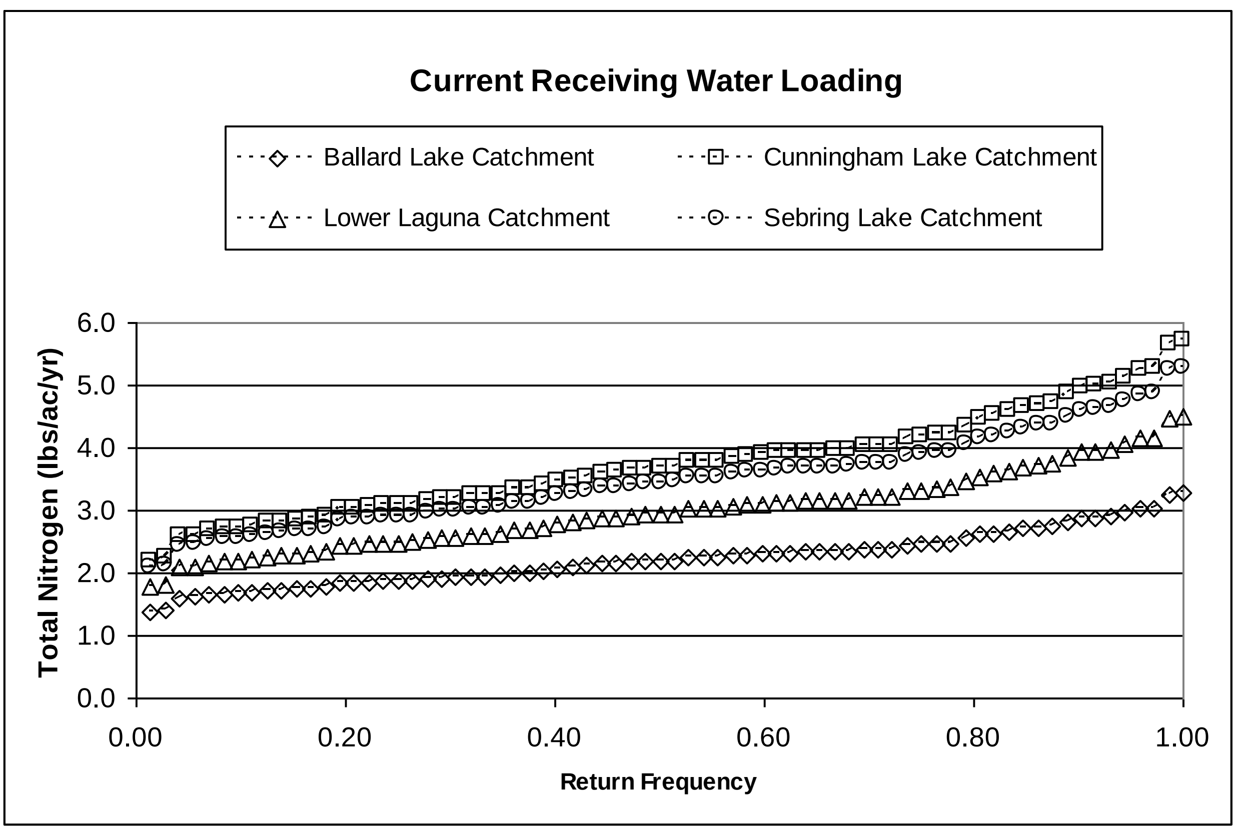

Figure 184. Comparison of Current Laguna Watershed Total Nitrogen Load Duration Curves

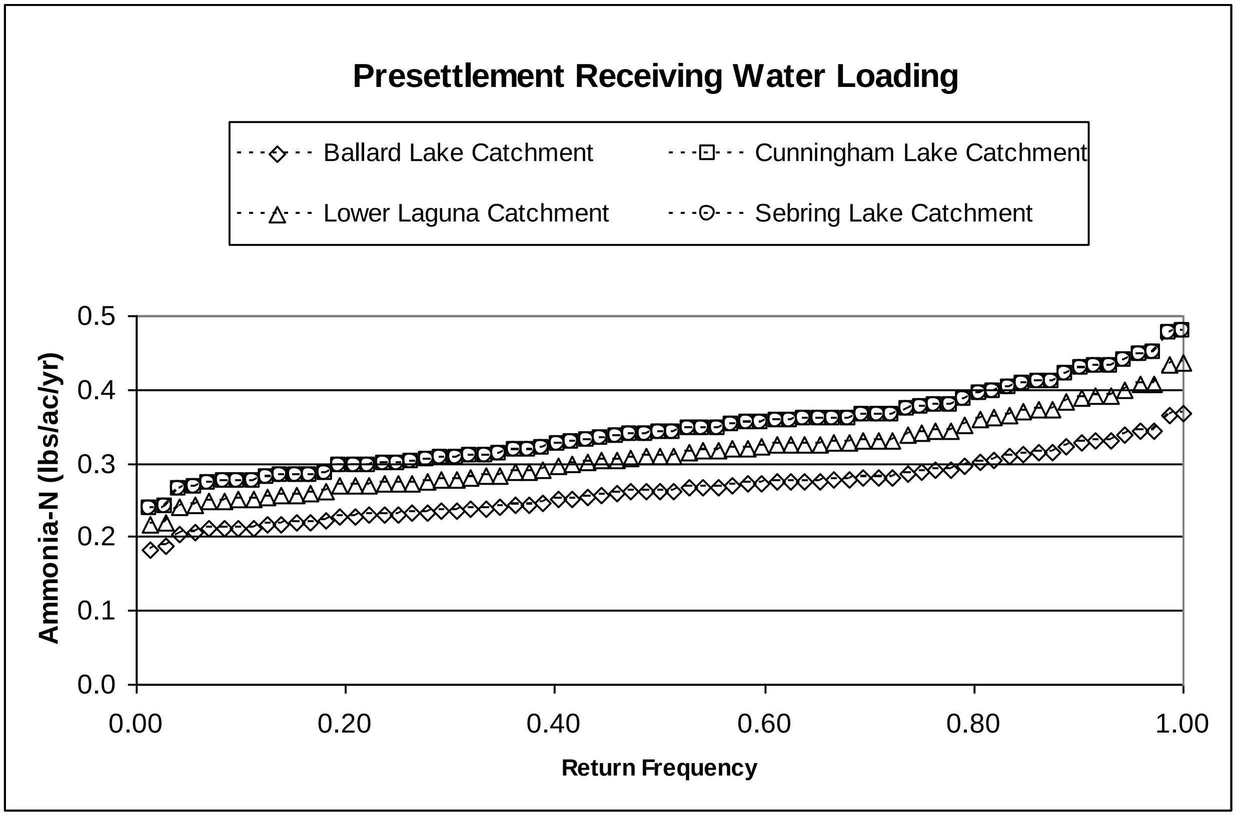

Figure 185. Comparison of Pre-Settlement Laguna Watershed Total Ammonia-N Load Duration Curves

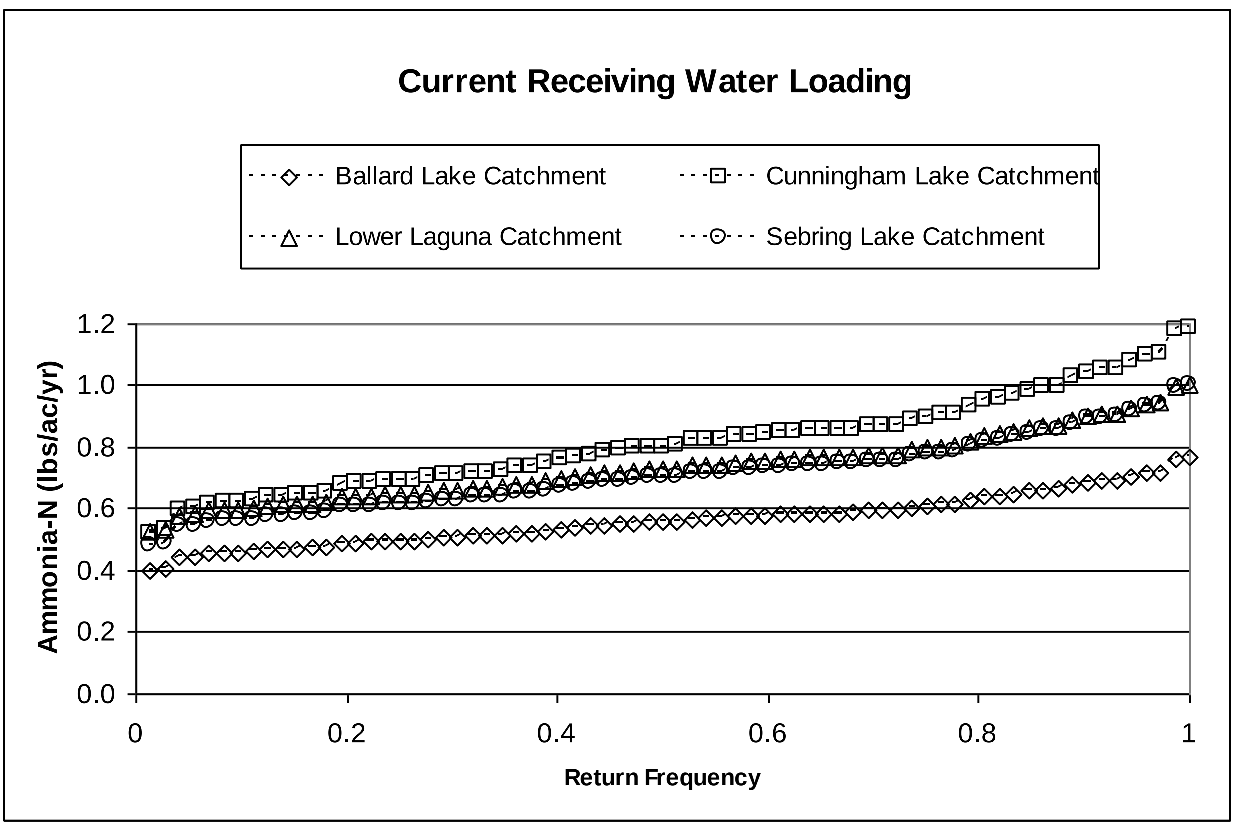

Figure 186. Comparison of Current Laguna Watershed Total Ammonia-N Load Duration Curves

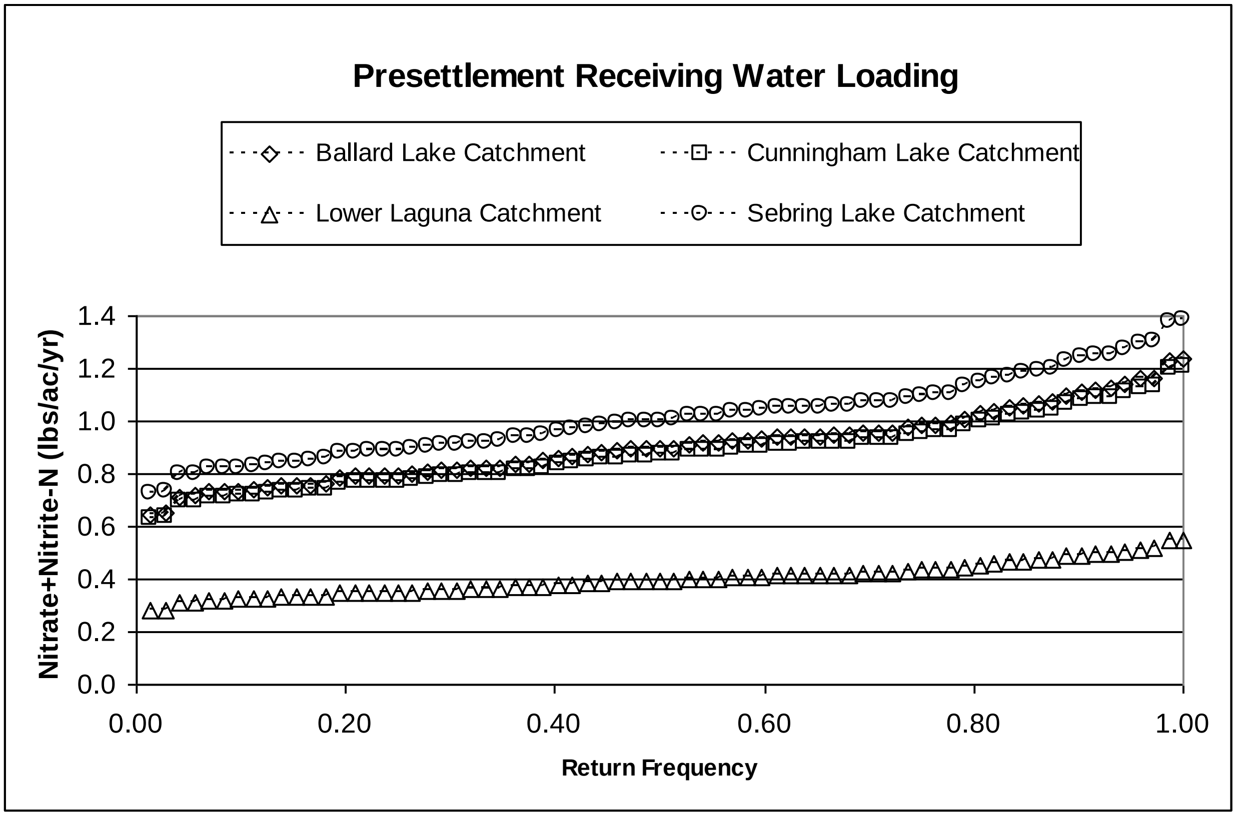

Figure 187. Comparison of Pre-Settlement Laguna Watershed Total Nitrate+Nitrite-N Load Duration Curves

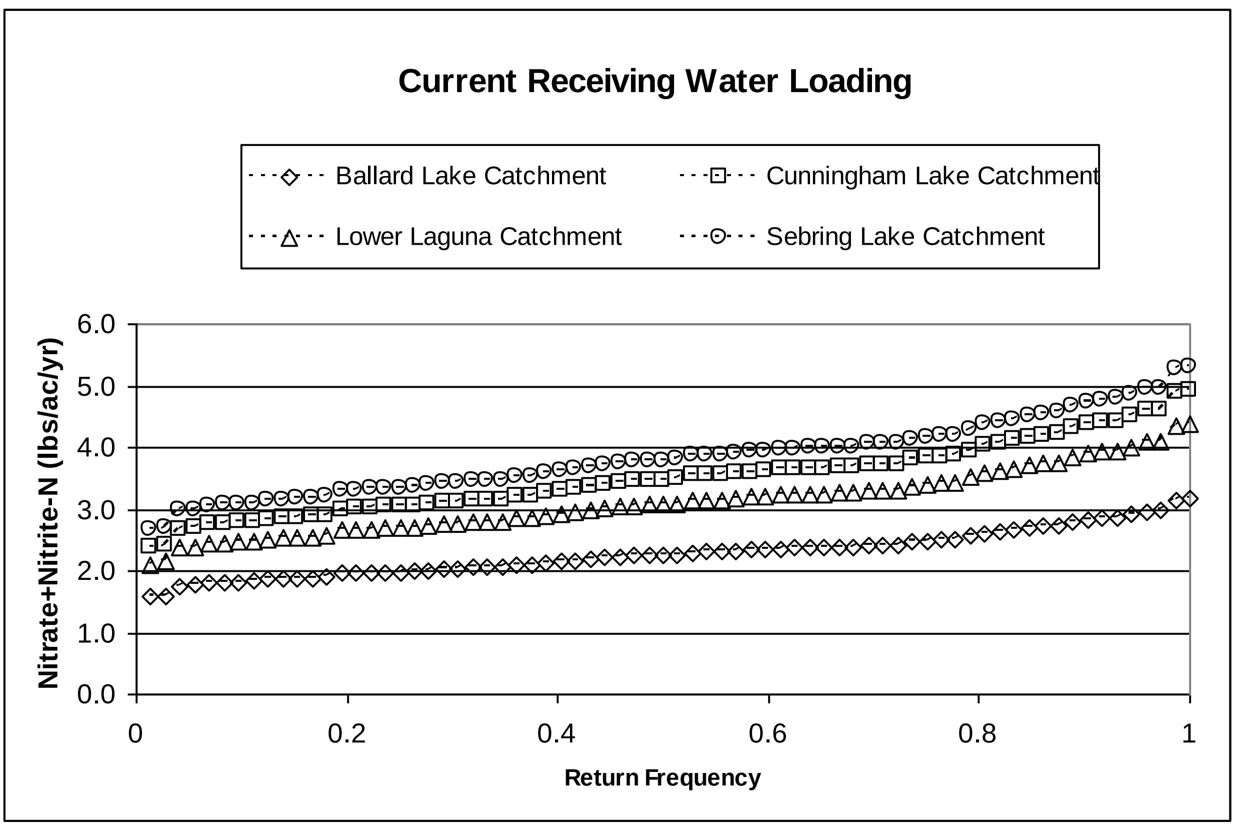

Figure 188. Comparison of Current Laguna Watershed Total Nitrate+Nitrite-N Load Duration Curves

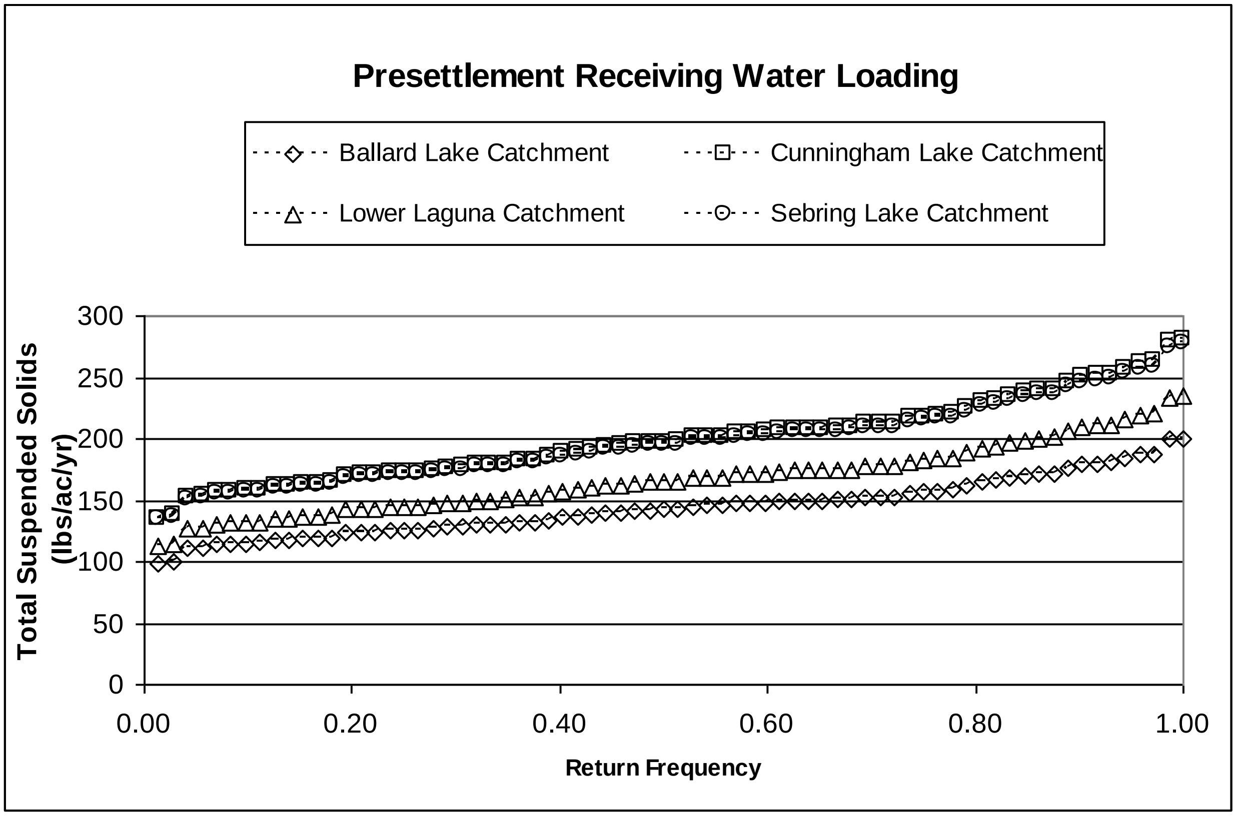

Figure 189. Comparison of Pre-Settlement Laguna Watershed Total Suspended Solids Load Duration Curves

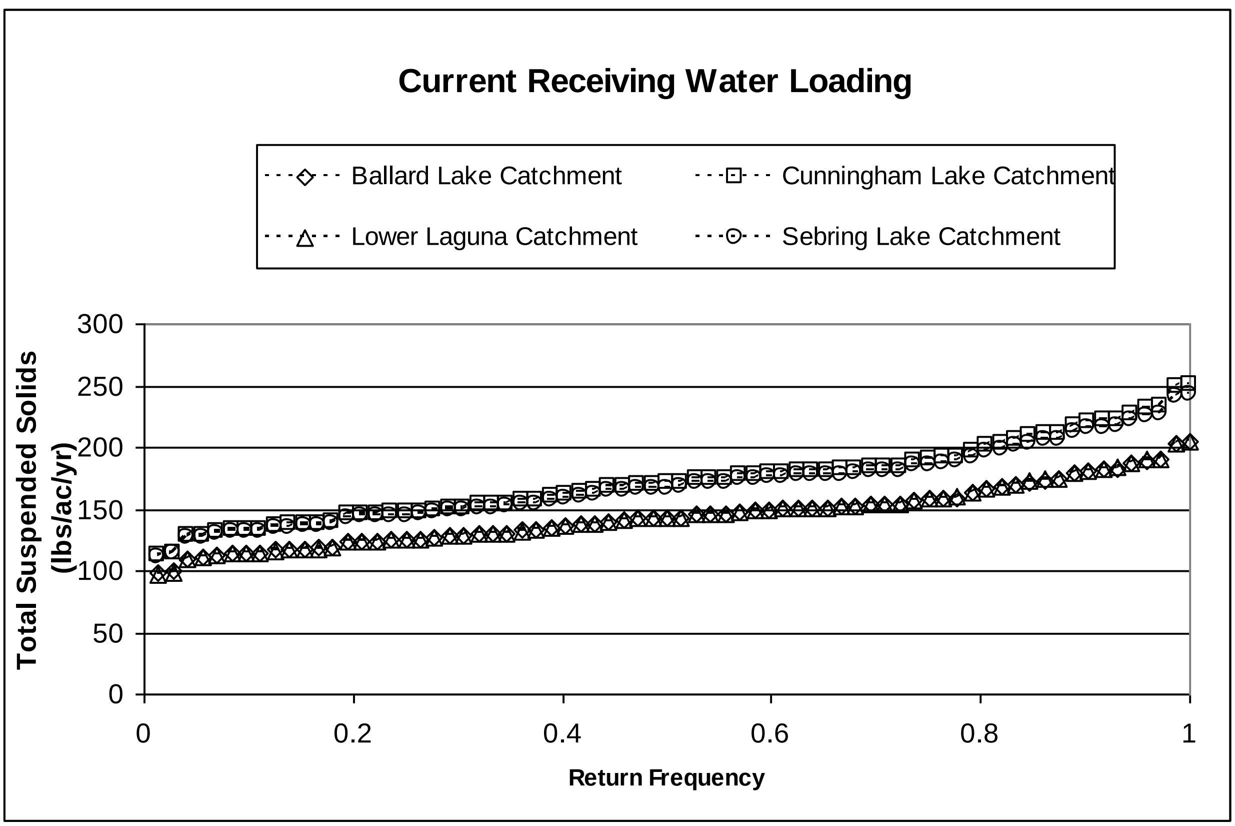

Figure 190. Comparison of Current Laguna Watershed Total Suspended Solids Load Duration Curves

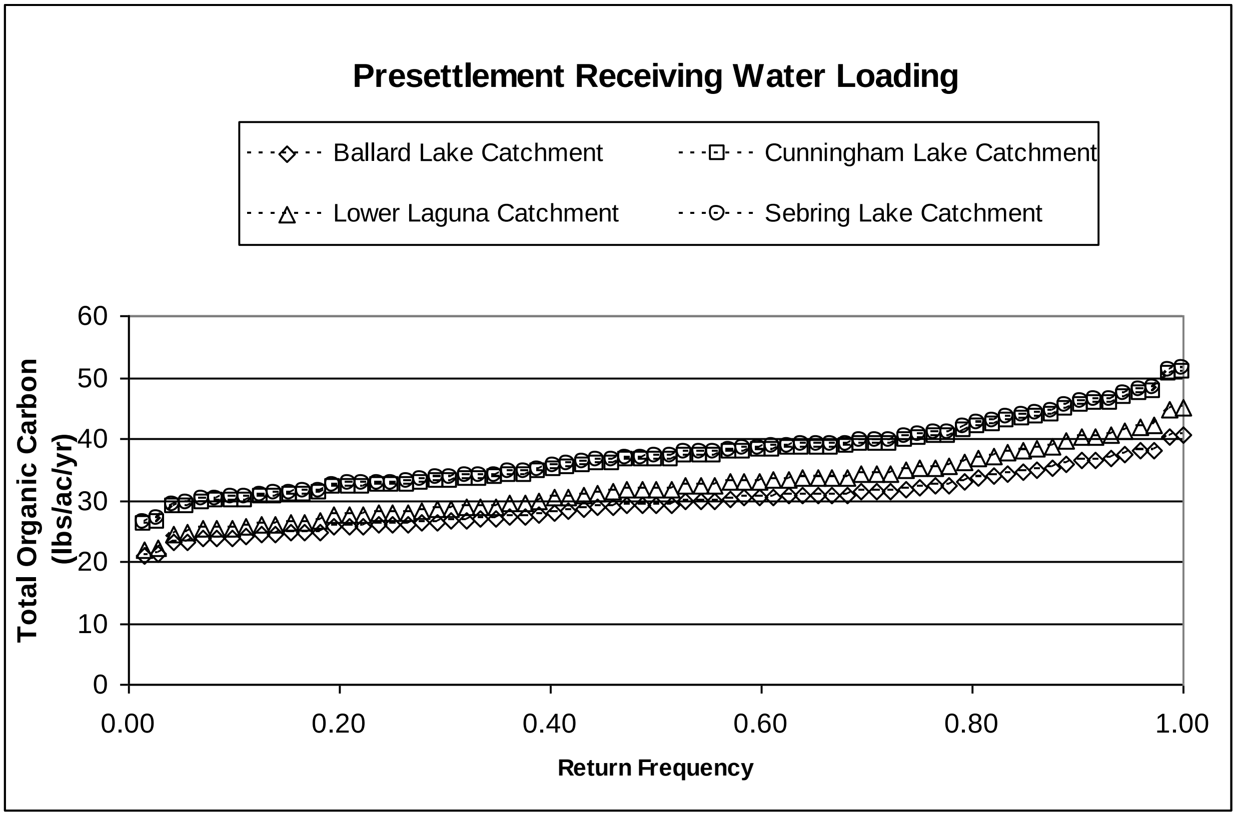

Figure 191. Comparison of Pre-Settlement Laguna Watershed Total Organic Carbon Load Duration Curves

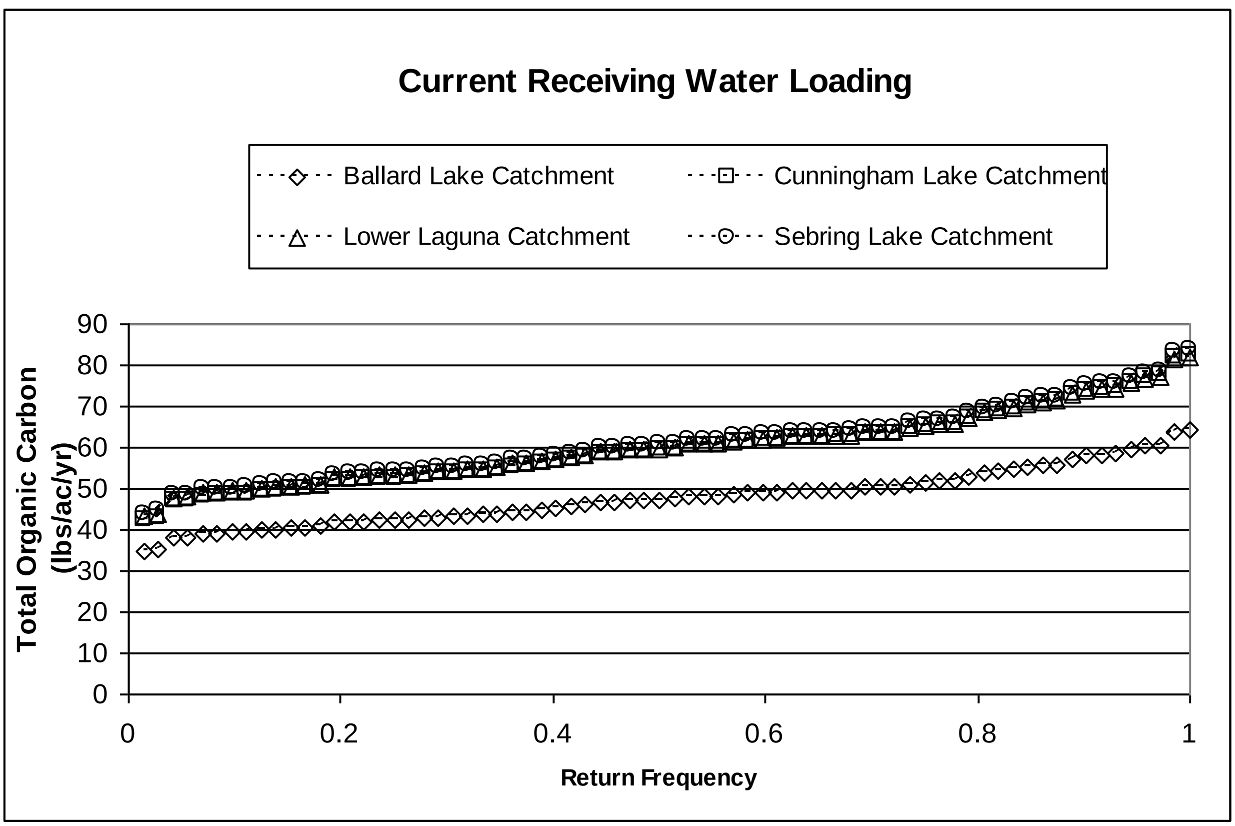

Figure 192. Comparison of Pre-Settlement Laguna Watershed Total Organic Carbon Load Duration Curves