**UNITED STATES ENVIRONMENTAL PROTECTION AGENCY**
**REGION 10**
1200 Sixth Avenue
Seattle, WA 98101

RECEIVED
JUN 13 2005
Department of
Environmental Conservati-

Reply To
Attn Of: OW-134

JUN 10 2005

Dan Easton, Director
Water Division
Alaska Dept. of Environmental Conservation
410 Willoughby Avenue, Suite 303
Juneau, AK 99801-1795

Dear Mr. Easton:

The U.S. Environmental Protection Agency is pleased to approve the Total Maximum Daily Loads (TMDLs) for fecal coliform bacteria for Chester Creek, University Lake and Westchester Lagoons in Anchorage, Alaska, submitted to us by Alaska Department of Environmental Conservation on May 20, 2005. By EPA's approval, this TMDL is now incorporated into the State's Water Quality Management Plan under Section 303(e) of the Clean Water Act.

We are impressed by the commitment and hard work shown by the Alaska Department of Environmental Conservation staff, in particular Tim Stevens, in developing these TMDLs. We look forward to continuing to work collaboratively on water quality issues in the Chester Creek watershed. If you have any questions, please feel free to call me at (206) 553-1261, or Jayne Carlin of my staff at (206) 553-8512.

Sincerely,

Christine Psyk for
Michael F. Gearheard, Director
Office of Water

cc: Tim Stevens, Division of Water, ADEC (Juneau)
Kent Patrick-Riley, Division of Water, ADEC (Anchorage)

# Total Maximum Daily Load for Fecal Coliform in Chester Creek, University Lake, and Westchester Lagoon, Anchorage, Alaska

## FINAL

Alaska Department of Environmental Conservation
555 Cordova Street
Anchorage , Alaska 99501

**May 2005**

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# Total Maximum Daily Load for Fecal Coliform in the Waters of Chester Creek in Anchorage, Alaska

## TMDL AT A GLANCE:

*TMDL is for:* Chester Creek, University Lake and Westchester Lagoon
*Water Quality-limited?* Yes
*Hydrologic Unit Code:* 19020401
*Criteria of Concern:* Fecal coliform
*Designated Uses Affected:* Water supply and water recreation
*Major Source(s):* Urban runoff
*Loading Capacity*: $6.46 \times 10^{11}$ to $4.15 \times 10^{12}$FC/year
*Wasteload Allocation:* $5.18 \times 10^{11}$ to $3.73 \times 10^{12}$FC/year (Sections 6 to 8 include monthly allocations)
*Load Allocation:* 0 FC/year
*Margin of Safety:* 10 percent
*Necessary Annual Reduction:* 54 to 98 percent (Sections 6 to 8 include monthly load reductions)

## EXECUTIVE SUMMARY

The Chester Creek watershed is located in the Municipality of Anchorage (MOA), the urban center of the Anchorage Bowl in south-central Alaska. Chester Creek flows through University Lake and Westchester Lagoon. The state of Alaska included the entire length of Chester Creek, University Lake and Westchester Lagoon on its 1990 303(d) list as water quality-limited due to fecal coliform, identifying urban runoff as the expected pollutant source. These waters have been included on all subsequent state 303(d) listings. A Total Maximum Daily Load (TMDL) is established in this document for these waters to meet requirements of Section 303(d)(1)(C) of the Clean Water Act and the U.S. Environmental Protection Agency's (EPA) implementing regulations (40 CFR Part 130), which require the establishment of a TMDL for the achievement of water quality standards when a waterbody is water quality-limited. A TMDL is composed of the sum of individual waste load allocations (WLAs) for point sources and load allocations (LAs) for nonpoint sources and natural background loads. In addition, the TMDL must include a margin of safety (MOS), either implicitly or explicitly, that accounts for the uncertainty in the relationship between pollutant loads and the quality of the receiving waterbody. A TMDL represents the amount of a pollutant the waterbody can assimilate while maintaining compliance with applicable water quality standards. Although separate TMDLs could have been prepared for each of the three waters, DEC integrated them into one TMDL as University Lake and Westchester Lagoon are part of the mainstem flow of Chester Creek and have no other natural inlets or outlets.

Applicable water quality standards for fecal coliform bacteria in Chester Creek, University Lake, and Westchester Lagoons establish protection for designated uses of water supply, water recreation, and growth and propagation of fish, shellfish, and other aquatic life, and wildlife. The TMDLs are developed for the most stringent of these—the fecal coliform criteria for drinking, culinary, and food processing water supply that states that in a 30-day period, the geometric mean may not exceed 20 FC/100 mL, and not more than 10 percent of the samples may exceed 40 FC/100 mL (18 AAC 70.020(2)(b)(2)(A)(i)). If the water quality is restored to meet drinking water criteria it will also meet other designated use criteria.

Fecal coliform data indicate that Chester Creek, University Lake and Westchester Lagoons do not meet the applicable water quality standards related to drinking water or water recreation uses. The largest and most frequent exceedances of the water quality criteria occur during summer months, likely due to increased storm water runoff. Fecal coliform concentrations are lower during colder winter months that experience less storm water runoff. Concentrations steadily increase during spring months, with increased surface runoff during spring thaw and breakup. Because of the substantial seasonal variation in fecal coliform levels, the Chester Creek, University Lake, and Westchester Lagoons TMDLs are developed on a monthly basis to isolate times of similar weather, runoff and in-stream conditions.

Due to the water quality criteria being based on a 30-day geometric mean, the urban character of the watershed, previous modeling efforts made by MOA, and availability of USGS flow data, the Storm Water Management Model (SWMM) (USEPA, 2000) was selected to estimate existing and potential future fecal coliform counts in the Chester Creek watershed. SWMM simulates the quantity and quality of runoff produced by storms, as well as during baseflow conditions, and is one of the most advanced tools available for evaluating water quality in urban watersheds. SWMM simulates real storm events based on rainfall and other meteorological inputs, such as evaporation and temperature, and watershed transport, storage and management practices to predict runoff quantity and quality. At the subwatershed scale, SWMM provides predictions of daily fecal coliform counts, which allows for a direct comparison with Alaska's water quality standards.

The SWMM model was first calibrated to observed hydrology and fecal coliform counts for the period 1987 to 1993 and was then used to assess the effectiveness of various implementation options. Seven "analysis points" were identified to evaluate conditions at various points along Chester Creek and in

University Lake and Westchester Lagoon. The following nine tables summarize the results of the TMDL analysis. They indicate that significant reductions in existing loads throughout the watershed are necessary to meet water quality standards. Areas of the watershed with the highest fecal coliform loading rates tend to be residential land uses with a high degree of imperviousness and located in close proximity to the stream. MOA (2003) reports that the likely sources associated with these land uses are warm-blooded animal sources including domestic pets (particularly cats and dogs) and wild animals.

Although all of Chester Creek originally was listed in 1990, the stretch actually impaired is smaller. This document identifies the section of stream that monitoring data indicates is water-quality limited and recommends that the listing be amended to reflect the new boundaries. Specifically, the available monitoring data indicate that the portion of Chester Creek above the Municipality of Anchorage/ Fort Richardson property line is not water-quality limited by bacteria impairment.

Through an evaluation of information collected in developing this TMDL and in a fecal coliform assessment of Chester Creek done through a DEC grant to the University of Alaska (to be published in July 2005), DEC believes three potential sources of fecal coliform contribute little or insignificant loads of fecal coliform bacteria to the Chester Creek system: onsite septic systems, illegal campsites, and leaking sewage lines. DEC believes that waterfowl and wildlife contribute little fecal coliform through most of the watershed, but at some locations may contribute higher amounts at certain times of the year. As any contributions they provide are not resulting from human actions, they are not included in the TMDL loading allocations. This TMDL focuses on stormwater discharges as the main component. These discharges in the MOA are regulated by a National Pollutant Discharge Elimination System (NPDES) storm water permit for municipal separate storm sewer systems (MS4), watershed loads delivered to Chester Creek are addressed through the wasteload allocation component of this TMDL.

Implementation of the stormwater control actions in this TMDL will be achieved through actions associated with the MOA's MS4 permit. EPA recommends that for NPDES-regulated municipal and small construction storm water discharges effluent limits should be expressed as best management practices (BMPs) or other similar requirements, rather than as numeric effluent limits. This recognizes the need for an iterative approach to control pollutants in storm water discharges and anticipates that a suite of BMPs will be used in the initial rounds of permits and that these BMPs will be tailored in subsequent rounds. Follow-up monitoring will be coordinated between DEC and MOA to track the progress of TMDL implementation and subsequent water quality response, track BMP effectiveness, and track the water quality of Chester Creek, University Lake, and Westchester Lagoons to evaluate future attainment of water quality standards.

Although the SWMM scenarios in this TMDL did not show that fecal coliform bacteria will be reduced to levels meeting state water quality standards, DEC believes the standards will be met because of the following mitigating issues: 1) although SWMM is considered the best model for the type and amount of data available, it was not designed for Alaska’s extreme northern climate and could have predicted conservative reductions under the implementation scenarios; 2) the data used are 10-15 years old and do not reflect improvements in stormwater management known to have occurred since the data was collected; and 3) recent monitoring data[1] consistently shows fecal coliform levels are considerably lower than levels seen in data used to develop the TMDL, translating into fewer reductions needed to meet state water quality standards than projected by the model. DEC will continue to monitor these waters for levels of fecal coliform bacteria and if sampling results show the actions are not achieving the target levels, DEC will, in coordination with the MOA, consider and take other actions to adjust and meet the targets.

[1] In 2004, DEC contracted with the University of Alaska, Anchorage to collect temporal and spatial fecal coliform data on Chester Creek. Unfortunately the data collected could not used in developing the TMDL because there wasn’t any corresponding flow data need for SWMM.

**Table ES-1. Summary of the Middle Fork Chester Creek TMDL (Analysis Point 112).**

| Month | Existing (FC/month) | Loading Capacity (FC/month) | Margin of Safety (FC/month) | Waste Load Allocation (FC/month) | Required Reduction |
|---|---|---|---|---|---|
| **Jan** | **3.11E+09** | **2.90E+09** | **2.90E+08** | **2.61E+09** | **7%** |
| **Feb** | **1.45E+12** | **4.78E+11** | **4.78E+10** | **4.30E+11** | **67%** |
| Mar | 8.51E+11 | 3.21E+10 | 3.21E+09 | 2.89E+10 | 96% |
| Apr | 9.58E+12 | 8.85E+10 | 8.85E+09 | 7.96E+10 | 99% |
| May | 2.99E+12 | 6.75E+10 | 6.75E+09 | 6.08E+10 | 98% |
| Jun | 1.10E+12 | 6.44E+10 | 6.44E+09 | 5.80E+10 | 94% |
| Jul | 2.05E+12 | 6.55E+10 | 6.55E+09 | 5.90E+10 | 97% |
| Aug | 5.13E+12 | 8.10E+10 | 8.10E+09 | 7.29E+10 | 98% |
| Sep | 5.12E+12 | 8.07E+10 | 8.07E+09 | 7.26E+10 | 98% |
| Oct | 1.15E+12 | 6.69E+10 | 6.69E+09 | 6.02E+10 | 94% |
| Nov | 2.01E+11 | 4.23E+10 | 4.23E+09 | 3.81E+10 | 79% |
| **Dec** | **2.50E+10** | **1.80E+10** | **1.80E+09** | **1.62E+10** | **28%** |
| Annual | 2.82E+13 | 6.46E+11 | 6.46E+10 | 5.81E+11 | 98% |

Bold denotes monthly values assessed for not-to-exceed standard.
Annual loads are given in FC/year.

**Table ES-2. Summary of the South Fork Chester Creek TMDL (Analysis Point 171).**

| Month | Existing (FC/month) | Loading Capacity (FC/month) | Margin of Safety (FC/month) | Waste Load Allocation (FC/month) | Required Reduction |
|---|---|---|---|---|---|
| Jan | 5.18E+11 | 3.63E+10 | 3.63E+09 | 3.27E+10 | 93% |
| Feb | 7.55E+11 | 3.75E+10 | 3.75E+09 | 3.38E+10 | 95% |
| Mar | 2.01E+12 | 7.25E+10 | 7.25E+09 | 6.53E+10 | 96% |
| Apr | 9.06E+12 | 1.97E+11 | 1.97E+10 | 1.77E+11 | 98% |
| May | 6.87E+12 | 1.66E+11 | 1.66E+10 | 1.49E+11 | 98% |
| Jun | 2.91E+12 | 1.46E+11 | 1.46E+10 | 1.32E+11 | 95% |
| Jul | 3.23E+12 | 1.43E+11 | 1.43E+10 | 1.28E+11 | 96% |
| Aug | 4.75E+12 | 1.74E+11 | 1.74E+10 | 1.56E+11 | 96% |
| Sep | 4.92E+12 | 1.78E+11 | 1.78E+10 | 1.60E+11 | 96% |
| Oct | 2.86E+12 | 1.52E+11 | 1.52E+10 | 1.37E+11 | 95% |
| Nov | 1.57E+12 | 9.81E+10 | 9.81E+09 | 8.83E+10 | 94% |
| Dec | 6.37E+11 | 5.80E+10 | 5.80E+09 | 5.22E+10 | 91% |
| Annual | 4.01E+13 | 1.46E+12 | 1.46E+11 | 1.31E+12 | 96% |

Annual loads are given in FC/year.

**Table ES-3. Summary of the South Fork Chester Creek TMDL (Analysis Point 350).**

| Month | Existing (FC/month) | Loading Capacity (FC/month) | Margin of Safety (FC/month) | Waste Load Allocation (FC/month) | Required Reduction |
|---|---|---|---|---|---|
| Jan | 6.42E+10 | 5.71E+10 | 5.71E+09 | 5.14E+10 | 11% |
| Feb | 1.32E+11 | 5.96E+10 | 5.96E+09 | 5.36E+10 | 55% |
| Mar | 9.09E+11 | 1.15E+11 | 1.15E+10 | 1.04E+11 | 87% |
| Apr | 4.66E+12 | 2.99E+11 | 2.99E+10 | 2.69E+11 | 94% |
| May | 2.88E+12 | 2.53E+11 | 2.53E+10 | 2.27E+11 | 91% |
| Jun | 1.08E+12 | 2.29E+11 | 2.29E+10 | 2.06E+11 | 79% |
| Jul | 1.26E+12 | 2.28E+11 | 2.28E+10 | 2.05E+11 | 82% |
| Aug | 2.28E+12 | 2.77E+11 | 2.77E+10 | 2.49E+11 | 88% |
| Sep | 2.22E+12 | 2.77E+11 | 2.77E+10 | 2.49E+11 | 88% |
| Oct | 1.15E+12 | 2.37E+11 | 2.37E+10 | 2.13E+11 | 79% |
| Nov | 5.77E+11 | 1.55E+11 | 1.55E+10 | 1.39E+11 | 73% |
| Dec | 1.28E+11 | 9.01E+10 | 9.01E+09 | 8.11E+10 | 30% |
| Annual | 1.73E+13 | 2.27E+12 | 2.27E+11 | 2.05E+12 | 87% |

Annual loads are given in FC/year.

**Table ES-4. Summary of the Chester Creek TMDL (Analysis Point 101).**

| Month | Existing (FC/month) | Loading Capacity (FC/month) | Margin of Safety (FC/month) | Waste Load Allocation (FC/month) | Required Reduction |
|---|---|---|---|---|---|
| **Jan** | **9.59E+09** | **8.69E+09** | **8.69E+08** | **7.82E+09** | **9%** |
| **Feb** | **1.26E+11** | **1.04E+11** | **1.04E+10** | **9.35E+10** | **18%** |
| **Mar** | **7.76E+11** | **4.02E+11** | **4.02E+10** | **3.62E+11** | **48%** |
| **Apr** | **4.28E+12** | **1.26E+12** | **1.26E+11** | **1.13E+12** | **71%** |
| **May** | **2.69E+11** | **1.50E+11** | **1.50E+10** | **1.35E+11** | **44%** |
| **Jun** | **2.69E+11** | **1.74E+11** | **1.74E+10** | **1.56E+11** | **36%** |
| **Jul** | **4.87E+11** | **2.76E+11** | **2.76E+10** | **2.49E+11** | **43%** |
| **Aug** | **9.51E+11** | **4.09E+11** | **4.09E+10** | **3.68E+11** | **57%** |
| **Sep** | **8.30E+11** | **3.89E+11** | **3.89E+10** | **3.51E+11** | **53%** |
| **Oct** | **2.85E+11** | **1.82E+11** | **1.82E+10** | **1.64E+11** | **36%** |
| **Nov** | **1.44E+11** | **1.01E+11** | **1.01E+10** | **9.11E+10** | **30%** |
| Dec | 1.63E+10 | 1.63E+10 | 1.63E+09 | 1.47E+10 | 0% |
| **Annual** | **8.44E+12** | **3.47E+12** | **3.47E+11** | **3.12E+12** | **59%** |

Bold denotes monthly values assessed for not-to-exceed standard.
Annual loads are given in FC/year.

**Table ES-5. Summary of the Chester Creek TMDL (Analysis Point CH2).**

| Month | Existing (FC/month) | Loading Capacity (FC/month) | Margin of Safety (FC/month) | Waste Load Allocation (FC/month) | Required Reduction |
|---|---|---|---|---|---|
| Jan | 1.21E+12 | 1.80E+11 | 1.80E+10 | 1.62E+11 | 85% |
| Feb | 1.23E+12 | 1.85E+11 | 1.85E+10 | 1.66E+11 | 85% |
| Mar | 1.98E+12 | 2.75E+11 | 2.75E+10 | 2.48E+11 | 86% |
| Apr | 3.40E+12 | 5.03E+11 | 5.03E+10 | 4.53E+11 | 85% |
| May | 2.84E+12 | 4.39E+11 | 4.39E+10 | 3.95E+11 | 85% |
| Jun | 3.14E+12 | 3.73E+11 | 3.73E+10 | 3.35E+11 | 88% |
| Jul | 3.45E+12 | 3.87E+11 | 3.87E+10 | 3.49E+11 | 89% |
| Aug | 3.28E+12 | 4.58E+11 | 4.58E+10 | 4.12E+11 | 86% |
| Sep | 2.69E+12 | 4.55E+11 | 4.55E+10 | 4.09E+11 | 83% |
| Oct | 2.80E+12 | 3.91E+11 | 3.91E+10 | 3.52E+11 | 86% |
| Nov | 2.91E+12 | 2.91E+11 | 2.91E+10 | 2.62E+11 | 90% |
| Dec | 1.74E+12 | 2.13E+11 | 2.13E+10 | 1.92E+11 | 88% |
| Annual | 3.07E+13 | 4.15E+12 | 4.15E+11 | 3.73E+12 | 86% |

Annual loads are given in FC/year.

**Table ES-6. Summary of the University Lake TMDL, Analysis Point 171.**

| Month | Existing (FC/month) | Loading Capacity (FC/month) | Margin of Safety (FC/month) | Waste Load Allocation (FC/month) | Required Reduction |
|---|---|---|---|---|---|
| Jan | 5.18E+11 | 3.63E+10 | 3.63E+09 | 3.27E+10 | 93% |
| Feb | 7.55E+11 | 3.75E+10 | 3.75E+09 | 3.38E+10 | 95% |
| Mar | 2.01E+12 | 7.25E+10 | 7.25E+09 | 6.53E+10 | 96% |
| Apr | 9.06E+12 | 1.97E+11 | 1.97E+10 | 1.77E+11 | 98% |
| May | 6.87E+12 | 1.66E+11 | 1.66E+10 | 1.49E+11 | 98% |
| Jun | 2.91E+12 | 1.46E+11 | 1.46E+10 | 1.32E+11 | 95% |
| Jul | 3.23E+12 | 1.43E+11 | 1.43E+10 | 1.28E+11 | 96% |
| Aug | 4.75E+12 | 1.74E+11 | 1.74E+10 | 1.56E+11 | 96% |
| Sep | 4.92E+12 | 1.78E+11 | 1.78E+10 | 1.60E+11 | 96% |
| Oct | 2.86E+12 | 1.52E+11 | 1.52E+10 | 1.37E+11 | 95% |
| Nov | 1.57E+12 | 9.81E+10 | 9.81E+09 | 8.83E+10 | 94% |
| Dec | 6.37E+11 | 5.80E+10 | 5.80E+09 | 5.22E+10 | 91% |
| Annual | 4.01E+13 | 1.46E+12 | 1.46E+11 | 1.31E+12 | 96% |

Annual loads are given in FC/year.

**Table ES-7. Summary of the University Lake TMDL, Analysis Point ULO.**

| Month | Existing (FC/month) | Loading Capacity (FC/month) | Margin of Safety (FC/month) | Waste Load Allocation (FC/month) | Required Reduction |
|---|---|---|---|---|---|
| Jan | 1.35E+11 | 5.71E+10 | 5.71E+09 | 5.14E+10 | 58% |
| Feb | 2.02E+11 | 5.95E+10 | 5.95E+09 | 5.36E+10 | 71% |
| Mar | 5.97E+11 | 1.10E+11 | 1.10E+10 | 9.92E+10 | 82% |
| Apr | 3.67E+12 | 2.80E+11 | 2.80E+10 | 2.52E+11 | 92% |
| May | 3.05E+12 | 2.48E+11 | 2.48E+10 | 2.23E+11 | 92% |
| Jun | 1.15E+12 | 2.25E+11 | 2.25E+10 | 2.02E+11 | 80% |
| Jul | 1.24E+12 | 2.21E+11 | 2.21E+10 | 1.99E+11 | 82% |
| Aug | 1.97E+12 | 2.65E+11 | 2.65E+10 | 2.39E+11 | 87% |
| Sep | 2.05E+12 | 2.68E+11 | 2.68E+10 | 2.41E+11 | 87% |
| Oct | 1.14E+12 | 2.32E+11 | 2.32E+10 | 2.09E+11 | 80% |
| Nov | 5.60E+11 | 1.53E+11 | 1.53E+10 | 1.38E+11 | 73% |
| Dec | 2.06E+11 | 9.00E+10 | 9.00E+09 | 8.10E+10 | 56% |
| Annual | 1.60E+13 | 2.21E+12 | 2.21E+11 | 1.99E+12 | 86% |

Annual loads are given in FC/year.

**Table ES-8. Summary of the Westchester Lagoon TMDL, Analysis Point CH2.**

| Month | Existing (FC/month) | Loading Capacity (FC/month) | Margin of Safety (FC/month) | Waste Load Allocation (FC/month) | Required Reduction |
|---|---|---|---|---|---|
| Jan | 1.21E+12 | 1.80E+11 | 1.80E+10 | 1.62E+11 | 85% |
| Feb | 1.23E+12 | 1.85E+11 | 1.85E+10 | 1.66E+11 | 85% |
| Mar | 1.98E+12 | 2.75E+11 | 2.75E+10 | 2.48E+11 | 86% |
| Apr | 3.40E+12 | 5.03E+11 | 5.03E+10 | 4.53E+11 | 85% |
| May | 2.84E+12 | 4.39E+11 | 4.39E+10 | 3.95E+11 | 85% |
| Jun | 3.14E+12 | 3.73E+11 | 3.73E+10 | 3.35E+11 | 88% |
| Jul | 3.45E+12 | 3.87E+11 | 3.87E+10 | 3.49E+11 | 89% |
| Aug | 3.28E+12 | 4.58E+11 | 4.58E+10 | 4.12E+11 | 86% |
| Sep | 2.69E+12 | 4.55E+11 | 4.55E+10 | 4.09E+11 | 83% |
| Oct | 2.80E+12 | 3.91E+11 | 3.91E+10 | 3.52E+11 | 86% |
| Nov | 2.91E+12 | 2.91E+11 | 2.91E+10 | 2.62E+11 | 90% |
| Dec | 1.74E+12 | 2.13E+11 | 2.13E+10 | 1.92E+11 | 88% |
| Annual | 3.07E+13 | 4.15E+12 | 4.15E+11 | 3.73E+12 | 86% |

Annual loads are given in FC/year.

**Table ES-9. Summary of the Westchester Lagoon TMDL, Analysis Point CL2.**

| Month | Existing (FC/month) | Loading Capacity (FC/month) | Margin of Safety (FC/month) | Waste Load Allocation (FC/month) | Required Reduction |
|---|---|---|---|---|---|
| **Jan** | **1.48E+11** | **1.34E+11** | **1.34E+10** | **1.21E+11** | **9%** |
| Feb | 2.14E+11 | 2.14E+11 | 2.14E+10 | 1.93E+11 | 0% |
| **Mar** | **5.41E+11** | **3.34E+11** | **3.34E+10** | **3.01E+11** | **38%** |
| Apr | 1.13E+12 | 2.80E+11 | 2.80E+10 | 2.52E+11 | 75% |
| May | 6.53E+11 | 2.58E+11 | 2.58E+10 | 2.33E+11 | 60% |
| Jun | 6.00E+11 | 2.49E+11 | 2.49E+10 | 2.24E+11 | 59% |
| Jul | 6.64E+11 | 2.59E+11 | 2.59E+10 | 2.33E+11 | 61% |
| Aug | 8.94E+11 | 2.71E+11 | 2.71E+10 | 2.44E+11 | 70% |
| Sep | 8.25E+11 | 2.62E+11 | 2.62E+10 | 2.36E+11 | 68% |
| Oct | 6.14E+11 | 2.58E+11 | 2.58E+10 | 2.32E+11 | 58% |
| Nov | 3.79E+11 | 2.33E+11 | 2.33E+10 | 2.10E+11 | 39% |
| Dec | 2.24E+11 | 2.08E+11 | 2.08E+10 | 1.87E+11 | 7% |
| Annual | 6.63E+12 | 2.92E+12 | 2.92E+11 | 2.63E+12 | 56% |

Bold denotes monthly values assessed for not-to-exceed standard.
Annual loads are given in FC/year.

# 1.0 DESCRIPTION OF THE WATERSHED AND WATERBODIES

Section 303(d)(1)(C) of the Clean Water Act and the U.S. Environmental Protection Agency's (EPA) implementing regulations (40 CFR Part 130) require the establishment of a Total Maximum Daily Load (TMDL) for the achievement of state water quality standards when a waterbody is water quality-limited. A TMDL identifies the amount of pollution control needed to maintain compliance with standards and includes an appropriate margin of safety. The focus of the TMDL is reduction of pollutant inputs to a level (or "load") that fully supports the designated uses of a given waterbody. The mechanisms used to address water quality problems after the TMDL is developed can include a combination of best management practices and/or effluent limits required through National Pollutant Discharge Elimination System (NPDES) permits.

The state of Alaska first included Chester Creek, University Lake and Westchester Lagoon on its 1990 303(d) list as water quality-limited due to fecal coliform and identified urban runoff as the expected pollutant source. These waters have been included on all subsequent 303(d) lists. This document establishes a TMDL to address the fecal coliform impairment throughout the Chester Creek watershed, including University Lake and Westchester Lagoon.

## 1.1 Location

The Chester Creek watershed is located in south-central Alaska, and is bounded on the east by the Chugach Mountains, on the north by the Ship Creek watershed, and on the south by the Campbell Creek watershed (see Figure 1-1). The basin lies entirely within Anchorage Borough and drains an area of approximately 30.2 square miles. Additionally, the Chester Creek watershed lies within the approximate 1,000 square mile, 8-digit U.S. Geological Survey hydrologic unit code (HUC) 19020401. University Lake and Westchester Lagoon are located within the Chester Creek watershed and are hydrologically connected to Chester Creek as shown in Figure 1-1.

The headwaters of Chester Creek are in the Chugach Mountains that form the eastern boundary of the Municipality of Anchorage (MOA). From the headwater region, the main stream flows toward the northwest and upon reaching the municipality flows to the west, through University Lake and Westchester Lagoons, and ultimately discharges into Cook Inlet.

For the purposes of storm water and drainage management, the MOA has identified three major subwatersheds within the Chester Creek watershed: the Lower Chester Creek subwatershed, the Upper Chester Creek subwatershed, and the Headwaters subwatershed (Figure 1-2; MOA, 2002). The Lower Chester Creek subwatershed is further subdivided into the Westchester drainage and the North Fork of Chester Creek drainage. Likewise, the Upper Chester subwatershed is comprised of the Middle Fork of Chester Creek drainage, the South Fork of Chester Creek drainage, and the Reflection Lake drainage. The Headwaters subwatershed is defined by the drainage divide of the Chugach Mountains, which forms the eastern-most boundary of the entire Chester Creek watershed, and the eastern boundary of the Municipality of Anchorage. Table 1-1 summarizes the major subwatersheds and drainages within the Chester Creek watershed.

**Table 1-1. Major Subwatersheds and Drainages within the Chester Creek Watershed.**

| Subwatershed Name | Area Acres | Area Square Miles |
|---|---|---|
| Lower Chester Creek | **3,838.6** | **6.0** |
| • Westchester drainage | 2,703.9 | 4.2 |
| • North Fork of Chester Creek drainage | 1,134.7 | 1.8 |
| Upper Chester Creek | **9,297.0** | **14.5** |
| • Middle Fork of Chester Creek drainage | 2,354.3 | 3.6 |
| • South Fork of Chester Creek drainage | 6,563.2 | 10.3 |
| • Reflection Lake drainage | 379.5 | 0.6 |
| Headwaters | **6,226.2** | **9.7** |
| **Total Watershed Area** | **19,361.8** | **30.2** |

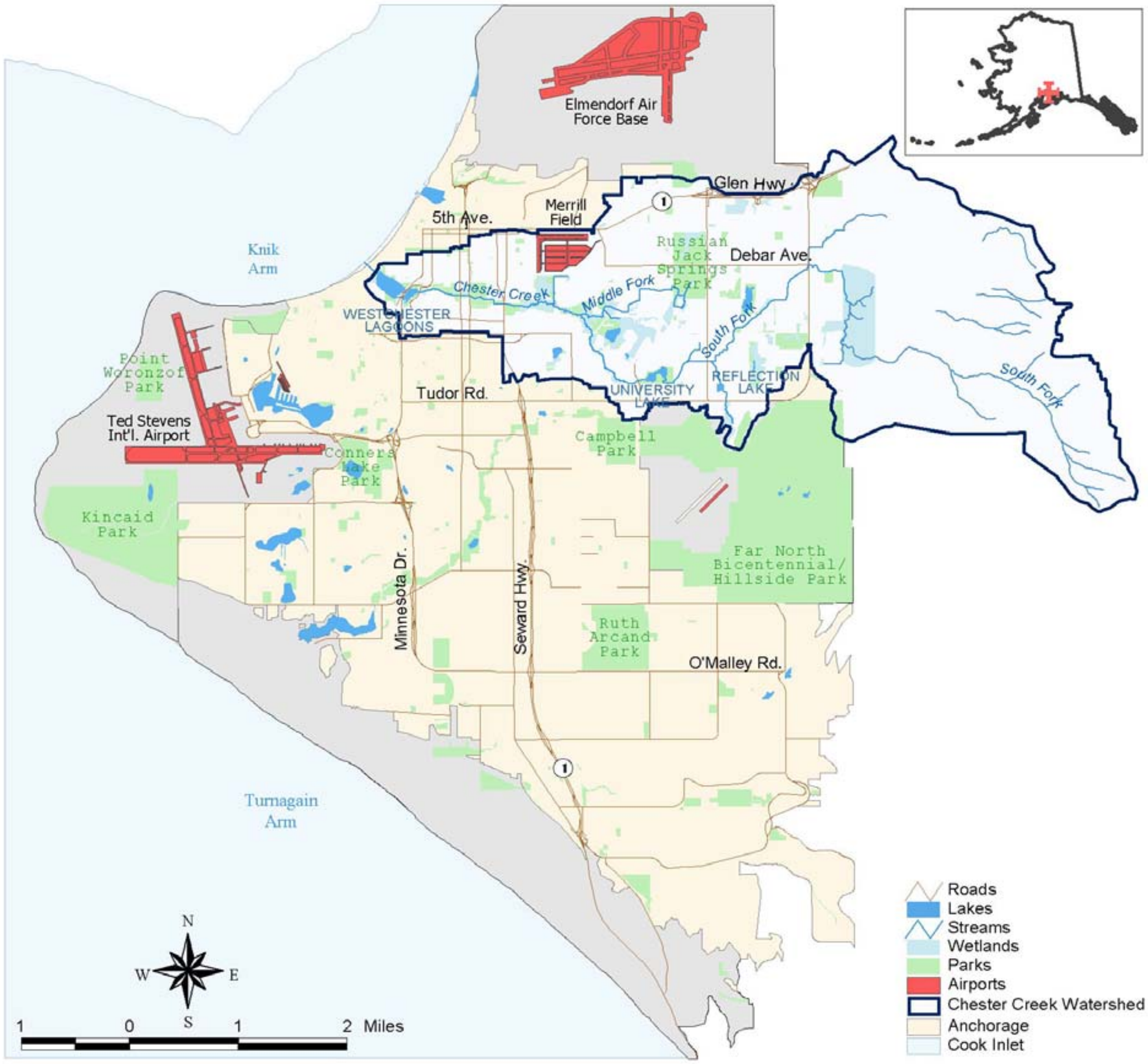



**Figure 1-1. Location of the Chester Creek watershed.**

## 1.2 Population

Population within the Chester Creek watershed was estimated using geographic information systems (GIS) analysis that incorporated 2000 census block data for the basin. Block level spatial and census data for the Municipality of Anchorage were downloaded from the online Geography Network (2002) and clipped to the watershed boundary. Population was then summed for each block within the watershed. The analysis resulted in an estimated population of 78,262 persons and a total of 30,319 households within the basin.

## 1.3 Topography

Elevations in the Chester Creek watershed range from 1,357 feet above sea level along the drainage divide in the Chugach Mountains to zero feet above sea level at the outlet into Cook Inlet. The rate of fall varies from an average of 931 feet per mile in the eastern mountainous region of the basin to an average of 73 feet per mile in the western portion of the basin. Slope gradients in the extreme western portion of the watershed are very low.

## 1.4 Land Cover

Information on land use and land cover is important because they significantly affect a stream's hydrology and water quality. MOA offers the best available land cover data for the Chester Creek watershed (MOA, 2002). The land cover data were derived from satellite imagery in the summer of 2000 and classified to provide information best suited for storm water management applications.

The land cover data include five major classes: Impervious, Barren Pervious, Vegetated Pervious, Snow and Ice, and Water. These land cover classes were further subdivided to reflect changes in perviousness due to different land development applications. For example, impervious surfaces are classified as either street surface, directly connected impervious, or indirectly connected impervious. Values for hydraulic connectedness (direct or indirect connection) are attributed to each mapped land parcel independently of the degree of surrounding pervious land cover. Vegetation classes were reclassified as either landscaped or forested. Wetlands were derived from features mapped by the MOA and superimposed on the land cover data. The MOA land cover classification scheme is given in Table 1-2.

Land cover in the Chester Creek watershed is shown in Figure 1-2 and summarized in Table 1-3. Figure 1-2 shows that at the higher elevations in the upper portion of the Chester Creek watershed, land cover is primarily forest with tenure by the federal government (military lands) and state parklands (Brabets et al., 1999). The lower portion of the watershed is dominated by urban residential and commercial land uses. Forest cover accounts for 51.3 percent of the total land cover in the basin (Table 1-3), while urban land covers (landscape, impervious surfaces, and streets) account for 42 percent of the total land cover in the basin.

**Table 1-2. The Municipality of Anchorage land cover classification system**

| Land Cover | Land Cover Description |
|---|---|
| Impervious | Large paved areas, parking lots, and rooftops. |
| Directly Connected Impervious | Impervious features (not including roads) that are immediately adjacent to paved roads and spatially intersect a 60-foot buffer from the edge of pavement. For example, a large parking lot that extends beyond 60 feet from the edge of a paved road will be categorized as directly connected impervious as long as a portion of that feature enters a 60-foot buffer from an adjacent roadway. |
| Indirectly Connected Impervious | Areas that do not intersect the 60-foot buffer from the edge of pavement are classified as Indirectly Connected Impervious (ICI). These include impervious areas that are adjacent and/or within the vicinity of dirt or unpaved roads. |
| Streets | Paved roadways. |
| Landscaped | Parks, open fields, residential yards, large areas of non-forested and non-wetland vegetation. |
| Forested | Areas of tree canopy—natural forest. |
| Barren | Includes areas of zero or little vegetation, exposed soil, non-active land-cover. |
| Wetland | Moist areas containing vegetation, marshes, bogs. |
| Lakes/Water | Areas of exposed water bodies, reservoirs. |

**Table 1-3. Land cover within the Chester Creek watershed.**

| Land Cover/Land Use | Area | | Percent of Watershed Area |
|---|---|---|---|
| | Acres | Square Miles | |
| Forested | 10,015.6 | 15.5 | 51.3 |
| Landscaped | 3,233.3 | 5.1 | 16.9 |
| Directly Connected Impervious | 2,746.9 | 4.3 | 14.2 |
| Street | 1,381.2 | 2.2 | 7.3 |
| Wetland | 1,124.4 | 1.8 | 6.0 |
| Indirectly Connected Impervious | 692.3 | 1.1 | 3.6 |
| Lakes | 156.7 | 0.2 | 0.7 |
| Barren | 11.5 | < 0.1 | < 0.1 |
| Total | **19,361.9** | **30.2** | **100.0** |

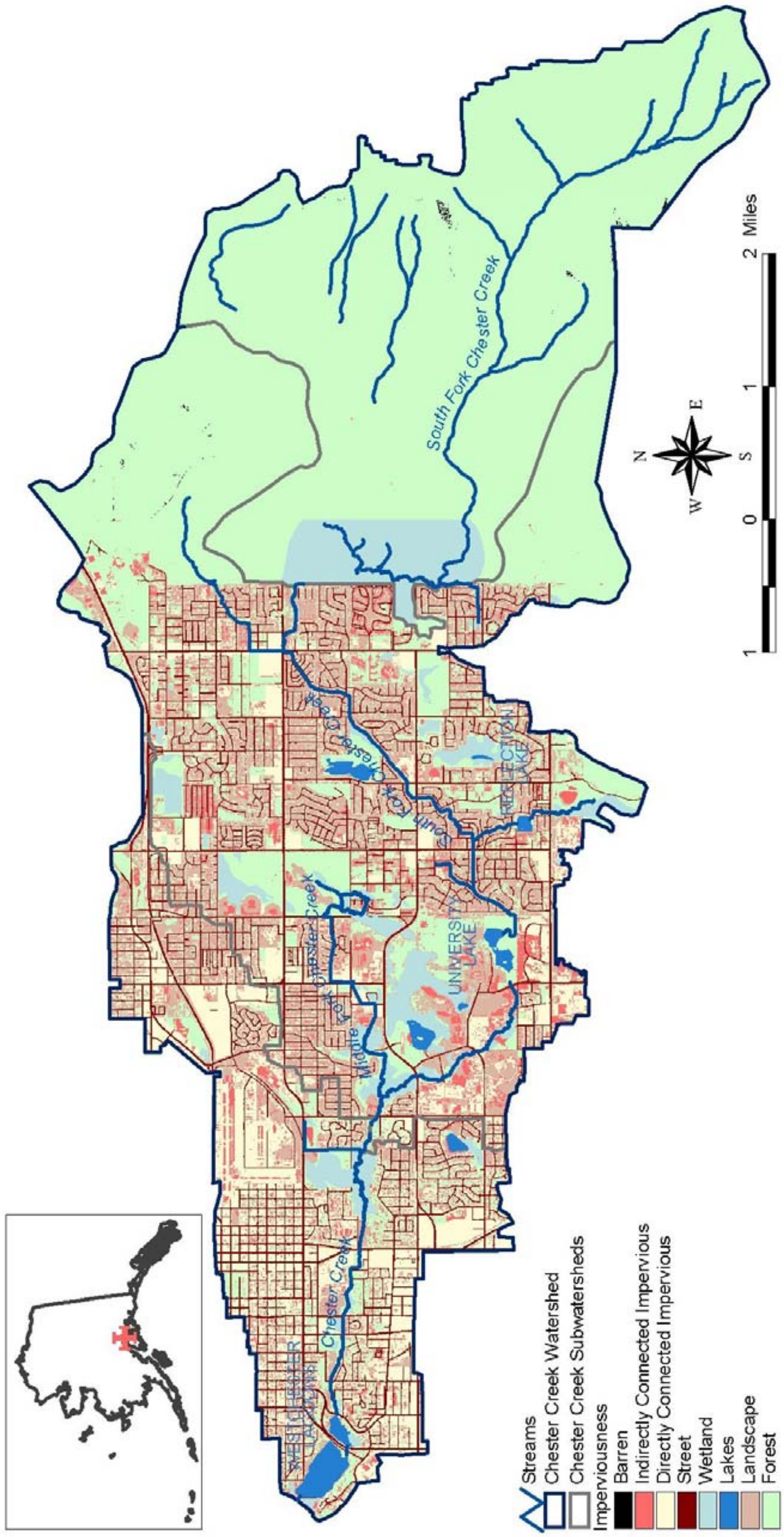



**Figure 1-2. Chester Creek watershed MOA land cover classification.**

Land cover may also be examined within major subwatershed divisions. Table 1-4 presents land cover within each of the three major subwatersheds in the Chester Creek basin. As seen in the table, the Lower Chester Creek subwatershed is the most urbanized subwatershed, with landscape, impervious surfaces, and streets accounting for 80.8 percent of the subwatershed area. Significant urbanization also occurs in the Upper Chester Creek subwatershed where landscape, impervious surfaces, and streets account for 53 percent of the total subwatershed area. A large portion of the Upper Chester Creek subwatershed, approximately 40 percent of the total subbasin area, is comprised of forest cover. In contrast to the lower portions of the Chester Creek watershed, the Headwaters subwatershed is comprised primarily of forested lands and wetlands, which together represent 99.8 percent of the total subwatershed area.

**Table 1-4. Land cover within the major subwatersheds of the Chester Creek watershed.**

| Subwatershed Name | Area | | Percent of Watershed Area |
|---|---|---|---|
| | Acres | Square Miles | |
| **Lower Chester Creek** | | | |
| Directly Connected Impervious | 1,515.7 | 2.4 | 39.4 |
| Landscaped | 763.1 | 1.2 | 19.9 |
| Street | 581.8 | 0.9 | 15.2 |
| Forested | 525.0 | 0.8 | 13.7 |
| Indirectly Connected Impervious | 241.5 | 0.4 | 6.3 |
| Wetland | 129.7 | 0.2 | 3.4 |
| Lakes | 81.8 | 0.1 | 2.1 |
| **Subwatershed Total** | **3,838.6** | **6.0** | **100.0** |
| **Upper Chester Creek** | | | |
| Forested | 3,753.3 | 5.9 | 40.4 |
| Landscaped | 2,469.5 | 3.9 | 26.7 |
| Directly Connected Impervious | 1,231.1 | 1.9 | 13.2 |
| Street | 799.3 | 1.2 | 8.6 |
| Wetland | 515.5 | 0.8 | 5.5 |
| Indirectly Connected Impervious | 450.2 | 0.7 | 4.8 |
| Lakes | 74.9 | 0.1 | 0.8 |
| Barren | 3.2 | < 0.1 | < 0.1 |
| **Subwatershed Total** | **9,297.0** | **14.5** | **100.0** |
| **Headwaters** | | | |
| Forested | 5737.3 | 9.0 | 92.1 |
| Wetland | 479.2 | 0.7 | 7.7 |
| Landscaped | 0.8 | < 0.1 | < 0.1 |
| Barren | 8.2 | < 0.1 | 0.1 |
| Directly Connected Impervious | 0.0 | < 0.1 | < 0.1 |
| Indirectly Connected Impervious | 0.6 | < 0.1 | < 0.1 |
| Street | 0.1 | < 0.1 | < 0.1 |
| **Subwatershed Total** | **6,226.2** | **9.7** | **100.0** |

## 1.5 Climate

Searby (1968) identified three distinct climate zones in the Cook Inlet region: continental, transition, and maritime. These climate zones are broadly defined by variations in precipitation and temperature. Chester Creek lies within the transition climate zone, where average annual precipitation is roughly 16 inches and annual average temperature is around 27 °F.

Figure 1-3 presents monthly average precipitation, snowfall, and temperature for Anchorage Ted Stevens International Airport (cooperative station number 500280) located at an elevation of 131.9 feet above sea level (WRCC, 2002). Figure 1-3 shows that the data for Anchorage fits within the transition climate zone discussed above, although average annual precipitation for the station is 15.7 inches, a bit lower than the zonal average. However, elevations in the eastern portion of the basin exceed 1,000 feet and precipitation is expected to increase accordingly. An average minimum monthly temperature of 15.8 °F occurs in January and an average maximum monthly temperature of 58.4 °F occurs in July. Most of the precipitation occurs from June through December, peaking in late summer during August and September with monthly mean precipitation of 2.7 inches and 2.6 inches, respectively. Snowfall occurs from September through May, with the greatest snowfall occurring during the months of December, February, and November.

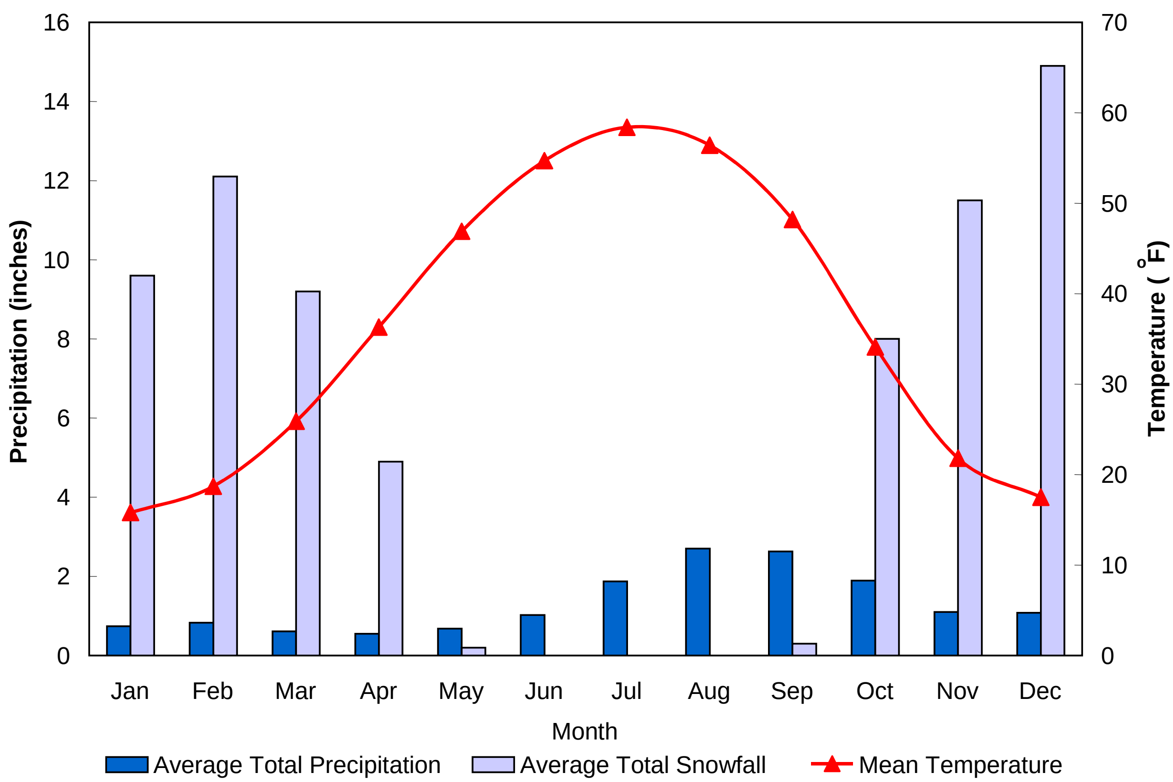



**Figure 1-3. Climate summary for Anchorage Ted Stevens International Airport. Data cover the period April 1, 1952 to March 31, 2003.**

### 1.6 Hydrology

Chester Creek originates from the combined flow of smaller tributary streams located in the Chugach Mountains. The creek flows through Anchorage on the way to its mouth along the Cook Inlet. Ice cover affects streams for a significant part of the year. Ice typically forms over the streams in late November to early December and open water reappears around the beginning of April (Ourso, 2001). The time of ice cover varies according to the elevation of a particular segment of the stream.

As shown in Figure 1-2, MOA has identified three major subwatersheds in the Chester Creek basin: the lower Chester Creek subwatershed, the upper Chester Creek subwatershed, and the headwaters of the Chester Creek watershed. The lower Chester Creek subwatershed is defined at its upper-most reach by a point just downstream of the confluence of the South Fork and Middle Fork of Chester Creek, and at its lower-most reach by the outlet of Westchester Lagoon to Cook Inlet. The upper Chester Creek subwatershed unit is bounded by the limits of the municipality at it upper-most reach, and the confluence of the South Fork and Middle Fork of Chester Creek at its lower-most reach. The headwaters subwatershed is defined by the drainage divide at the upper-most reach and the limits of the municipality at its lower-most reach.

Much of Chester Creek has been modified through wetland drainage for development and Westchester Lagoon and University Lake are two man-made waterbodies directly connected to Chester Creek. Westchester Lagoon is located in the lowermost portion of the watershed. A dam with a concrete weir was constructed across the Chester Creek estuary in 1971 forming the Westchester Lagoon (Davis and Muhlberg, 2001). Minnesota Drive and Spenard Road divide the lagoon into three sections. The upper lagoon basin is located from the mouth of Chester Creek to Spenard Road and covers approximately two acres. The upper basin is a major site for sediment deposition within the Chester Creek system. The middle basin lies between Spenard Road and Minnesota Road and cover 17 acres. The middle basin provides most of the waterfowl nesting and rearing area in the lagoon. The lower basin extends from Minnesota Road to the concrete weir, and covers approximately 65 acres. The lower basin provides recreational opportunities for canoeists and kayakers, and habitat for waterfowl. Overall the lagoon basin system is very shallow with maximum depths of 1.5 feet in the upper, most eastern basin, 5-feet in the middle basin, and 22 feet near the weir in the old stream channel in the lower, larger basin.

University Lake is located on the South Fork of Chester Creek and has a surface area of approximately 35 acres. The lake was originally a gravel pit subject to groundwater intrusion. Chester Creek was channeled through the gravel pit in 1983 forming University Lake. The lake does not have any control structures and is typically regarded as a wide stream reach in the South Fork of Chester Creek. The lake is used for recreational purposes, such as boating and fishing, and provides a nesting and rearing area for waterfowl.

The United States Geological Survey (USGS) has measured continuous streamflow in Chester Creek at two stations (15275000 and 15275100) over the past 34 years. Only one of these stations (USGS stream gage 15275100) is in operation today and is located on Arctic Boulevard, near the stream outlet into Westchester Lagoons. This gage site has a long-term mean annual flow of 21 cubic feet per second (cfs). Long-term daily average flow for the site is presented in Figure 1-4. The figure shows that daily mean flows peak in late April due primarily to snowmelt and again in early fall, primarily in response to precipitation. The amount of water available in Chester Creek at any given time and location is impacted by a variety of consumptive uses and by the influence of shallow and deep-water aquifers (groundwater systems) through natural processes and disturbances within the streambed. In turn, some water is gained from returns by non-consumptive users and from springs from groundwater systems. In addition, seasonal flow fluctuations make available stream flow highly variable, while most consumptive user demand tends to be more constant. The exceptions are seasonal uses such as golf course irrigation, watering of lawns and trees, etc.

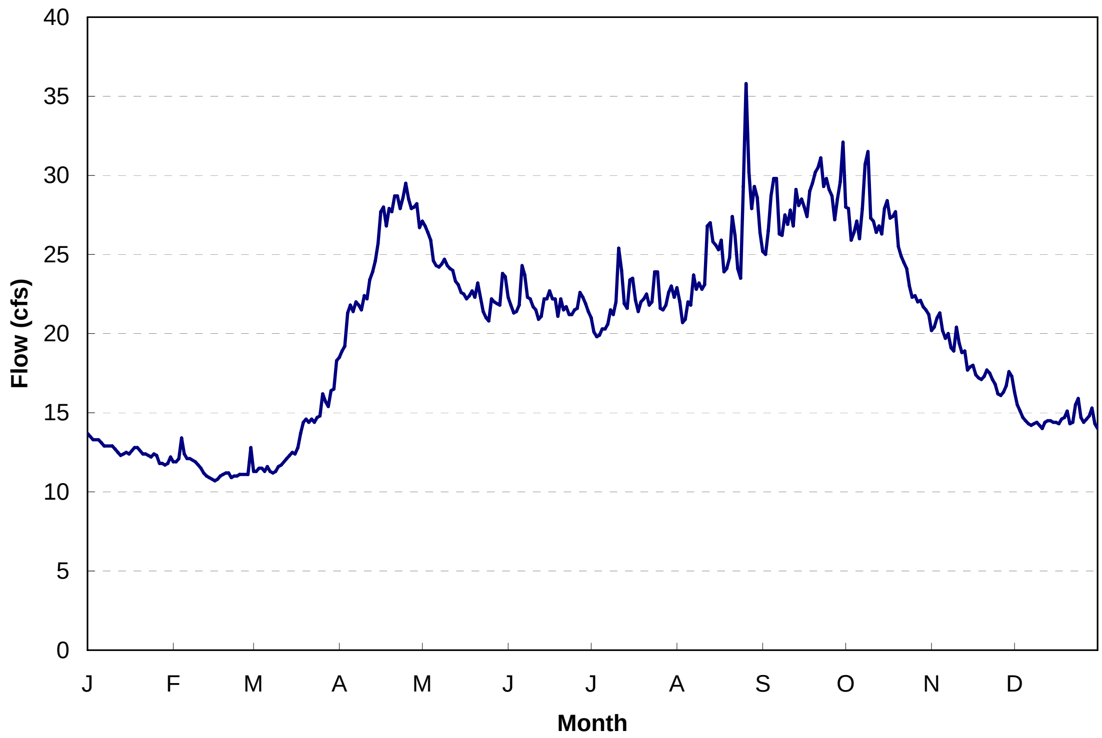



**Figure 1-4. Average daily streamflow in Chester Creek at USGS stream Gage # 15275100. Data cover the period June 17, 1966 to September 30, 2001.**

## 2.0 WATER QUALITY STANDARDS, TMDL TARGET AND AREA OF COVERAGE

The purpose of developing a TMDL is to identify the allowable loads of a pollutant such that water quality standards will be met. This section of the report presents the water quality standards for fecal coliform that apply to Chester Creek, University Lake, and Westchester Lagoon.

### 2.1 Applicable Water Quality Standards

Within the State of Alaska, water quality standards are published pursuant to Title 46 of the Alaska Statutes (AS). Regulations dealing with water quality (46.03.02 & 46.03.080) are found in Title 18, Chapter 70 of the Alaska Administrative Code (AAC). Through the adoption of water quality standards, Alaska has defined the beneficial uses to be protected in each of its drainage basins and the criteria necessary to protect these uses (see Table 2-1).

Water quality criteria are developed for each designated use and give guidance on how much pollution a waterbody can accommodate while still supporting the designated uses. The most stringent of Alaska's water quality standards with respect to fecal coliform bacteria (FC) is for drinking, culinary, and food processing water supply. The applicable standard states that

> *In a 30-day period, the geometric mean may not exceed 20 FC/100 mL, and not more than 10% of the samples may exceed 40 FC/100 mL. (*18 AAC 70.020(2)(b)(2)(A)(i)*)*

The TMDL must therefore identify the allowable load (or loading capacity) such that both the 30-day geometric mean and the not-to-exceed portions of the standards will be met.

**Table 2-1. Alaska water quality standards for fecal coliform.**

| Water Use | Description of Standard |
|---|---|
| (A) Water Supply<br>(i) drinking, culinary and food processing | In a 30-day period, the geometric mean may not exceed 20/FC/100 ml, and not more than 10% of the samples may exceed 40 FC/100 ml. For groundwater, the FC concentration must be less than 1 FC/100 ml, using the fecal coliform Membrane Filter Technique, or less than 3 FC/100 ml, using the fecal coliform most probable number (MPN) technique. |
| (A) Water Supply<br>(ii) agriculture, including irrigation and stock watering | The geometric mean of samples taken in a 30-day period may not exceed 200 FC/100 ml, and not more than 10% of the samples may exceed 400 FC/100 ml. For products not normally cooked and for dairy sanitation of unpasteurized products, the criteria for dinking water supply, (1)(A)(i), apply. |
| (A) Water Supply<br>(iii) aquaculture | For products normally cooked, the geometric mean of samples taken in a 30-day period may not exceed 200 FC/100 ml, and not more than 10% of the samples may exceed 400 FC/100 ml. For products not normally cooked, the criteria for drinking water supply, (1)(A)(i), apply. |
| (A) Water Supply<br>(iii) Industrial | Where worker contact is present, the geometric mean of samples taken in a 30-day period may not exceed 200 FC/100 ml, and not more than 10% of the samples may exceed 400 FC/100 ml. |
| (B) Water Recreation<br>(i) contact recreation | In a 30-day period, the geometric mean of samples may not exceed 100 FC/100 ml, and not more than one sample or more than 10% of the samples if there are more than 10 samples, may exceed 200 FC/100 ml. |
| (B) Water Recreation<br>(ii) secondary contact | In a 30-day period, the geometric mean of samples may not exceed 200 FC/100 ml, and not more than 10% of the total samples may exceed 400 FC/100 ml. |
| (C) Growth and Propagation of Fish, Shellfish, other Aquatic Life and Wildlife | Not applicable. |

## 2.2 Designated Use Impacts

Designated uses for Alaska's waters are established by regulation and are specified in the State of Alaska Water Quality Standards (18 AAC 70). For fresh waters of the state, designated uses include (1) water supply, (2) water recreation, and (3) growth and propagation of fish, shellfish, other aquatic life, and wildlife. Chester Creek does not support its designated uses of water supply and water recreation due to elevated fecal coliform levels. The presence of fecal coliform indicates an increased risk of pathogen contamination. Consumption of or contact with pathogen-contaminated water can result in a variety of gastrointestinal, respiratory, eye, ear, nose, throat, and skin diseases.

## 2.3 Area of Coverage

Because of the lack of delineating information at the time of listing, all of Chester Creek was listed as impaired. However, monitoring data included in the studies listed in Section 3.1 below show the portion of Chester Creek above the Municipality of Anchorage/ Fort Richardson property line is not water-quality limited by bacteria impairment. Based on the evaluation of this data, this document proposes a new boundary for the 303(d)-listed stretch. The TMDL concludes that the actual water-quality limited areas are the upper and lower subwatershed areas from the Municipal/Fort Richardson property line to the Cook Inlet. The section of stream is best depicted in Figure 3-1.

## 3.0 DATA ANALYSIS

Several important previous water quality studies have been performed for the Chester Creek watershed. These earlier studies provide some insight to the fecal coliform loadings in the Chester Creek watershed and were consulted during the development of the TMDL. This section of the report summarizes these previous studies and also presents the available fecal coliform sampling data.

### 3.1 Previous Studies

Brabets (1986) performed a water quantity and quality study of the Chester Creek watershed and found that water quality in the watershed varies according to season and flow conditions. The study found that average fecal coliform counts in Chester Creek ranged from 211 to 4,000 FC/ 100 mL, and that fecal coliform counts near the mouth of Chester Creek exceeded water quality standards during all flow ranges. The study also concluded that the primary source of fecal coliform bacteria originated from residential areas.

MOA conducted a water quality monitoring program, of which fecal coliform was one of the observed parameters, that included nine stations in the Chester Creek watershed during the period 1986 to 1994. The data observed during the monitoring period suggest that fecal coliform counts were lowest in the winter months and increased in the spring during snowmelt. MOA concluded that the primary source of fecal coliform bacteria was storm drain runoff from urban areas (MOA, 1990).

A draft water quality assessment for Chester Creek was completed in April 1993 (ADEC, 1993). The assessment concluded that the Chester Creek drainage was water-quality limited due to violations of the fecal coliform standard. Potential point sources identified included Merrill Field Landfill and public sanitary sewers upstream of University Lake. To alleviate the impact of the landfill, the report recommended that North Fork of Chester Creek be rerouted around the landfill facility. This project was begun in 1993 and is now completed. Potential nonpoint sources identified by the report include urban runoff, waterfowl, and domestic animals.

The USGS collected fecal coliform in five creeks characterized as “undeveloped”, “semi-developed”, and “developed areas” in Anchorage from August 19 to September 4, 1998 (USGS, 1999). Included in this study were three samples collected from an undeveloped site on upper Chester Creek, located on Fort Richardson approximately three miles upstream from Muldoon Road. Additionally, one sample was collected on a developed site in the lower reach of Chester Creek, near Arctic Boulevard. The data collected at the undeveloped site in upper Chester Creek ranged from 2 FC/100 ml to 10 FC/100 ml, while the single sample collected in the developed portion of lower Chester Creek yielded 80 FC/100 ml.

Frenzel and Couvillion (2002) evaluated fourteen sites in Anchorage to determine the effects of urbanization on water quality. Three of the sites were on Chester Creek and a total of sixteen samples were collected from these three stations during the period March 2000 to November 2000. As part of the overall study the authors concluded that higher counts of fecal coliform, *Escherichia coli*, and enterococci were measured at the most urbanized sites. They also found that fecal indicator bacteria counts were higher in the summer than in the winter, but that seasonal differences were not significant.

MOA released a report in 2003 discussing fecal coliform sources and transport processes in Anchorage streams (MOA, 2003). This report indicated that the least likely sources of fecal coliform included municipal community piped sanitary sewer systems, on-site wastewater disposal systems, and street surfaces. MOA investigators attributed the primary source of fecal coliform concentrations to animal (non-human) origin. Warm-blooded animal sources include domestic pets (particularly cats and dogs) and wild animals (particularly terrestrial and aquatic birds, shrews, rabbits, rodents, foxes, coyotes, wolves, bears, and moose). MOA also suggests that elevated fecal coliform concentrations result from a complex relationship between sources and transport processes within local storm drainage systems and the streams themselves.

### 3.2 Data Inventory

The fecal coliform data collected by MOA during the period 1986 to 1994 are the data used in this study because they are the most recent data set with both good spatial and temporal coverage and have corresponding USGS flow data [1]. The data are available at eleven different stations within the Chester Creek watershed. The locations of these stations are shown in Figure 3-1 relative to the major subwatersheds comprising the Chester Creek drainage. Most data are from the period 1988 to 1994, although some older and a few more recent data are also available.

### 3.3 Data Analysis

The available fecal coliform data in Chester Creek were compared to the geometric mean and not-to-exceed standards to evaluate impairment and water quality standards violations. Table 3-1 presents the results of the not-to-exceed comparison for each standard. All stations exceeded the standard more than 10 percent of the time.

**Table 3-1. Summary of available fecal coliform data for Chester Creek.**

| Station | No. of Samples | Start Date | End Date | Min | Average | Max | Over 40 FC/100 mL | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | No. | Percentage |
| CH11 | 62 | 3/16/1993 | 12/20/1994 | 0 | 442 | 7,000 | 53 | 85% |
| CH10 | 58 | 3/16/1993 | 9/30/1994 | 0 | 147 | 2,500 | 18 | 31% |
| CH9 | 431 | 4/15/1986 | 9/30/1994 | 0 | 564 | 28,000 | 365 | 85% |
| CH7A | 375 | 12/16/1987 | 9/30/1994 | 0 | 133 | 3,940 | 159 | 42% |
| CH7 | 409 | 4/15/1986 | 9/17/1992 | 0 | 555 | 27,600 | 167 | 41% |
| CH6 | 354 | 4/15/1988 | 9/30/1994 | 0 | 136 | 4,400 | 192 | 54% |
| ULI | 371 | 1/20/1988 | 9/30/1994 | 0 | 524 | 12,089 | 340 | 92% |
| ULO | 369 | 1/20/1988 | 9/30/1994 | 0 | 135 | 6,100 | 224 | 61% |
| CH2 | 94 | 4/15/1986 | 2/5/1988 | 8 | 417 | 2,800 | 88 | 94% |
| CL3 | 281 | 3/31/1988 | 9/30/1994 | 0 | 210 | 20,000 | 156 | 56% |
| CL2 | 341 | 3/31/1988 | 12/20/1994 | 0 | 371 | 24,000 | 217 | 64% |

For comparison to the geometric mean criterion, geometric means were calculated for every possible 30-day period included in the dataset, based on all individual observations within that 30-day period. The results are summarized Tables 3-2 to 3-10 and Figures 3-2 to 3-10. The tables include the monthly average, median, minimum, maximum, and 25$^{th}$ and 75$^{th}$ percentiles of all calculated geometric means. The tables also present a ratio and percentage of the number of 30-day geometric means included in each month that exceed the 20 FC/100 mL criterion (“Exceedances: Count” and “Percentage of Exceedances”). The highest levels of bacteria in Chester Creek generally occur during the summer months (July to September), possibly due to the increased rain events and resulting storm water runoff. Freezing

[1] The data used for this study are based on a report provided by ADEC to Tetra Tech during a site visit in 2000. The data were not available electronically and therefore had to be manually input to a database to allow for analysis and modeling. The data were evaluated for quality assurance purposes to screen for data entry errors but no other testament can be made as to the quality of the data.

temperatures during October and November decrease surface runoff, resulting in lower in-stream bacteria counts. Slight increases in bacteria during December and January are likely due to occasional periods of above-freezing temperatures and runoff-producing thaw. Runoff from the spring break-up and thaw result in increasing bacteria counts from March to April. A brief discussion of seasonal patterns at each site follows. The sites are discussed moving from upstream to downstream locations.

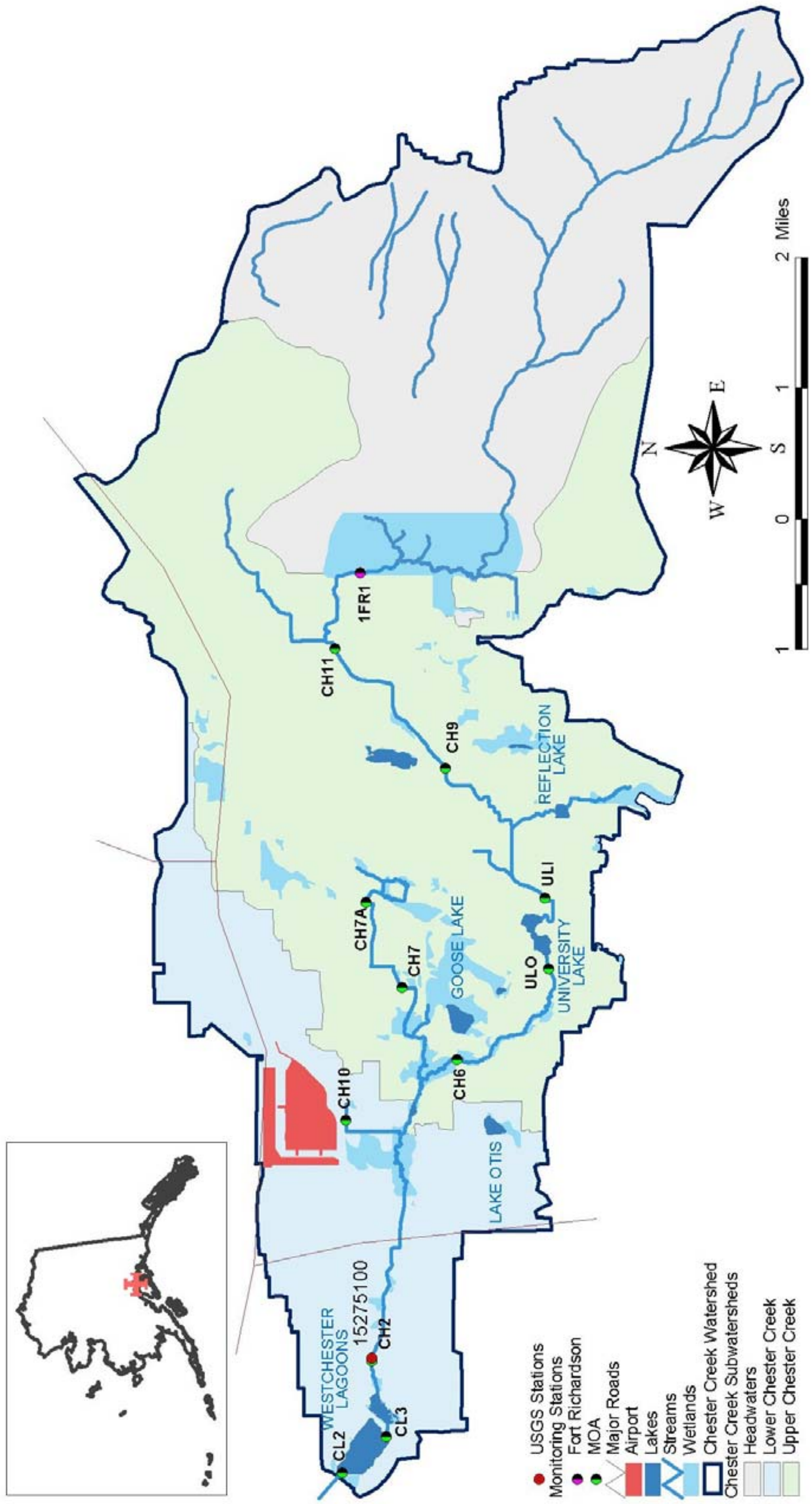



**Figure 3-1. Location of MOA monitoring stations and modeling units.**

### 3.3.1 Station CH11, South Fork Chester Creek, Upper Chester Creek Subwatershed

Station CH11 is located on the South Fork of the Chester Creek drainage and is the most upstream sampling station. Although it drains a predominantly forested watershed, the area immediately upstream includes land cover classified by MOA as mobile home parks and multi-family homes. There are also approximately 10 storm water outfalls upstream of the station. Sampling data are available for the period March 16, 1993 to December 20, 1994 and the results are summarized in Table 3-2 and Figure 3-2.

Counts of fecal coliform at station CH11 appear to have a bimodal distribution, with peaks during late winter and late summer. Counts increase steadily from May to September and then begin to decrease during the winter. Most calculated 30-day geometric means exceed the water quality standard.

**Table 3-2. Summary statistics of geometric means calculated using observed fecal coliform data at station CH11. Data cover the period March 16, 1993 to December 20, 1994.**

| Month | Average[1] | Median[1] | Min[1] | Max[1] | 25th[1] | 75th[1] | Exceedances: Count[2] | Percentage of Exceedances[3] |
|---|---|---|---|---|---|---|---|---|
| Jan | 27 | 28 | 15 | 35 | 23 | 35 | 4:5 | 80% |
| Feb | 217 | 217 | 87 | 347 | 152 | 282 | 2:2 | 100% |
| Mar | 144 | 97 | 34 | 300 | 66 | 199 | 3:3 | 100% |
| Apr | 115 | 122 | 92 | 131 | 107 | 127 | 3:3 | 100% |
| May | 59 | 51 | 43 | 98 | 45 | 63 | 6:6 | 100% |
| Jun | 149 | 133 | 79 | 247 | 93 | 201 | 8:8 | 100% |
| Jul | 470 | 153 | 101 | 1076 | 140 | 839 | 7:7 | 100% |
| Aug | 513 | 511 | 242 | 937 | 385 | 574 | 9:9 | 100% |
| Sep | 495 | 482 | 86 | 944 | 333 | 644 | 15:15 | 100% |
| Oct | 402 | 402 | 346 | 458 | 374 | 430 | 2:2 | 100% |
| Nov | 63 | 63 | 63 | 63 | 63 | 63 | 1:1 | 100% |
| Dec | 33 | 42 | 0 | 47 | 30 | 45 | 3:4 | 75% |

[1]Average, median, minimum, maximum and 25th and 75th percentile values of all 30-day geometric means calculated for the month (i.e., using samples within the month).
[2] Ratio of number of calculated 30-day geometric means that exceed the water quality criterion to the number of calculated 30-day geometric means in the month.
[3] Percentage of all calculated 30-day geometric means for the month that exceed the water quality criterion.

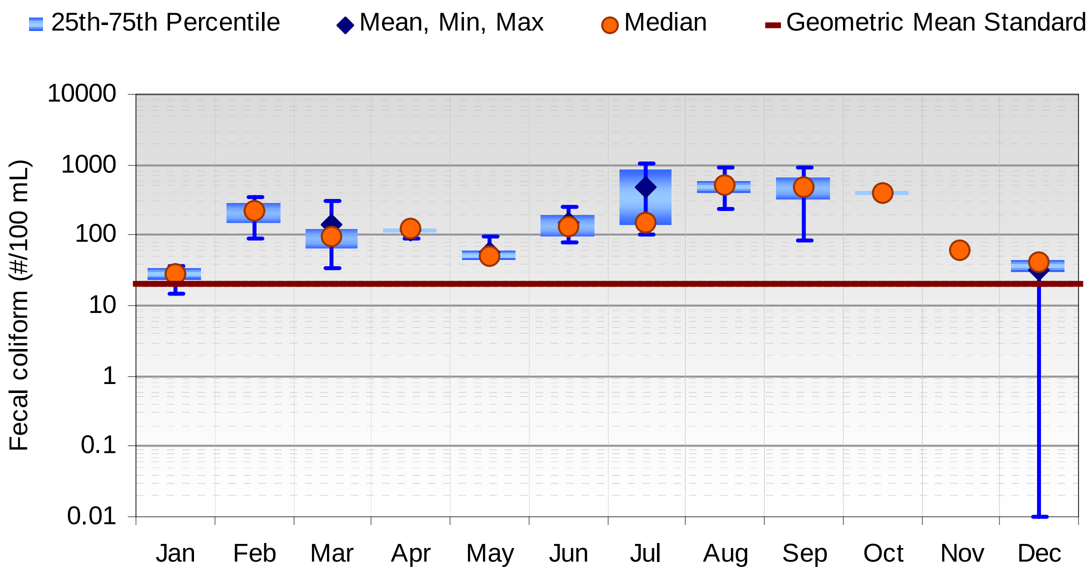



**Figure 3-2. Summary of calculated monthly geometric means of fecal coliform at station CH11.**

### 3.3.2 Station CH9, South Fork Chester Creek, Upper Chester Creek Subwatershed

Station CH9 is located downstream of station CH11 in the upper Chester Creek watershed and drains an area consisting primarily of single family homes. Data are available for the period April 15, 1986 to September 30, 1994 and the results are summarized in Table 3-3 and Figure 3-3.

Many fecal coliform data are available for station CH9 and almost all calculated 30-day geometric means are above the water quality standard. Counts rise during the spring and summer and then begin to decrease in September.

**Table 3-3. Summary statistics of geometric means calculated using observed fecal coliform data at station CH9. Data cover the period April 15, 1986 to September 30, 1994.**

| Month | Average[1] | Median[1] | Min[1] | Max[1] | 25th[1] | 75th[1] | Exceedances: Count[2] | Percentage of Exceedances[3] |
|---|---|---|---|---|---|---|---|---|
| Jan | 60 | 59 | 9 | 138 | 21 | 85 | 26:34 | 76% |
| Feb | 121 | 76 | 12 | 302 | 43 | 219 | 32:36 | 89% |
| Mar | 168 | 175 | 14 | 340 | 111 | 208 | 44:46 | 96% |
| Apr | 221 | 227 | 82 | 440 | 160 | 260 | 36:36 | 100% |
| May | 129 | 97 | 28 | 397 | 64 | 187 | 34:34 | 100% |
| Jun | 183 | 189 | 44 | 399 | 105 | 242 | 35:35 | 100% |
| Jul | 473 | 404 | 132 | 1222 | 267 | 664 | 40:40 | 100% |
| Aug | 851 | 680 | 238 | 2525 | 407 | 1155 | 40:40 | 100% |
| Sep | 789 | 314 | 24 | 4229 | 204 | 845 | 45:45 | 100% |
| Oct | 261 | 171 | 18 | 725 | 57 | 368 | 28:29 | 97% |
| Nov | 147 | 111 | 20 | 452 | 66 | 184 | 28:28 | 100% |
| Dec | 66 | 51 | 7 | 233 | 31 | 72 | 23:27 | 85% |

[1]Average, median, minimum, maximum and 25th and 75th percentile values of all 30-day geometric means calculated for the month (i.e., using samples within the month).
[2] Ratio of number of calculated 30-day geometric means that exceed the water quality criterion to the number of calculated 30-day geometric means in the month.
[3] Percentage of all calculated 30-day geometric means for the month that exceed the water quality criterion.

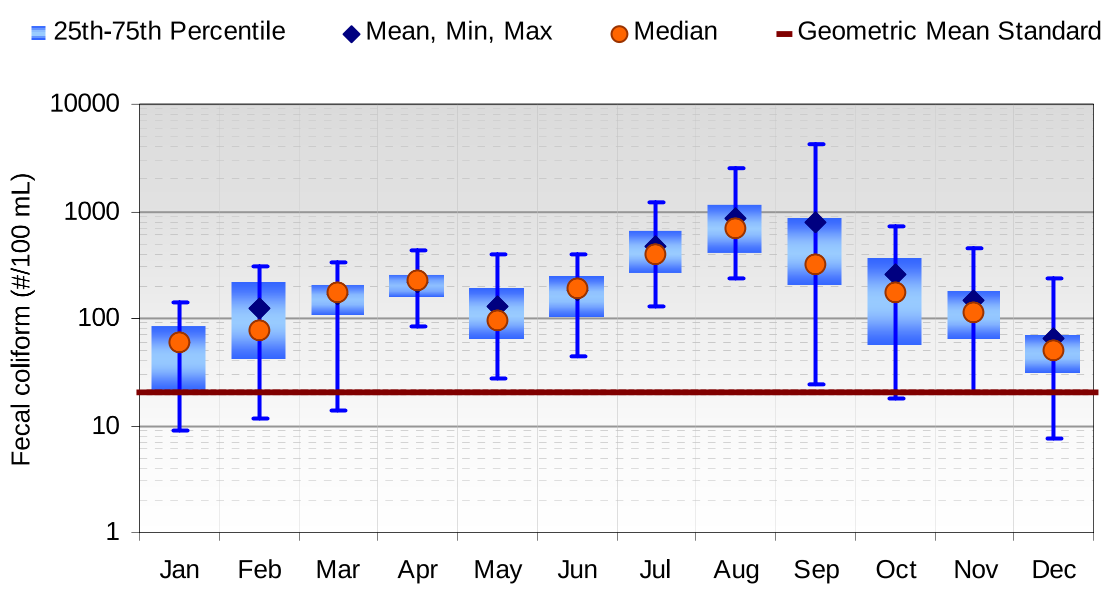



**Figure 3-3. Summary of calculated monthly geometric means of fecal coliform at station CH9.**

### 3.3.3 Station ULI (inlet to University Lake), South Fork Chester Creek, Upper Chester Creek Subwatershed

Station ULI is located at the inlet to University Lake and drains an area of multi-family homes, mobile home parks, and parks. Data are available for the period January 20, 1988 to September 30, 1994 and are summarized in Table 3-4 and Figure 3-4.

Fecal coliform counts at ULI appear to be bimodal. There is a distinct peak in the calculated 30-day geometric means in August at approximately 600 FC/ 100 mL and a slight peak in February at approximately 350 FC/ 100 mL. Counts are at their lowest point in May and increase steadily from May to August.

**Table 3-4. Summary statistics of geometric means calculated using observed fecal coliform data at station ULI-351. Data cover the period January 20, 1988 to September 30, 1994.**

| Month | Average[1] | Median[1] | Min[1] | Max[1] | 25th[1] | 75th[1] | Exceedances: Count[2] | Percentage of Exceedances[3] |
|---|---|---|---|---|---|---|---|---|
| Jan | 262 | 284 | 41 | 461 | 203 | 331 | 32:32 | 100% |
| Feb | 268 | 320 | 40 | 489 | 153 | 366 | 27:27 | 100% |
| Mar | 230 | 234 | 3 | 462 | 73 | 372 | 28:33 | 85% |
| Apr | 196 | 188 | 10 | 534 | 88 | 282 | 28:31 | 90% |
| May | 78 | 66 | 5 | 209 | 42 | 87 | 28:32 | 88% |
| Jun | 173 | 151 | 32 | 518 | 102 | 227 | 29:29 | 100% |
| Jul | 521 | 376 | 157 | 1761 | 248 | 660 | 37:37 | 100% |
| Aug | 758 | 537 | 164 | 3034 | 355 | 762 | 35:35 | 100% |
| Sep | 446 | 383 | 29 | 1663 | 166 | 471 | 37:37 | 100% |
| Oct | 208 | 158 | 63 | 537 | 121 | 227 | 27:27 | 100% |
| Nov | 222 | 207 | 4 | 524 | 73 | 335 | 21:26 | 81% |
| Dec | 263 | 286 | 4 | 479 | 240 | 340 | 23:25 | 92% |

[1]Average, median, minimum, maximum and 25th and 75th percentile values of all 30-day geometric means calculated for the month (i.e., using samples within the month).
[2] Ratio of number of calculated 30-day geometric means that exceed the water quality criterion to the number of calculated 30-day geometric means in the month.
[3] Percentage of all calculated 30-day geometric means for the month that exceed the water quality criterion.

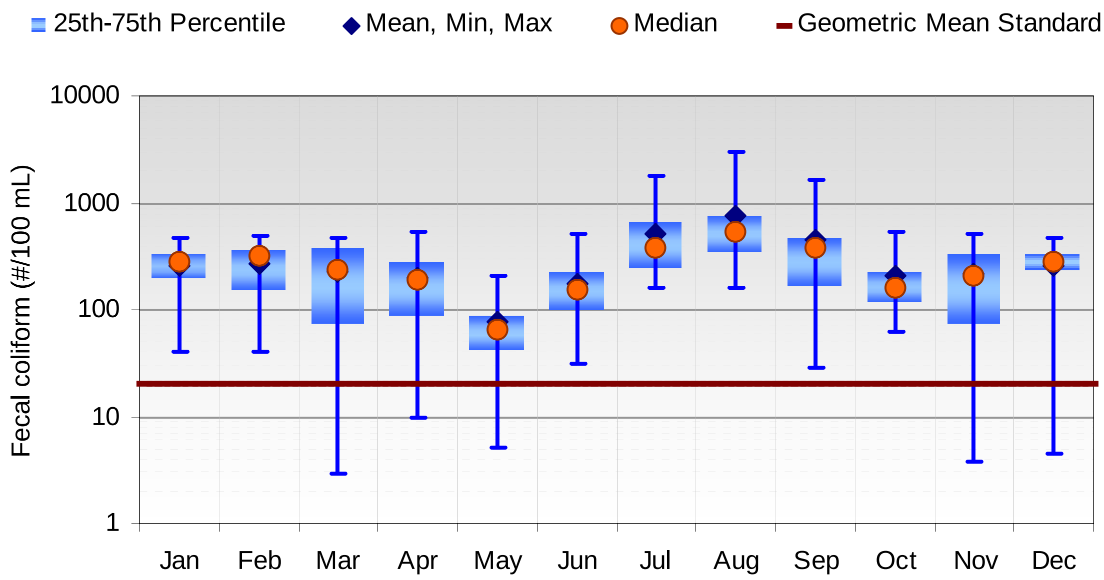



**Figure 3-4. Summary of calculated monthly geometric means of fecal coliform at station ULI.**

### 3.3.4 Station ULO (outlet of University Lake), South Fork Chester Creek, Upper Chester Creek Subwatershed

Station ULO is located at the outlet of University Lake. Data are available for the period January 20, 1988 to September 30, 1994 and are summarized in Table 3-5 and Figure 3-5.

Fecal coliform counts at the output from the lake do not appear to have a clearly defined distribution. There are slight peaks in fecal coliform counts in January, April, and August.

It is noteworthy that fecal coliform counts appear to drop significantly from station ULI-351 to ULO. The calculated 30-day geometric means are approximately 70 percent less below the lake than they are above, indicating that the lake is a net sink of bacteria.

**Table 3-5. Summary statistics of geometric means calculated using observed fecal coliform data at station ULO. Data cover the period January 20, 1988 to September 30, 1994.**

| Month | Average[1] | Median[1] | Min[1] | Max[1] | 25th[1] | 75th[1] | Exceedances: Count[2] | Percentage of Exceedances[3] |
|---|---|---|---|---|---|---|---|---|
| Jan | 72 | 69 | 0 | 181 | 13 | 116 | 20:33 | 61% |
| Feb | 56 | 41 | 2 | 313 | 19 | 63 | 19:26 | 73% |
| Mar | 77 | 49 | 1 | 800 | 4 | 100 | 23:32 | 72% |
| Apr | 92 | 75 | 1 | 336 | 13 | 159 | 19:29 | 66% |
| May | 23 | 20 | 1 | 72 | 5 | 37 | 16:32 | 50% |
| Jun | 31 | 27 | 1 | 74 | 11 | 46 | 19:29 | 66% |
| Jul | 55 | 50 | 11 | 126 | 41 | 67 | 35:37 | 95% |
| Aug | 74 | 62 | 10 | 229 | 45 | 93 | 30:35 | 86% |
| Sep | 118 | 40 | 6 | 634 | 13 | 138 | 22:37 | 59% |
| Oct | 100 | 51 | 17 | 418 | 33 | 127 | 26:27 | 96% |
| Nov | 92 | 70 | 0 | 224 | 47 | 142 | 26:27 | 96% |
| Dec | 89 | 83 | 1 | 247 | 57 | 117 | 22:25 | 88% |

[1]Average, median, minimum, maximum and 25th and 75th percentile values of all 30-day geometric means calculated for the month (i.e., using samples within the month).
[2] Ratio of number of calculated 30-day geometric means that exceed the water quality criterion to the number of calculated 30-day geometric means in the month.
[3] Percentage of all calculated 30-day geometric means for the month that exceed the water quality criterion.

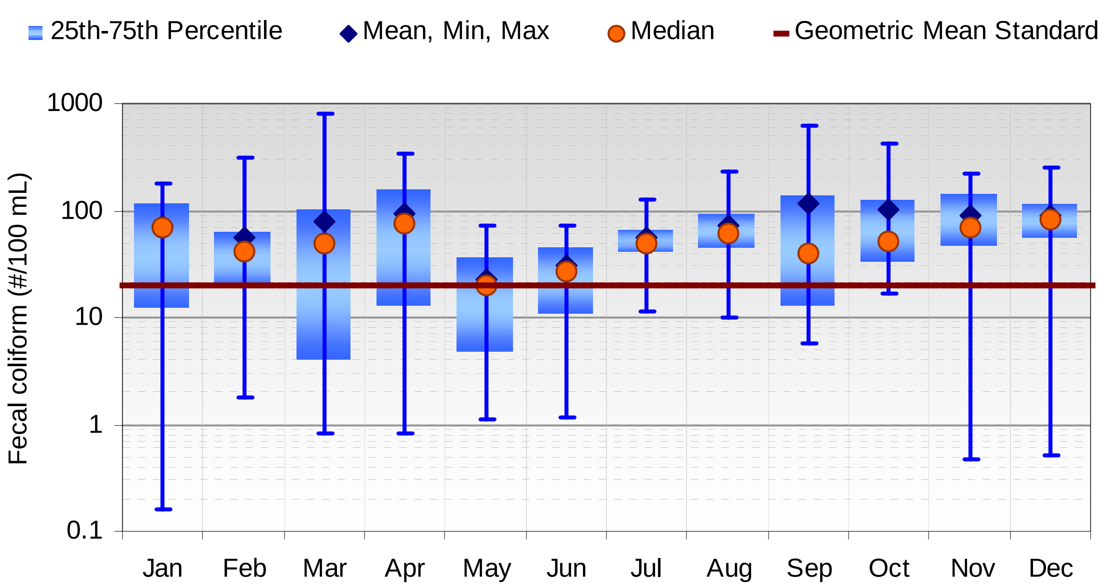



**Figure 3-5. Summary of calculated monthly geometric means of fecal coliform at station ULO.**

### 3.3.5 Station CH6, Downstream of Station ULO, South Fork Chester Creek, Upper Chester Creek Subwatershed

Station CH6 is located on the South Fork of Chester Creek in the upper Chester Creek subwatershed and drains an area consisting of parks and single-family detached homes. Data are available for the period April 15, 1988 to September 30, 1994 and the results are summarized in Table 3-6 and Figure 3-6.

Most calculated 30-day geometric means at station CH6 are above the standard. Average geometric means vary from 24 to 117 FC/100ml with the highest counts in April and September. Counts drop from April to May and then slowly increase during the summer.

**Table 3-6. Summary statistics of geometric means calculated using observed fecal coliform data at station CH6. Data cover the period April 15, 1988 to September 30, 1994.**

| Month | Average[1] | Median[1] | Min[1] | Max[1] | 25th[1] | 75th[1] | Exceedances: Count[2] | Percentage of Exceedances[3] |
|---|---|---|---|---|---|---|---|---|
| Jan | 63 | 63 | 15 | 145 | 33 | 92 | 24:29 | 83% |
| Feb | 58 | 43 | 4 | 295 | 19 | 70 | 18:24 | 75% |
| Mar | 50 | 30 | 4 | 212 | 16 | 60 | 16:25 | 64% |
| Apr | 117 | 111 | 20 | 337 | 37 | 183 | 25:26 | 96% |
| May | 24 | 24 | 7 | 48 | 13 | 32 | 17:29 | 59% |
| Jun | 31 | 30 | 6 | 68 | 17 | 42 | 22:31 | 71% |
| Jul | 53 | 48 | 15 | 130 | 35 | 66 | 33:35 | 94% |
| Aug | 53 | 41 | 11 | 185 | 27 | 76 | 28:34 | 82% |
| Sep | 103 | 68 | 6 | 654 | 13 | 103 | 25:37 | 68% |
| Oct | 69 | 59 | 16 | 209 | 32 | 90 | 26:27 | 96% |
| Nov | 57 | 43 | 29 | 174 | 37 | 62 | 28:28 | 100% |
| Dec | 65 | 70 | 13 | 122 | 30 | 91 | 28:29 | 97% |

[1]Average, median, minimum, maximum and 25th and 75th percentile values of all 30-day geometric means calculated for the month (i.e., using samples within the month).
[2] Ratio of number of calculated 30-day geometric means that exceed the water quality criterion to the number of calculated 30-day geometric means in the month.
[3] Percentage of all calculated 30-day geometric means for the month that exceed the water quality criterion.

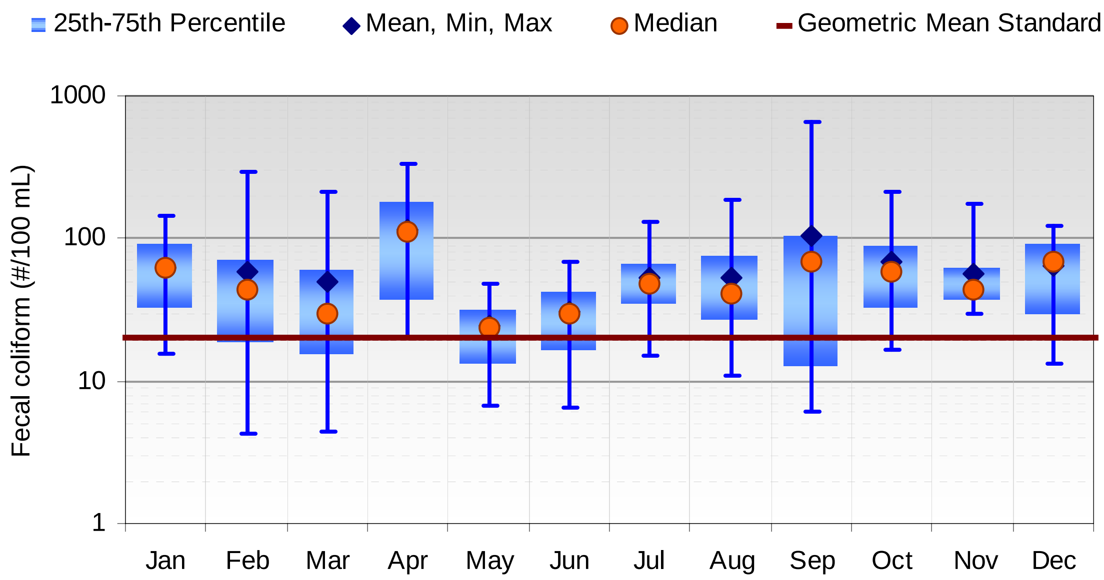



**Figure 3-6. Summary of calculated monthly geometric means of fecal coliform at station CH6.**

### 3.3.6 Station CH7A, Middle Fork Chester Creek, Upper Chester Creek Subwatershed

Station CH7A is located on the Middle Fork of Chester Creek in the upper Chester Creek subwatershed and drains an area consisting of parks, wetlands, and multi-family homes. Data are available for the period December 16, 1987 to September 30, 1994 and the results are summarized in Table 3-7 and Figure 3-7.

Many fecal coliform data are available for station CH7A. Most samples during the winter and early spring are above the 20 FC/100 mL standard whereas values during the rest of the year are both above and below the standard. A significant decrease in fecal coliform counts occurs between April and May, possibly due to greater flows associated with snowmelt.

**Table 3-7. Summary statistics of geometric means calculated using observed fecal coliform data at station CH7A. Data cover the period December 16, 1987 to September 30, 1994.**

| Month | Average[1] | Median[1] | Min[1] | Max[1] | 25th[1] | 75th[1] | Exceedances: Count[2] | Percentage of Exceedances[3] |
|---|---|---|---|---|---|---|---|---|
| Jan | 80 | 22 | 1 | 359 | 10 | 40 | 19:36 | 53% |
| Feb | 80 | 42 | 1 | 445 | 16 | 69 | 20:29 | 69% |
| Mar | 97 | 86 | 6 | 287 | 44 | 134 | 28:34 | 82% |
| Apr | 245 | 216 | 28 | 672 | 81 | 385 | 30:30 | 100% |
| May | 38 | 15 | 2 | 143 | 9 | 45 | 14:31 | 45% |
| Jun | 33 | 21 | 1 | 101 | 5 | 59 | 16:30 | 53% |
| Jul | 35 | 17 | 3 | 140 | 10 | 58 | 14:34 | 41% |
| Aug | 24 | 13 | 1 | 117 | 3 | 26 | 12:34 | 35% |
| Sep | 12 | 8 | 0 | 104 | 5 | 12 | 4:36 | 11% |
| Oct | 17 | 10 | 0 | 71 | 5 | 24 | 9:29 | 31% |
| Nov | 32 | 12 | 0 | 188 | 4 | 50 | 10:26 | 38% |
| Dec | 70 | 5 | 0 | 510 | 3 | 18 | 6:26 | 23% |

[1]Average, median, minimum, maximum and 25th and 75th percentile values of all 30-day geometric means calculated for the month (i.e., using samples within the month).
[2] Ratio of number of calculated 30-day geometric means that exceed the water quality criterion to the number of calculated 30-day geometric means in the month.
[3] Percentage of all calculated 30-day geometric means for the month that exceed the water quality criterion.

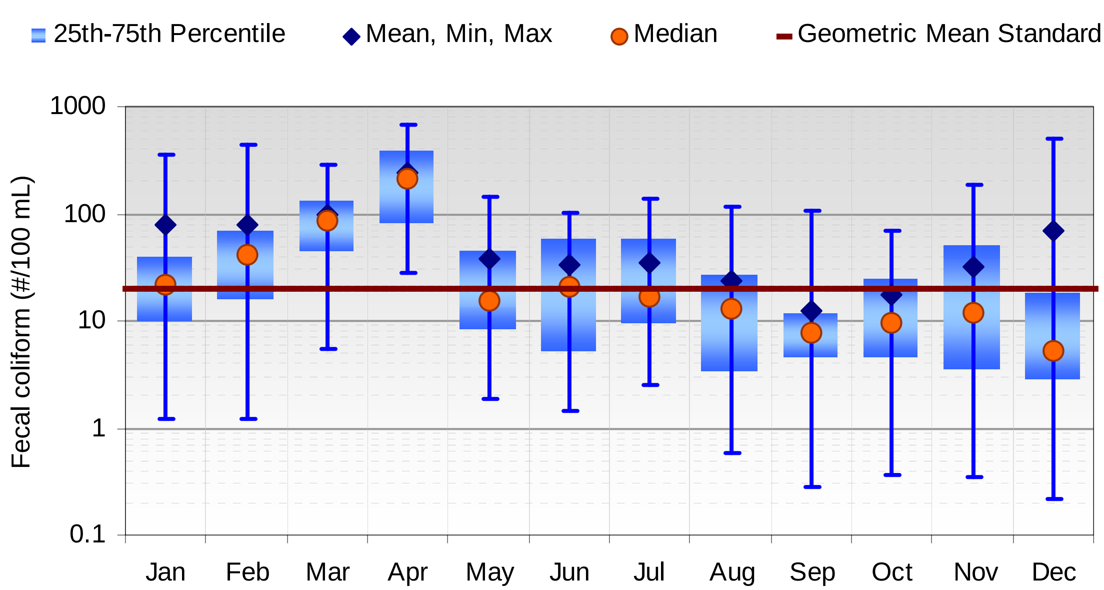



**Figure 3-7. Summary of calculated monthly geometric means of fecal coliform at station CH7A.**

### 3.3.7 Station CH7, Downstream of Station CH7A, Middle Fork Chester Creek, Upper Chester Creek Subwatershed

Station CH7 is located on the Middle Fork of Chester Creek downstream of station CH7A in the upper Chester Creek subwatershed. The station represents a drainage area consisting of primarily multi-family homes. Data are available for the period April 15, 1986 to September 30, 1994 and the results are summarized in Table 3-8 and Figure 3-8.

Calculated 30-day geometric means at station CH7 usually exceeded the 20 FC/ 100 mL standard but dropped below the standard in November and December. Fecal coliform distribution appears to be annually bimodal having peaks in April and August. There is a sharp drop in fecal coliform counts from April to May, similar to what is observed at station 7A. Counts drop from May to June and then increase from July through September.

**Table 3-8. Summary statistics of geometric means calculated using observed fecal coliform data at station CH7. Data cover the period December 16, 1987 to September 30, 1994.**

| Month | Average[1] | Median[1] | Min[1] | Max[1] | 25th[1] | 75th[1] | Exceedances: Count[2] | Percentage of Exceedances[3] |
|---|---|---|---|---|---|---|---|---|
| Jan | 39 | 22 | 2 | 185 | 7 | 39 | 15:28 | 54% |
| Feb | 89 | 51 | 1 | 317 | 33 | 82 | 21:25 | 84% |
| Mar | 110 | 46 | 3 | 789 | 13 | 135 | 25:35 | 71% |
| Apr | 262 | 242 | 4 | 895 | 23 | 328 | 29:37 | 78% |
| May | 57 | 28 | 1 | 257 | 7 | 71 | 22:36 | 61% |
| Jun | 36 | 23 | 1 | 213 | 8 | 40 | 17:31 | 55% |
| Jul | 144 | 50 | 3 | 1510 | 22 | 147 | 32:42 | 76% |
| Aug | 104 | 76 | 11 | 323 | 38 | 155 | 37:40 | 93% |
| Sep | 104 | 63 | 5 | 575 | 18 | 139 | 31:43 | 72% |
| Oct | 39 | 24 | 2 | 222 | 10 | 53 | 18:29 | 62% |
| Nov | 28 | 19 | 3 | 85 | 9 | 45 | 15:31 | 48% |
| Dec | 50 | 13 | 3 | 258 | 7 | 51 | 13:33 | 39% |

[1]Average, median, minimum, maximum and 25th and 75th percentile values of all 30-day geometric means calculated for the month (i.e., using samples within the month).
[2] Ratio of number of calculated 30-day geometric means that exceed the water quality criterion to the number of calculated 30-day geometric means in the month.
[3] Percentage of all calculated 30-day geometric means for the month that exceed the water quality criterion.

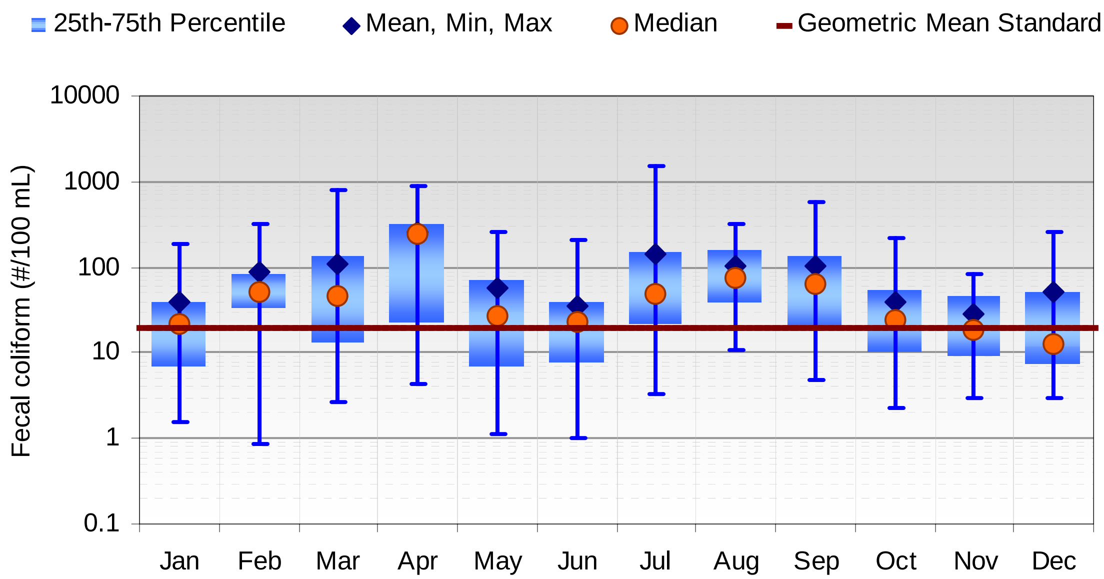



**Figure 3-8. Summary of calculated monthly geometric means of fecal coliform at station CH7.**

### 3.3.8 Station CH10, North Fork Chester Creek, Lower Chester Creek Subwatershed

Station CH10 is located on the North Fork of the Chester Creek drainage in the lower Chester Creek subwatershed and drains an area consisting of single family homes, multi-family homes, and commercial/transportation land uses. There are two storm water outfalls located near the sampling station. Data are available for the period March 16, 1993 to September 30, 1994 and the results are summarized in Table 3-9 and Figure 3-9.

Fecal coliform data at station CH10 appear to be highly variable, perhaps due to the limited number of samples. Calculated 30-day geometric means during the spring and summer are usually below water quality standards, while the limited data for the winter show more exceedances of the standard.

**Table 3-9. Summary statistics of geometric means calculated using observed fecal coliform data at station CH10. Data cover the period March 16, 1993 to September 30, 1994.**

| Month | Average[1] | Median[1] | Min[1] | Max[1] | 25th[1] | 75th[1] | Exceedances: Count[2] | Percentage of Exceedances[3] |
|---|---|---|---|---|---|---|---|---|
| Jan | 29 | 24 | 17 | 49 | 20 | 33 | 3:4 | 75% |
| Feb | 244 | 244 | 130 | 359 | 187 | 302 | 2:2 | 100% |
| Mar | 14 | 14 | 14 | 14 | 14 | 14 | 0:1 | 0% |
| Apr | 0 | 0 | 0 | 0 | 0 | 0 | 0:2 | 0% |
| May | 6 | 0 | 0 | 28 | 0 | 1 | 1:5 | 20% |
| Jun | 6 | 4 | 0 | 19 | 2 | 7 | 0:6 | 0% |
| Jul | 4 | 3 | 1 | 9 | 2 | 5 | 0:7 | 0% |
| Aug | 23 | 9 | 2 | 63 | 3 | 51 | 3:9 | 33% |
| Sep | 94 | 36 | 6 | 454 | 25 | 75 | 13:15 | 87% |
| Oct | 256 | 256 | 144 | 368 | 200 | 312 | 2:2 | 100% |
| Nov | 6 | 6 | 6 | 6 | 6 | 6 | 0:1 | 0% |
| Dec | 13 | 12 | 9 | 17 | 9 | 15 | 0:4 | 0% |

[1]Average, median, minimum, maximum and 25th and 75th percentile values of all 30-day geometric means calculated for the month (i.e., using samples within the month).
[2] Ratio of number of calculated 30-day geometric means that exceed the water quality criterion to the number of calculated 30-day geometric means in the month.
[3] Percentage of all calculated 30-day geometric means for the month that exceed the water quality criterion.

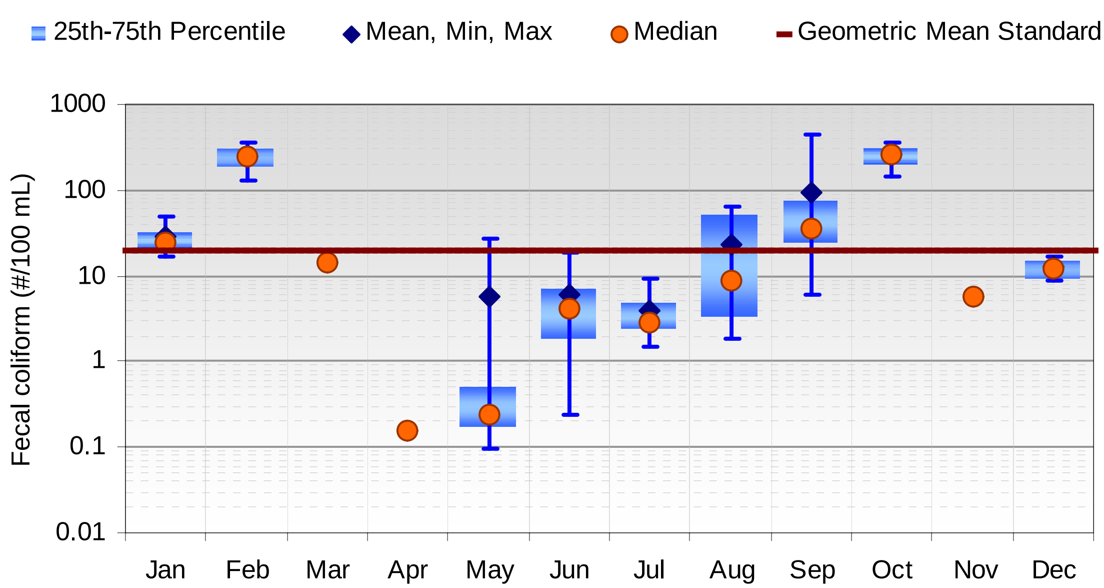



**Figure 3-9. Summary of calculated monthly geometric means of fecal coliform at station CH10.**

### 3.3.9 Station CH2, Chester Creek, Lower Chester Creek Subwatershed

Station CH2 is located on Chester Creek in the lower Chester Creek subwatershed and drains a majority of the watershed. Data are available for the period April 15, 1986 to February 5, 1988 and are summarized in Table 3-10 and Figure 3-10.

Every calculated 30-day geometric mean at station CH2 was above the water quality standard of 20 FC/100 mL. The distribution of fecal coliform at the station is annually bimodal having peaks in April and August. A significant decrease in fecal coliform counts occurs between April and May, as is observed at many of the other stations in the watershed.

**Table 3-10. Summary statistics of geometric means calculated using observed fecal coliform data at station CH2. Data cover the period April 15, 1986 to February 5, 1988.**

| Month | Average[1] | Median[1] | Min[1] | Max[1] | 25th[1] | 75th[1] | Exceedances: Count[2] | Percentage of Exceedances[3] |
|---|---|---|---|---|---|---|---|---|
| Jan | 106 | 97 | 79 | 151 | 87 | 116 | 4:4 | 100% |
| Feb | 117 | 122 | 85 | 140 | 113 | 124 | 6:6 | 100% |
| Mar | 285 | 257 | 207 | 408 | 226 | 349 | 8:8 | 100% |
| Apr | 324 | 336 | 224 | 431 | 263 | 371 | 10:10 | 100% |
| May | 188 | 208 | 106 | 223 | 175 | 216 | 10:10 | 100% |
| Jun | 316 | 335 | 107 | 539 | 115 | 502 | 7:7 | 100% |
| Jul | 452 | 416 | 114 | 764 | 311 | 673 | 10:10 | 100% |
| Aug | 647 | 682 | 276 | 1026 | 388 | 895 | 10:10 | 100% |
| Sep | 336 | 302 | 106 | 745 | 240 | 437 | 13:13 | 100% |
| Oct | 90 | 93 | 78 | 96 | 89 | 94 | 4:4 | 100% |
| Nov | 89 | 95 | 66 | 106 | 72 | 105 | 5:5 | 100% |
| Dec | 153 | 52 | 39 | 640 | 47 | 124 | 7:7 | 100% |

[1] Average, median, minimum, maximum and 25th and 75th percentile values of all 30-day geometric means calculated for the month (i.e., using samples within the month).
[2] Ratio of number of calculated 30-day geometric means that exceed the water quality criterion to the number of calculated 30-day geometric means in the month.
[3] Percentage of all calculated 30-day geometric means for the month that exceed the water quality criterion.

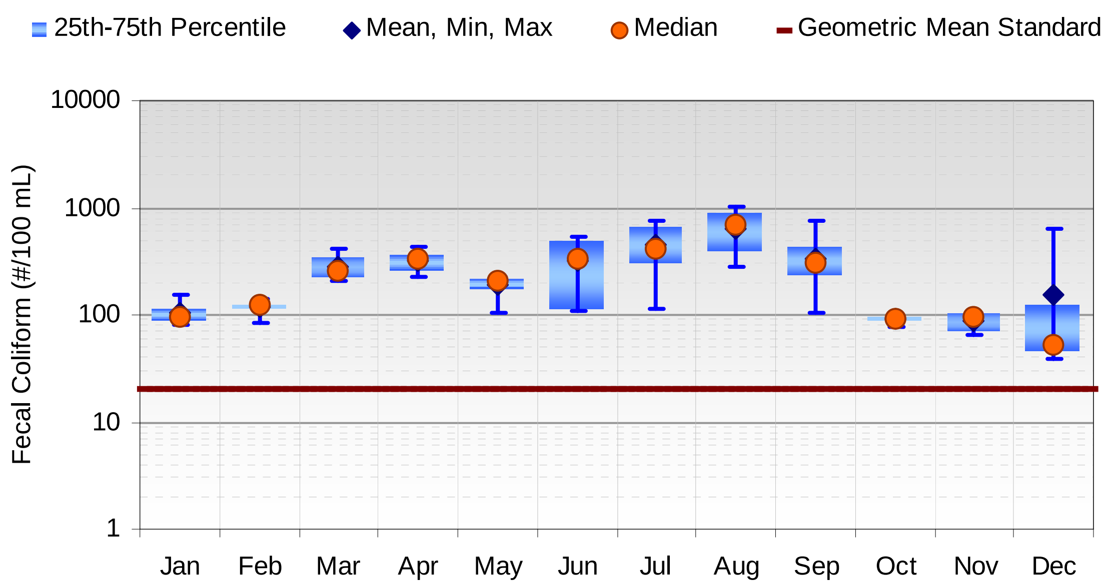



**Figure 3-10. Summary of calculated monthly geometric means of fecal coliform at station CH2.**

### 3.3.10 Station CL3, Near Inlet from Chester Creek to Westchester Lagoon

Station CL3 is located in the southeastern edge of the Westchester Lagoon, to the west of Minnesota Avenue. The site drains nearly the entire Chester Creek watershed. Forest cover characterizes the immediate area surrounding the monitoring site. Data are available for the period March 31, 1988 to September 30, 1994 and the results are summarized in Table 3-11 and Figure 3-11.

All calculated 30-day geometric means at station CL3 are above the standard. Average monthly geometric means range from 14 to 287 FC/ 100 mL with the highest geometric means occurring in March and April. Average geometric means decline from May through July, and then increase during August and September, and decline again from October through February. The greatest variability in monthly geometric means occurs in January.

**Table 3-11. Summary Statistics of geometric mean calculated using observed fecal coliform data at Station CL3. Data cover the period March, 31 1988 to September 30, 1994.**

| Month | Average[1] | Median[1] | Min[1] | Max[1] | 25th[1] | 75th[1] | Exceedances: Count[2] | Percent of Exceedences[3] |
|---|---|---|---|---|---|---|---|---|
| Jan | 33 | 36 | 0 | 73 | 26 | 40 | 24:29 | 83% |
| Feb | 47 | 43 | 18 | 83 | 32 | 60 | 9:10 | 90% |
| Mar | 112 | 83 | 40 | 404 | 57 | 126 | 14:14 | 100% |
| Apr | 287 | 161 | 36 | 808 | 68 | 605 | 17:17 | 100% |
| May | 78 | 25 | 5 | 332 | 15 | 95 | 13:22 | 59% |
| Jun | 14 | 16 | 3 | 30 | 7 | 19 | 5:21 | 24% |
| Jul | 55 | 30 | 6 | 257 | 14 | 70 | 21:32 | 66% |
| Aug | 89 | 61 | 6 | 283 | 19 | 129 | 22:32 | 69% |
| Sep | 96 | 66 | 3 | 431 | 24 | 122 | 24:31 | 77% |
| Oct | 59 | 64 | 1 | 145 | 32 | 84 | 20:24 | 83% |
| Nov | 43 | 50 | 0 | 123 | 7 | 56 | 18:25 | 72% |
| Dec | 35 | 35 | 3 | 68 | 24 | 45 | 18:24 | 75% |

[1]Average, median, minimum, maximum and 25th and 75th percentile values of all 30-day geometric means calculated for the month (i.e., using samples within the month).
[2] Ratio of number of calculated 30-day geometric means that exceed the water quality criterion to the number of calculated 30-day geometric means in the month.
[3] Percentage of all calculated 30-day geometric means for the month that exceed the water quality criterion.

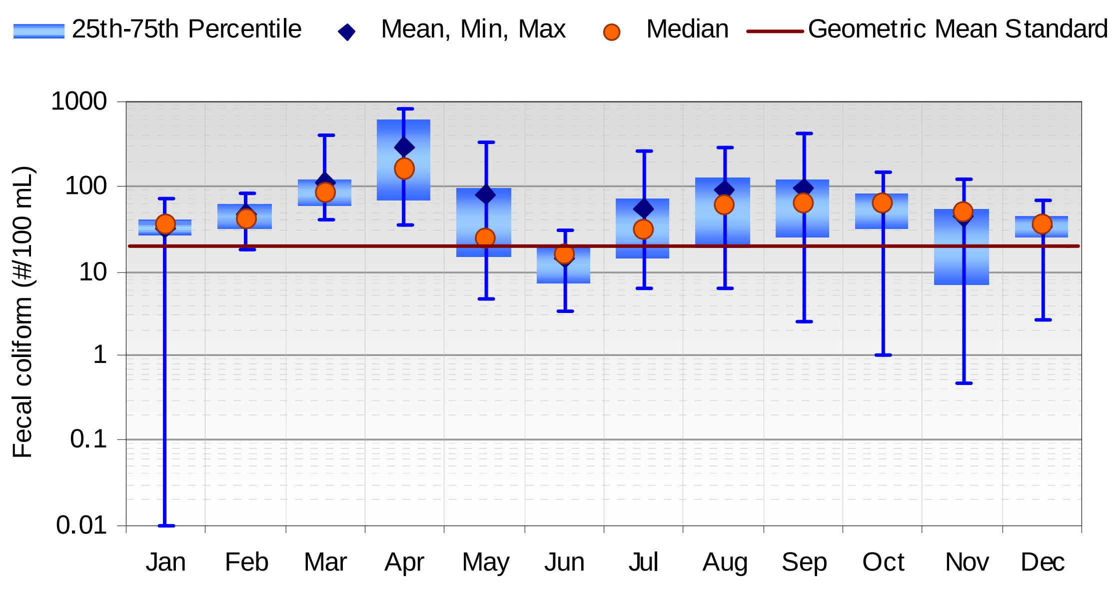



**Figure 3-11. Summary of calculated monthly geometric means of fecal coliform at station CL3.**

### 3.3.11 Station CL2, Near Outlet into Cook Inlet

Station CL2 is located at the outlet of Westchester Lagoon, adjacent to the weir and the conveyance pipe used to discharge into the inlet. The site drains the entire Chester Creek watershed. Data are available for the period March 31, 1988 to December 20, 1994, and the results are summarized in Table 3-12 and Figure 3-12.

Most of the calculated 30-day geometric means at station CL3 are above the standard. Average monthly geometric means vary between 28 and 231 FC/100 mL. Monthly average geometric means peak in April and remain high during May, then decrease rapidly in June. Mean monthly geometric means increase rapidly in July and remain high through August, September, and October. Minimum average geometric means occur in February, June, and January, respectively.

**Table 3-12. Summary Statistics of geometric mean calculated using observed fecal coliform data at Station CL2. Data cover the period March, 31 1988 to December 20, 1994.**

| Month | Average[1] | Median[1] | Min[1] | Max[1] | 25th[1] | 75th[1] | Exceedances: Count[2] | Percent of Exceedences[3] |
|---|---|---|---|---|---|---|---|---|
| Jan | 58 | 55 | 1 | 127 | 23 | 88 | 22:28 | 79% |
| Feb | 28 | 15 | 4 | 61 | 13 | 48 | 8:17 | 47% |
| Mar | 58 | 33 | 13 | 167 | 15 | 103 | 12:22 | 55% |
| Apr | 231 | 197 | 9 | 754 | 130 | 276 | 25:26 | 96% |
| May | 144 | 93 | 3 | 573 | 22 | 161 | 25:32 | 78% |
| Jun | 46 | 28 | 2 | 231 | 20 | 62 | 23:30 | 77% |
| Jul | 195 | 68 | 15 | 1435 | 40 | 205 | 33:35 | 94% |
| Aug | 178 | 91 | 12 | 1205 | 24 | 252 | 27:35 | 77% |
| Sep | 168 | 79 | 2 | 855 | 12 | 300 | 24:39 | 62% |
| Oct | 129 | 74 | 10 | 356 | 49 | 251 | 24:28 | 86% |
| Nov | 79 | 79 | 19 | 221 | 43 | 99 | 26:27 | 96% |
| Dec | 59 | 70 | 2 | 97 | 32 | 84 | 18:23 | 78% |

[1]Average, median, minimum, maximum and 25th and 75th percentile values of all 30-day geometric means calculated for the month (i.e., using samples within the month).
[2] Ratio of number of calculated 30-day geometric means that exceed the water quality criterion to the number of calculated 30-day geometric means in the month.
[3] Percentage of all calculated 30-day geometric means for the month that exceed the water quality criterion.

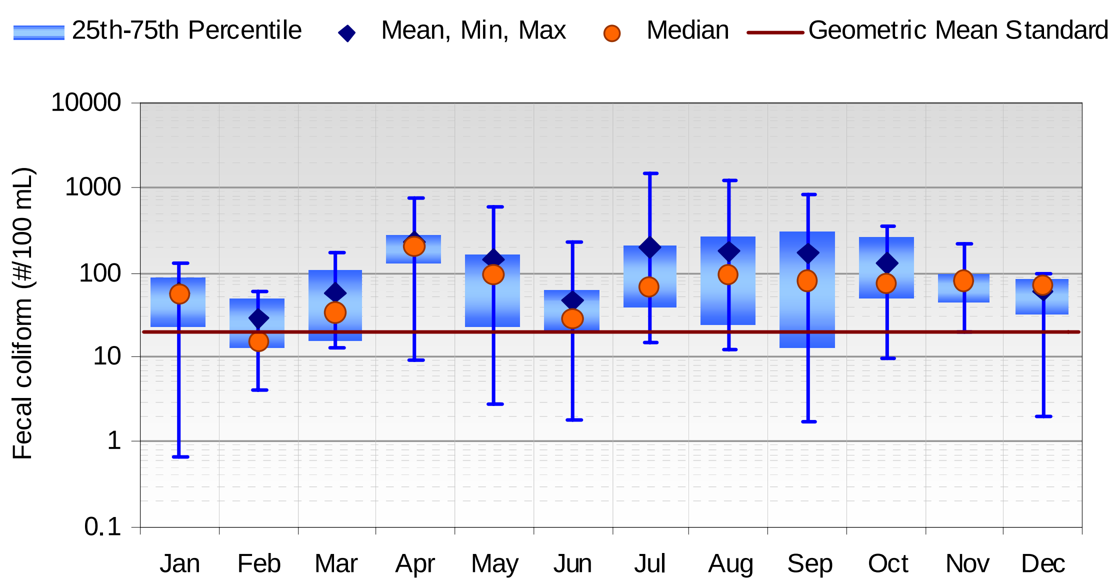



**Figure 3-12. Summary of calculated monthly geometric means of fecal coliform at station CL2.**

A statistical summary of all fecal coliform monitoring stations in the Chester Creek watershed is presented in Figure 3-13. The figure shows significant variability in observed fecal coliform counts for all monitoring stations, and that mean fecal coliform counts exceed the geometric mean standard of 20 per 100 mL at all stations. Similarly, median fecal coliform counts exceed the geometric mean standard at all stations except CH10.

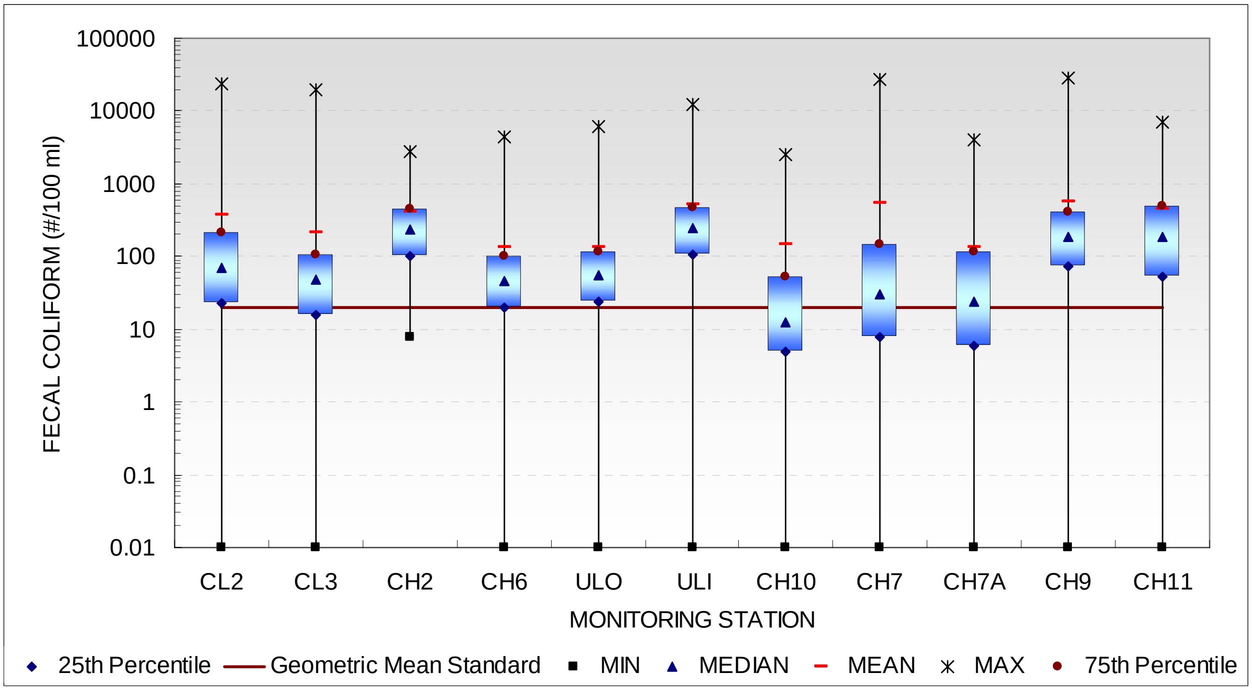



**Figure 3-13. Summary of calculated monthly geometric means of fecal coliform for all monitoring stations.**

## 4.0 POLLUTANT SOURCES

The identification of sources is important to the successful implementation of a TMDL and the control of pollutant loading to a stream. Characterizing watershed sources can provide information on the relative magnitude and influence of each source and its impact on in-stream water quality conditions. This section discusses the potential sources of fecal coliform to Chester Creek, University Lake and Westchester Lagoon.

### 4.1 Point Sources, Nonpoint Sources, and Natural Sources

The Alaska 303(d) impaired waters list identifies urban runoff as the primary source of fecal coliform to Chester Creek, University Lake, and Westchester Lagoon. Snowmelt and rainfall transport bacteria that is deposited and accumulated on the surface of residential and urban areas. Likely sources of the accumulated bacteria are waterfowl, domestic animals (e.g., cats and dogs) and native animals (e.g., moose, bear, etc.). Animals can deposit fecal matter directly into the watershed streams or on the land surface where it is available for overland transport in surface runoff. MOA (1990) concludes that pet and waterfowl feces appear to the major sources of fecal coliform for runoff in the Anchorage area. Additionally, cracked or leaking sanitary sewer lines, failing on site septic systems, and indigent people living near the creek may also contribute fecal coliform bacteria to Chester Creek

Wildlife may be a considerable source of fecal coliform to Chester Creek, University Lake, and Westchester Lagoon, both through direct deposition and deposition on watershed surfaces; however, it is difficult to estimate fecal coliform contributions from wildlife in the Anchorage area. It is not feasible to isolate wildlife populations for the Chester Creek watershed due to the mobility and large home ranges of the wildlife throughout the area. Additionally, while fecal coliform production of many agricultural animals has been researched, there is little or no information on the bacteria production rates of wildlife species native to the Anchorage area.

Although the information is not available to quantify the direct loading from wildlife sources in the watershed, Alaska Department of Fish and Game (ADF&G) provided qualitative estimates of wildlife populations in the Anchorage area that are used to provide general background on the types of animals that may be contributing to the fecal coliform impairments in the area. The following summarizes the information provided by ADF&G (Rick Sinnott, personal communication, 1/30/03):

- Approximately 200 to 300 moose live in the Anchorage Bowl, not including moose that live solely in Fort Richardson or Chugach State Park, and as many as 1,000 moose are in the Anchorage Bowl in winter.
- About 2,000 Canada geese inhabit the Anchorage Bowl. Most of these geese are located west of Lake Otis Boulevard and north of Tudor Road (i.e., Fish Creek area) in grassy parks, school grounds, and athletic fields in April and July-October and in bogs, ponds, and lakes in May-July.
- Thousands more Canada and other geese fly through the area in spring and fall, primarily in the Anchorage Coastal Wildlife Refuge (located on the Turnagain Arm and including Potter Marsh).
- Anchorage may contain 2,000 or more mallards in the winter, with most located in open creeks (Ship Creek and Chester Creek).
- Anchorage also has several thousand pigeons, primarily downtown and midtown.
- At most, there are 100 to 150 beavers in the Anchorage Bowl.
- Latest counts showed no more than 6 brown bears and 30-40 black bears in the Anchorage Bowl.

Septic systems have the potential to contribute fecal coliform to receiving waters through surface breakouts and subsurface malfunctions. Failing septic systems located in close proximity to receiving waterbodies are more likely to impact in-stream conditions. The majority of septic systems in the Anchorage area are located more than 100 feet away from any streams and the majority of the houses (more than 95 percent ) in the Chester Creek watershed are connected to city sewer and do not use onsite septic systems. Additionally, 99 to 100 percent of homes built close to the stream are connected to city sewer (Kevin Kleweno, ADEC, Division of Environmental Health, Drinking Water & Wastewater Program, personal communication to Timothy Stevens, ADEC, January 31, 2003). Therefore, DEC believes septic systems have no or insignificant contribution of fecal coliform to Chester Creek.

An ongoing water quality study conducted by the University of Alaska on the spatial, temporal, and phase distribution of fecal coliform in Chester Creek indicates the number of indigent people living near the creek has been drastically reduced by an intensive city wide effort to remove homeless camps from city parks and greenbelts. As a result of this ongoing action the potential for fecal coliform contribution by indigent people has been eliminated as a significant source of fecal coliform impacting Chester Creek.

The University of Alaska study also investigated the potential of leaking sewer lines to contribute fecal coliform to Chester Creek. Based on selection criteria and field observations two sewer line stream crossings were chosen for sampling and analysis. Ground water and surface water samples were collected above and below the stream crossings for analysis. Preliminary data indicate these sewer lines are not contributing fecal coliform to Chester Creek.

Storm water is traditionally considered a nonpoint source, carrying pollutants to receiving waters through surface runoff. However, when storm water is permitted and carried through conveyances to discrete discharges to streams, it is considered a point source. Unlike most constant point sources (e.g., waste water treatment plant (WWTP) discharges), storm water is precipitation-driven and impacts the receiving stream during times of surface runoff. The MOA is subject to an NPDES storm water permit that covers all of the storm drains in the Chester Creek watershed and therefore the storm water runoff that occurs within the MOS is considered a point source for regulatory purposes. Storm water runoff that occurs outside of the MOA boundaries is considered a nonpoint source.

## 5.0 TECHNICAL APPROACH

Developing TMDLs requires a combination of technical analysis, practical understanding of important watershed processes, and interpretation of watershed loadings and receiving water responses to those loadings. In identifying the technical approach for development of fecal coliform TMDL for Chester Creek, University Lake, and Westchester Lagoon, the following core set of principles was identified and applied:

- ***The TMDLs must be based on scientific analysis and reasonable and acceptable assumptions.*** All major assumptions have been made based on available data and in consultation with appropriate agency staff.

- ***The TMDLs must use the best available data.*** All available data in the watershed were reviewed and were used in the analysis where possible or appropriate.

- ***Methods should be clear and as simple as possible to facilitate explanation to stakeholders.*** All methods and major assumptions used in the analysis are described. The TMDL document has been presented in a format accessible by a wide range of audiences, including the public and interested stakeholders.

The technical approach used to estimate the loading capacity, existing loads, and load allocations presented below relies on these principles and provides a TMDL calculation that uses the best available information to represent watershed and in-stream processes.

### 5.1 Modeling Approach

This section presents the hydrologic and water quality modeling approach employed to estimate in-stream fecal coliform counts and loadings in the Chester Creek watershed, including University Lake and Westchester Lagoon. A watershed model is essentially a series of algorithms applied to watershed characteristics and meteorological data to simulate naturally occurring land-based processes over an extended period of time, including hydrology and pollutant transport. Many watershed models are also capable of simulating in-stream processes using the land-based calculations as input. Once a model has been adequately set up and calibrated for a watershed it can be used to quantify the existing loading of pollutants from subwatersheds. Models can also be used to assess the potential benefits of various restoration scenarios (e.g., implementation of certain best management practices).

The relevant numeric water quality criteria for fecal coliform are presented in Section 2. Since the water quality criteria are based upon a 30-day period, a requirement of the technical approach was that it would simulate daily in-stream fecal coliform counts. Given the criteria and the urban character of the watershed, as well as previous modeling efforts made by MOA, the Storm Water Management Model (SWMM) (Huber and Dickinson, 2001) was selected to estimate fecal coliform counts in Chester Creek. SWMM simulates the quantity and quality of runoff produced by storms in urban watersheds. SWMM simulates real storm events based on rainfall and other meteorological inputs, such as evaporation and temperature, and watershed transport, storage and management practices to predict runoff quantity and quality. At the subwatershed scale, SWMM provides for evaluation of in-stream conditions, which allows for the direct comparison with relevant water quality standards.

SWMM is comprised of several computational blocks, or modules, of which the Rain, Temperature, Runoff and Transport blocks were used for the Chester Creek study. These modules essentially generate surface runoff and route it to the stream channel based on user-defined inputs such as precipitation, land use, and topography. Various hydrologic, pollutant buildup/washoff, and in-channel parameters must also be specified by the user. SWMM represents the stream network system as a series of links and nodes with the links representing stream or channel segments and nodes representing contributing subcatchment inlet points. Consequently, the model represents Chester Creek as a series of hydrologically connected subwatersheds.

Hydrologic and water quality simulations of the watershed were performed for Chester Creek. The modeling approach included continuous simulation of rainfall and runoff, as well as in-stream fecal coliform counts. Once the model was calibrated, it was used to evaluate the existing conditions in Chester Creek, University Lake, and Westchester Lagoon and to develop allocation scenarios that result in attainment of Alaska's water quality standards.

## 5.2 Model Configuration

As mentioned above the SWMM model was configured for the Chester Creek watershed as a series of hydrologically connected subwatersheds. Configuration of the model involved subdivision of the watershed into modeling units, followed by continuous simulation of flow and water quality for these units using meteorological and land use information. This section summarizes the configuration process and key components of the model and more detailed information is provided in Appendix A.

### 5.2.1 Watershed Subdivision

To simulate watershed loadings and resulting counts of fecal coliform, the Chester Creek watershed was divided into numerous modeling subcatchments using spatial (map) data and tabular data provided by MOA. The modeling subcatchments for the lower and upper Chester Creek subwatersheds are shown in and Figures 5-1 and 5-3, respectively. Figures 5-2 and 5-4 display the impervious land cover classes found in the lower and upper Chester Creek subwatersheds, respectively. Hydrology and fecal coliform for the headwaters subwatershed of the Chester Creek basin was not simulated in SWMM. Estimated stream flow and observed fecal coliform concentration discharging from the headwaters subwatershed, referred to as boundary conditions, were instead used as input into the model.

### 5.2.2 Watershed Parameters

Required input data for each subcatchment include area, imperviousness, slope, Manning's roughness coefficient, a conceptual subcatchment width (total width of overland flow), depression storage, and infiltration parameters. These data have been computed and estimated by MOA for SWMM modeling applications of Chester Creek. The MOA SWMM parameter values were compiled for each land cover class within each subcatchment in the Chester Creek watershed. The land cover classes reflect the degree of imperviousness for a given cover type. Watershed parameters were lumped, that is spatially weighted or averaged, for each modeling subcatchment. Since information about the storm drain network's hydraulic characteristics (such as pipe diameter and roughness characteristics) were not available, the Runoff block was set up to "route" runoff to each subcatchment outlet.

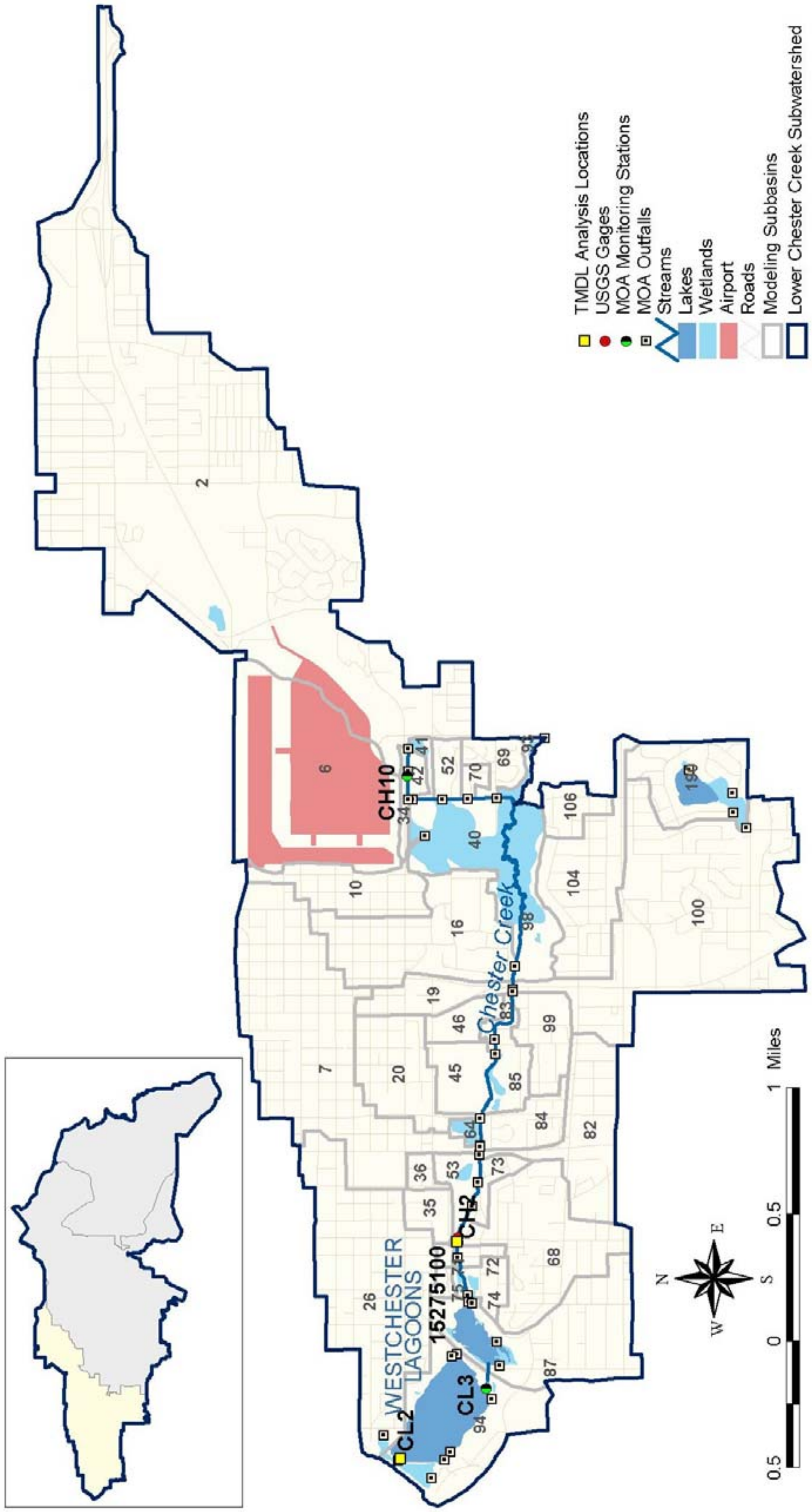



**Figure 5-1.** **SWMM subcatchments in the lower Chester Creek subwatershed.**

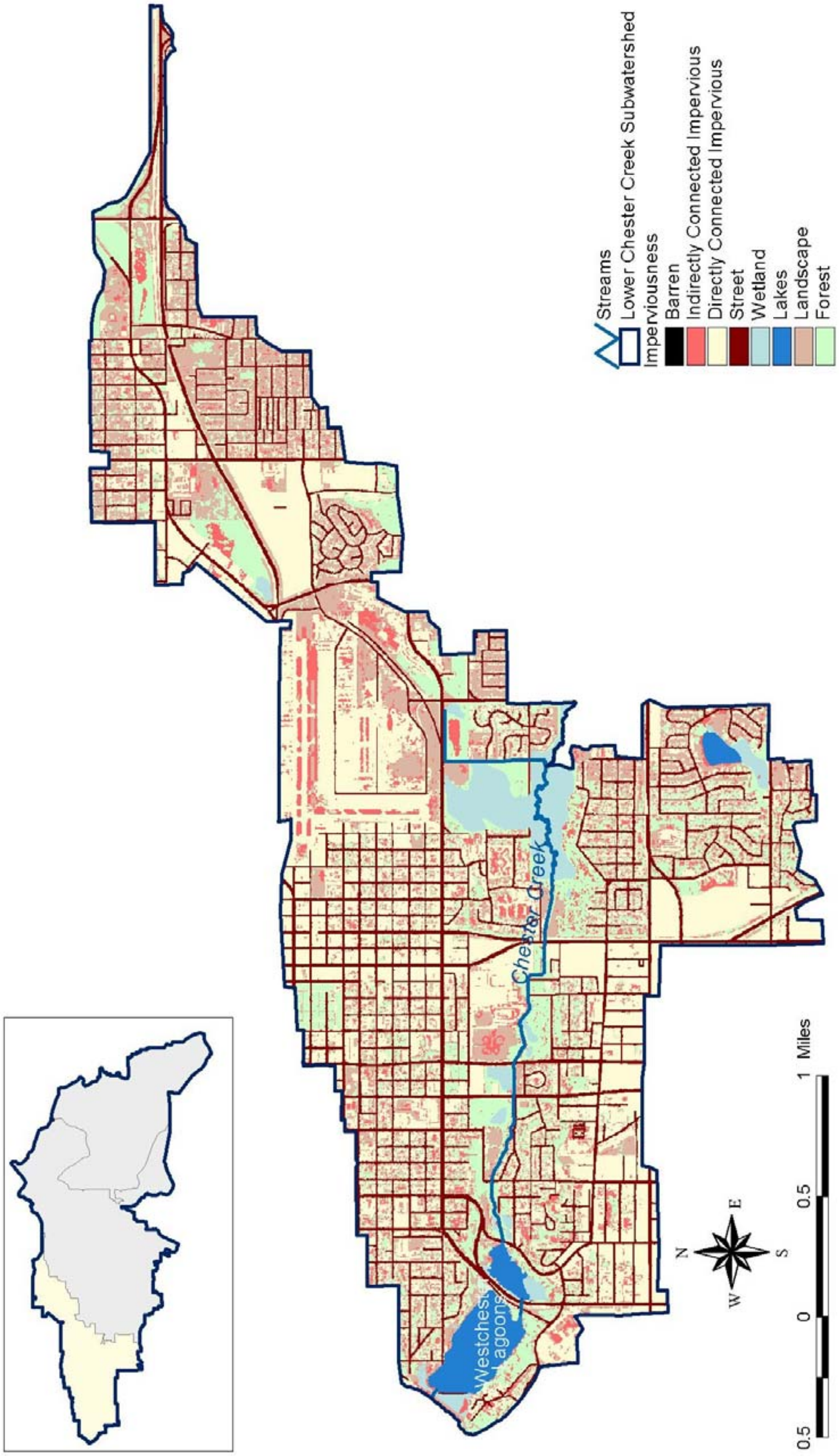



**Figure 5-2. Imperviousness within the lower Chester Creek subwatershed.**

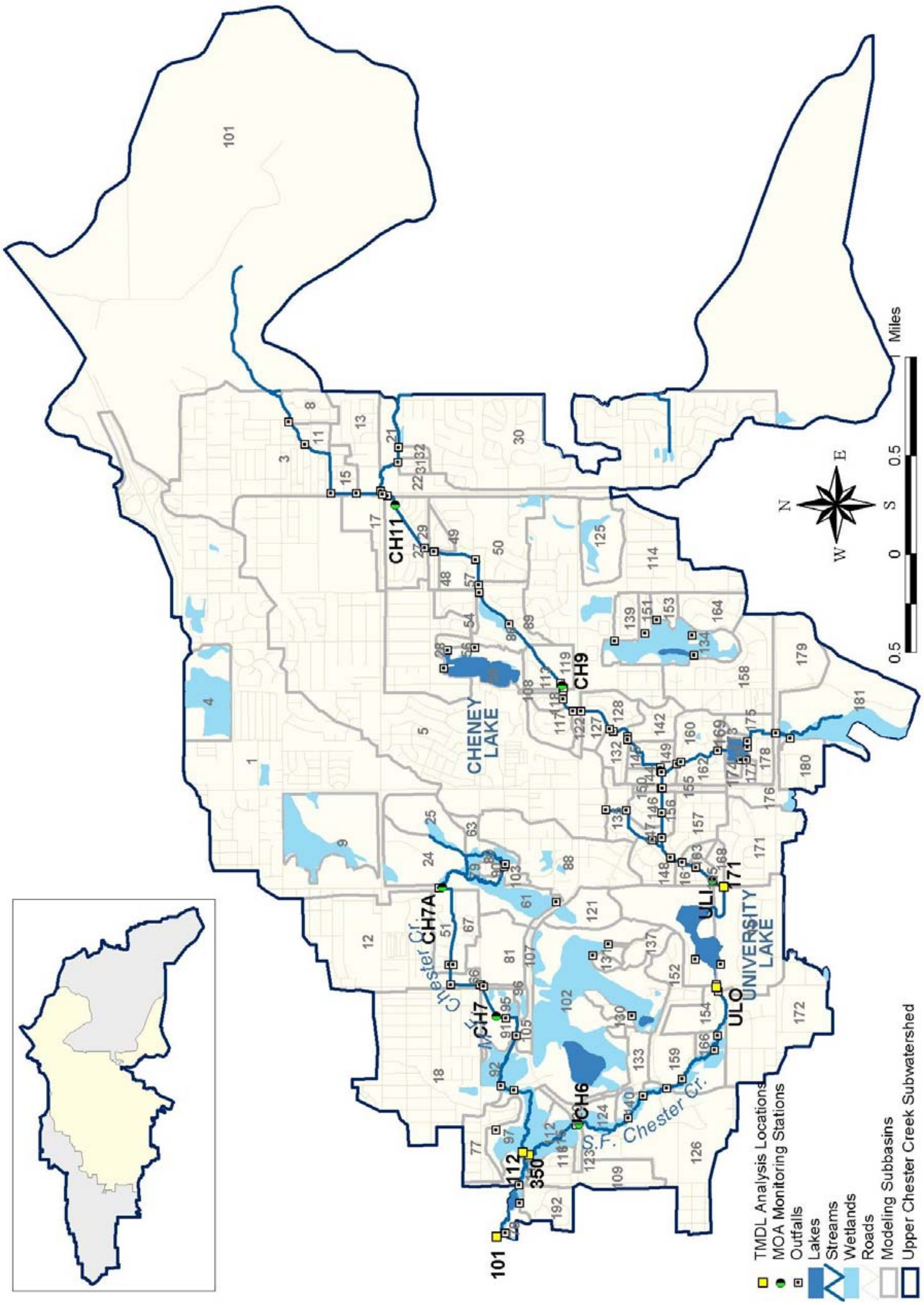



**Figure 5-3. SWMM subcatchments in the upper Chester Creek subwatershed.**

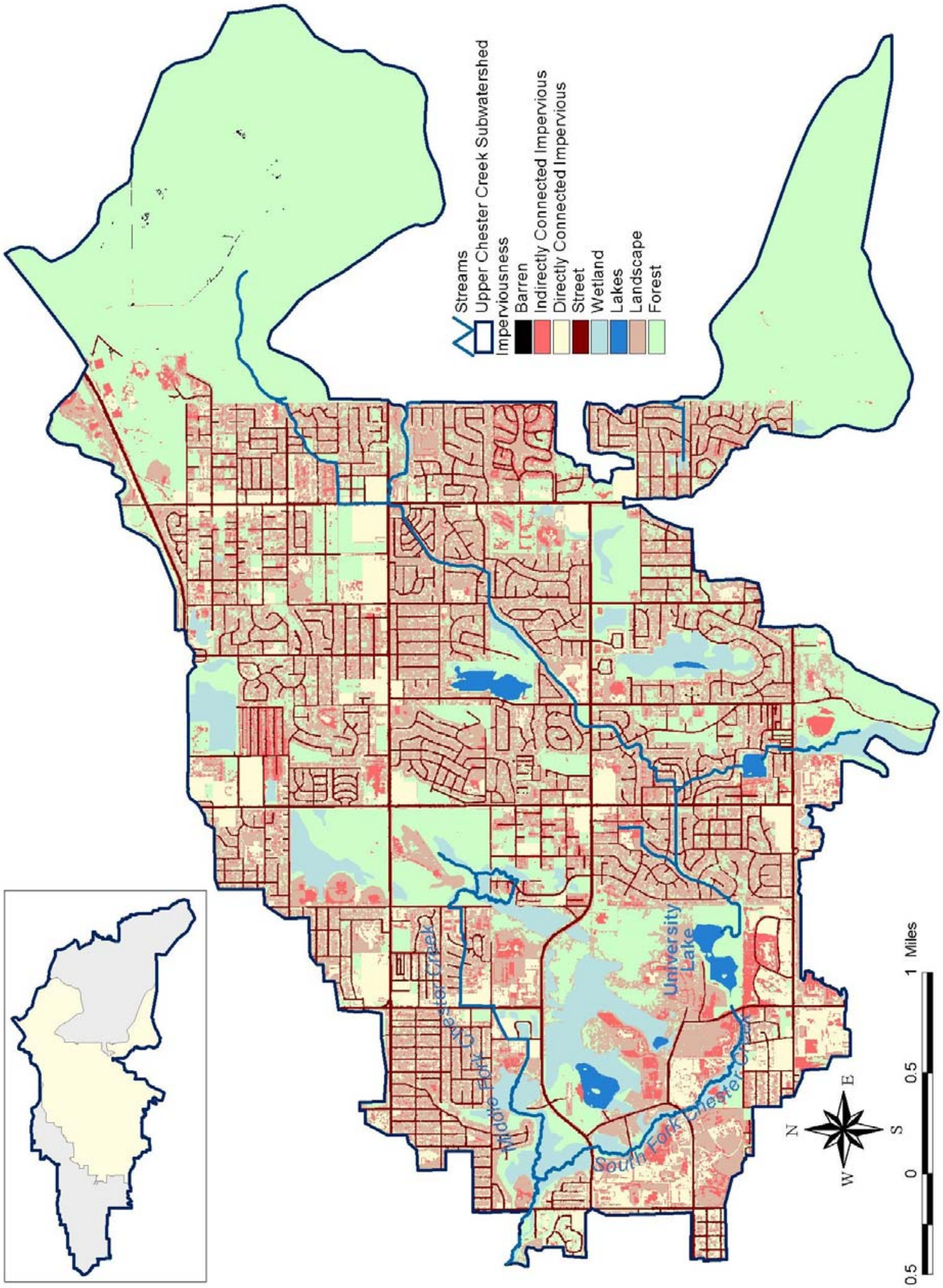



**Figure 5-4. Imperviousness within the upper Chester Creek subwatershed.**

#### 5.2.3 Meteorological Data

Daily precipitation and temperature data, available from the National Climatic Data Center (NCDC) weather station at the Ted Stevens International Airport from 1952 through 2003, were used for the Chester Creek watershed SWMM modeling.

### 5.3 Model Calibration

After the model was configured, calibration was performed at multiple locations in the watershed. Calibration is the adjustment or fine-tuning of model parameters to reproduce observations. Model calibration focused on two main areas: hydrology and water quality. Upon completion of the calibration at selected locations, a calibrated data set containing parameter values for modeled sources and pollutants was developed. This data set was applied to areas for which calibration data were not available.

#### 5.3.1 Hydrologic Calibration

Hydrology was the first model component calibrated. The hydrologic calibration involved a comparison of model results to in-stream flow observations recorded at the USGS stream gage (15275100) located near Arctic Boulevard (see Figure 3-1). This is the only operative stream gage in the entire Chester Creek watershed. This gage recorded daily mean flow from June 17, 1966 through September 30, 1993, and from October 1, 1998 to September 30, 2000. The stream gage was not operational from October 1, 1993 to September 30, 1998. The period of hydrologic calibration was therefore selected as July 1, 1987 to September 30, 1993. This period is deemed sufficient to calibrate the hydrologic response of Chester Creek to rainfall events.

Key considerations addressed during the hydrologic calibration included the high-flow/low-flow distribution, storm flows, and seasonal variation. The calibration involved the adjustment of surface runoff and depression storage parameters within the range of accepted values. The results of the hydrologic calibration are presented in Appendix A. The model adequately captures baseflow conditions, most storm events, and snowmelt events. The model over predicts several periods of streamflow, possibly due to rainfall that was recorded at the weather station that did not actually occur in the watershed.

#### 5.3.2 Water Quality Calibration

After hydrology had been sufficiently calibrated, water quality calibration was performed. The approach taken to calibrate water quality focused on matching trends identified during the water quality analysis summarized in Section 3.0. Daily average in-stream counts estimated by the model were compared to observed data collected at several locations within the watershed (see Table 3-1 and Figure 5-5). Modeled versus observed in-stream fecal coliform counts were directly compared during calibration. The water quality calibration consisted of executing the watershed model, comparing water quality time-series output to available water quality observation data, and adjusting the model water quality parameters within the range of acceptable values. The following fecal coliform monitoring station data were used in the water quality calibration: CH7, CH9, ULO, ULI, CH6, CH2, CL3, and CL2.

The calibrated parameters characterize the buildup and washoff of fecal coliform for individual land uses in the Chester Creek watershed. Fecal coliform buildup is dependent upon the accumulation rate and the time allotted for constituent storage. The landscape impervious cover class was assigned the greatest fecal build-up rate, followed by forest, wetland, lake, indirectly connected impervious, directly connected impervious, and street cover types. Additionally, a monthly street sweeping time interval with a fifty percent efficiency (based on the MOA SWMM input data), was assumed for streets, directly connected impervious and indirectly connected impervious land covers during April, May, and June. Washoff is a nonlinear function of fecal coliform storage, surface runoff, and parameters that describe fecal susceptibility to washoff. High concentration peaks may occur when enough time has elapsed for significant buildup, which then becomes part of the runoff and pollutant load of the next storm event. A thorough presentation of the SWMM water quality model parameters, and the calibration results, are given in Appendix A.

### 5.4 Model Application

After hydrologic and water quality calibration were completed, the model was run for a five-year period, January 1, 1996 through December 31, 2000, to determine existing and allowable fecal counts. This five-year period was chosen because it includes below average (1998), average (1996; 2000), and above average (1997) total annual rainfalls.

Output from the model was evaluated at seven "analysis points" within the watershed. These points were selected to represent water quality within the various subwatersheds as well as University Lake and Westchester Lagoon. The purpose of evaluating water quality at multiple sites is to identify the load reductions that are necessary to ensure that water quality standards are met throughout the watershed (rather than just at its most downstream point). The results of the analysis and the various TMDL components are presented in Section 6.0 for Chester Creek, Section 7.0 for University Lake, and Section 8.0 for Westchester Lagoon.

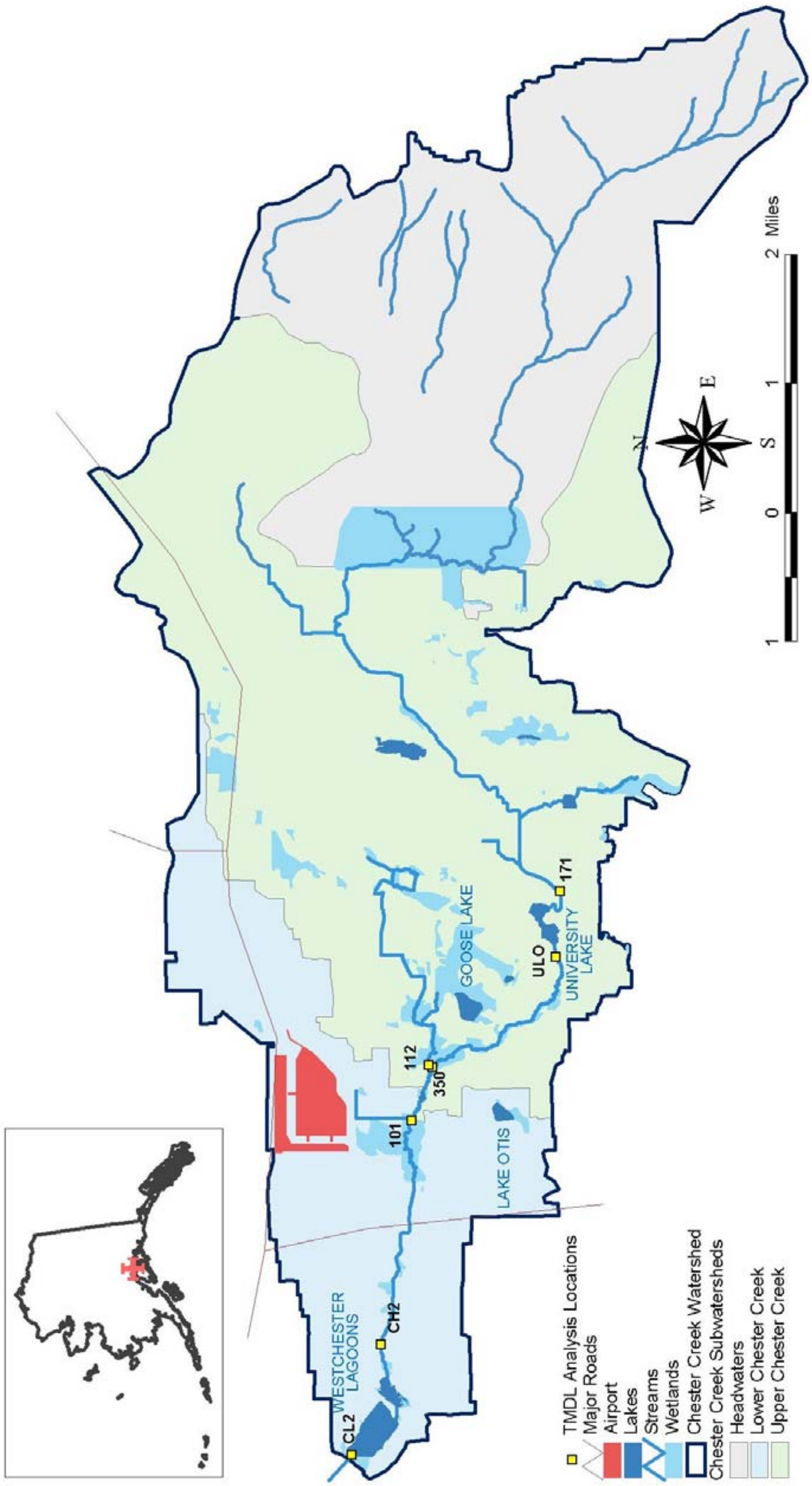



**Figure 5-5. TMDL analysis point locations for the Chester Creek, University Lake and Westchester Lagoon TMDLs.**

## 6.0 CHESTER CREEK ALLOCATION ANALYSIS

One purpose in developing a TMDL is to determine a water's loading capacity, or the greatest amount of loading that a water can receive without violating water quality standards [40 CFR §130.2(f)]. The loading capacity is then allocated to the sum of individual waste load allocations (WLAs) for point sources and load allocations (LAs) for nonpoint sources and natural background loads. In addition, the TMDL must also include a margin of safety (MOS), either implicitly or explicitly, that accounts for the uncertainty in the relationship between pollutant loads and the quality of the receiving waterbody. Conceptually, this definition can be denoted by the equation

$$\text{TMDL} = \text{Loading Capacity} = \Sigma\ \text{WLAs} + \Sigma\ \text{LAs} + \text{MOS}$$

The following sections describe how these components were derived for the Chester Creek TMDL.

### 6.1 Identification of Loading Capacity

The calibrated SWMM model was used to determine the existing and allowable loads of fecal coliform for the Chester Creek TMDL analysis points 112, 171, 350, 101, and CH2 (see Figures 5-1, 5-3, and 5-5). The SWMM model was also used to assess the effectiveness of various implementation scenarios that are described in more detail below. The results of the TMDL and implementation modeling scenarios for the five TMDL assessment points are presented graphically in Figures 6-1 through 6-10. For each TMDL assessment point, existing fecal coliform loads and the three scenario loads are compared to both the 30-day geometric mean standard of 20 FC/100 mL and to the 10 percent not-to-exceed standard of 40 FC/100 mL. Monthly loading capacities were then identified for each assessment point that will result in meeting both components of the standard, as discussed in more detail below.

The 30-day geometric mean standard of 20 FC/100 mL is expressed as a daily allowable load that varies according to daily flow volume. Figures 6-1, 6-3, 6-5, 6-7, and 6-9 show that the loading capacity varies seasonally, with the greatest capacity typically present in the summer months (higher flows), and the lowest capacity typically present in the winter months (lower flows). The figures also indicate that existing loads usually exceed the loading capacity, although this does not hold true for certain months at certain assessment points.

It should also be noted that Figure 6-7 shows that the loading capacity at TMDL assessment point 101 is much less variable than the other assessment points. This is due to the fact assessment point 101 is located in very close proximity to the confluence of the North Fork of Chester Creek with the main stem of Chester Creek and therefore experiences a relatively constant base flow with some attenuation of storm flows. Consequently, the loading capacity, which is dependent on stream flow, is less variable over time.

The 10 percent not-to-exceed standard of 40 FC/100 mL is graphically expressed as the percentage of daily simulated fecal coliform counts that exceed the standard in a particular 30-day period. Figures 6-2, 6-6, and 6-8, representing TMDL analysis points 112, 350, and 101, respectively, show that simulated daily fecal coliform counts generally meet the not-to-exceed standard during winter months. However, during the remainder of the year, simulated fecal coliform counts greatly exceed the standard. Figure 6-10, representing TMDL analysis point CH2, shows that simulated fecal coliform counts are almost always greater than the not-to-exceed standard. Similarly, one hundred percent of the simulated existing fecal coliform counts for TMDL analysis point 171 (South Fork Chester Creek; shown in Figure 6-4) also exceed the standard.

As mentioned previously, monthly loading capacities were identified to ensure compliance with both components of the water quality standard for the entire modeling period (January 1, 1996 through

December 31, 2000). Fecal coliform reductions required by the 30-day geometric mean standard were assessed by computing a running 30-day geometric mean for simulated daily fecal coliform loading estimated by SWMM and comparing those loads to the loading capacity derived from the 30-day geometric mean standard of 20 FC/100 mL. Reductions were calculated for those days when the existing load was greater than the loading capacity and results were summed by month.

The 10 percent not-to-exceed standard of 40 FC/100 mL was assessed by first examining the simulated daily output according to a continuously running 30-day period. The standard allows only 10 percent, or no more than 3 observations, within a 30-day period to exceed the 40 FC/100 mL threshold. Using a running 30-day assessment period covering the entire period of simulated SWMM output, daily loading values were queried and ranked. For each running 30-day period, the fourth-ranked loading value was identified, and if it exceeded the standard, reductions were calculated such that it and all subsequent non-allowable exceedances were reduced to the 40 FC/100 mL level.

Figures 6-1 through 6-10 and show that, with the exception of TMDL analysis point 101, the 30-day geometric mean standard is typically more restrictive than the 10 percent not-to-exceed standard. However, the 10 percent not-to-exceed standard is more restrictive in certain months for TMDL analysis points 112 and 101. Therefore, the summary of existing fecal coliform loads, wasteload allocations, and required reductions presented in Tables 6-1 through 6-5 are based on whichever component of the standard is most restrictive. In this way the final TMDL monthly allocations identify the reductions necessary to achieve both the 30-day geometric mean standard and the 10 percent not-to-exceed standard. Finally, it should be noted that the annual loads and percent reductions presented in Tables 6-1 through 6-5 are solely to allow comparison with other TMDL assessment points on Chester Creek. The monthly allocations present the “official” TMDL loads.

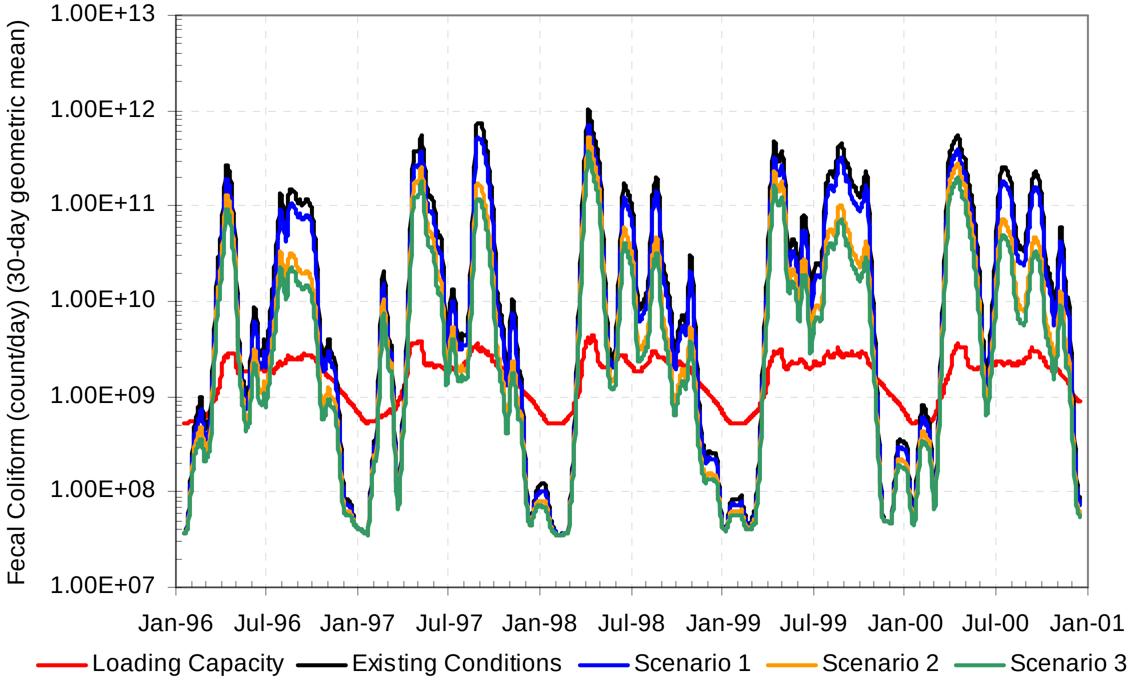



**Figure 6-1. Evaluation of the 30-day geometric mean standard at TMDL analysis point 112 on the Middle Fork of Chester Creek.**

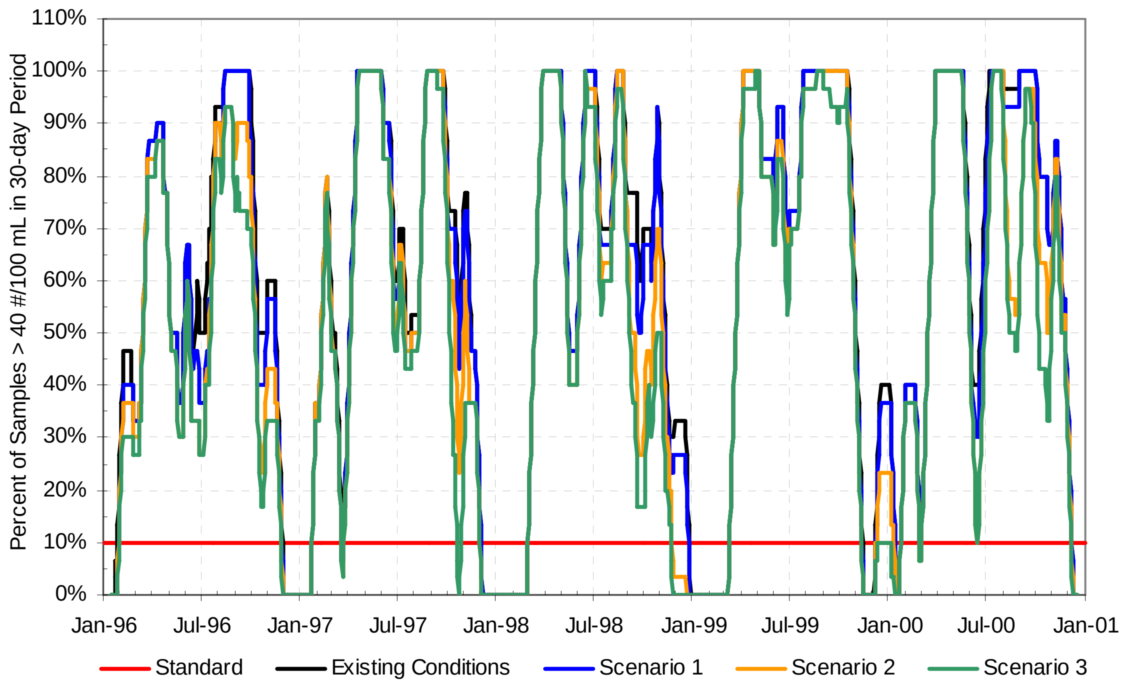



**Figure 6-2. Evaluation of the 30-day not-to-exceed standard at TDML analysis point 112 on the Middle Fork of Chester Creek.**

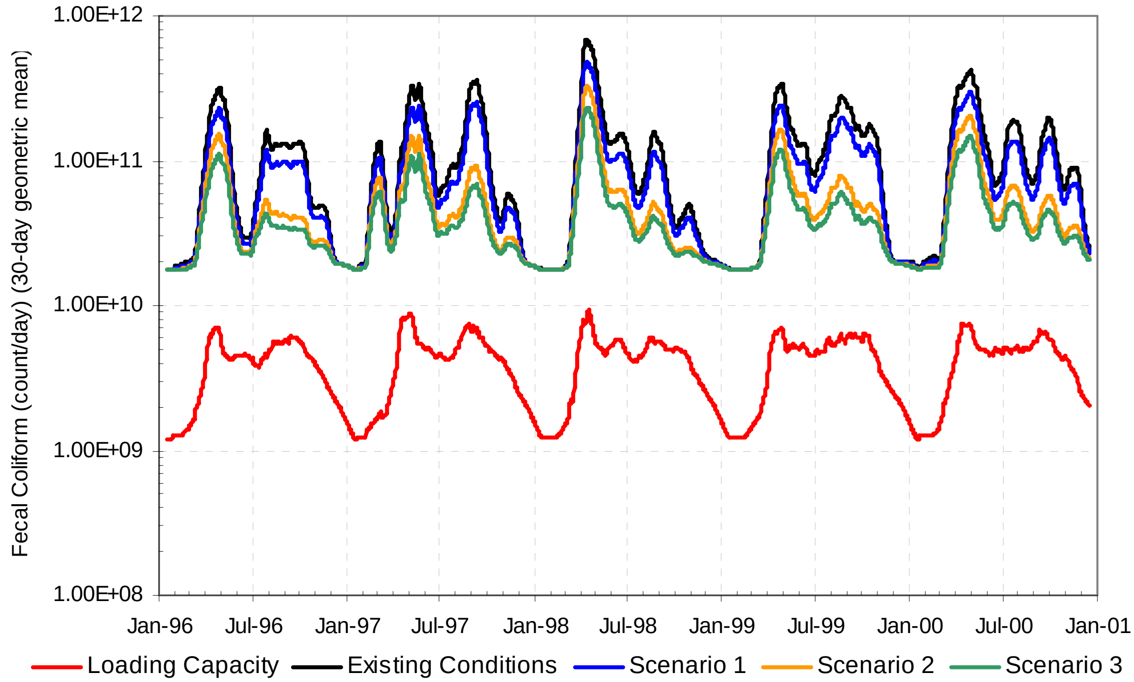



**Figure 6-3. Evaluation of the 30-day geometric mean standard at TMDL analysis point 171 on the South Fork of Chester Creek.**

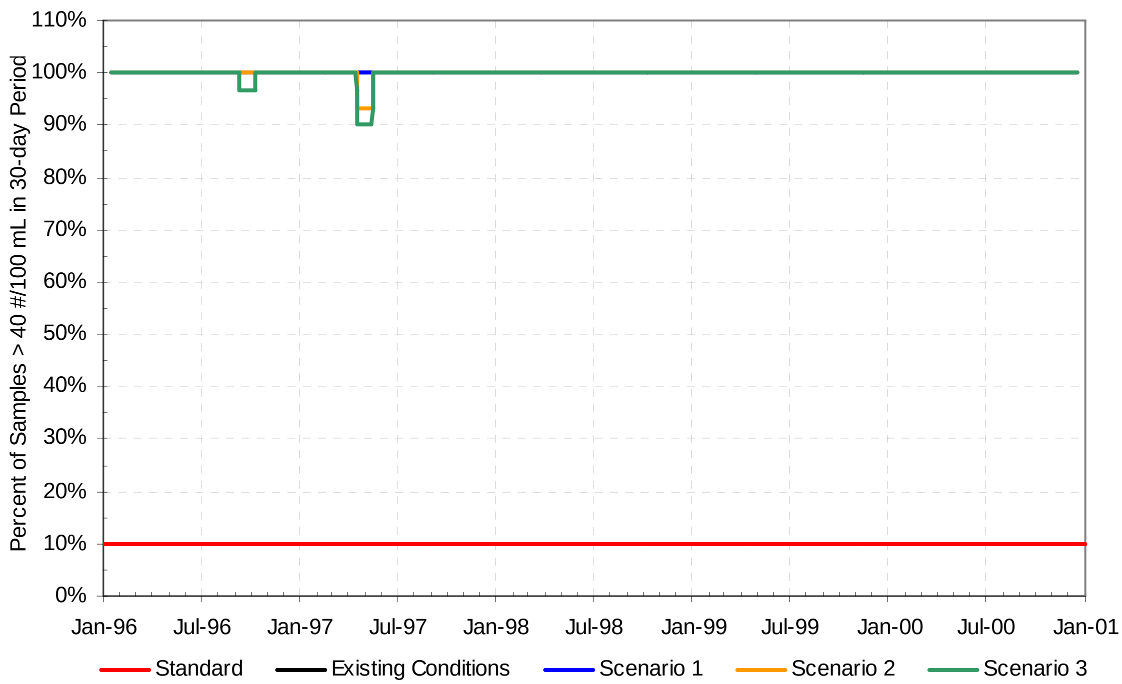



**Figure 6-4. Evaluation of the 30-day not-to-exceed standard at TMDL analysis point 171 on the South Fork of Chester Creek.**

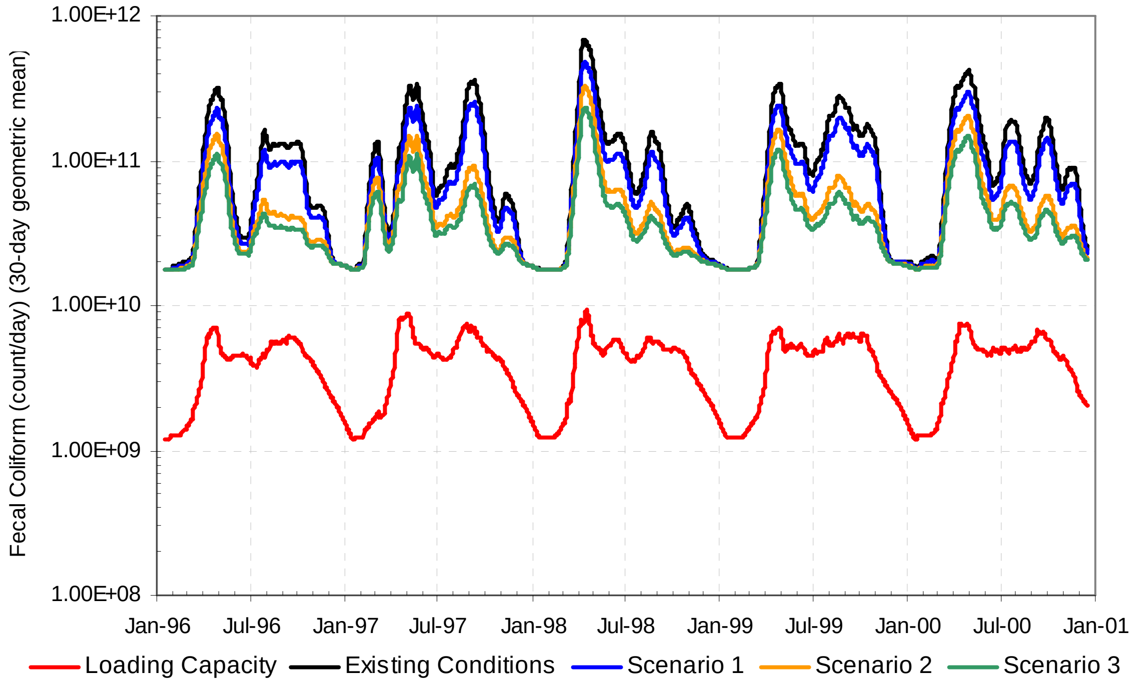



**Figure 6-5. Evaluation of the 30-day geometric mean standard at TMDL analysis point 350 on the South Fork of Chester Creek.**

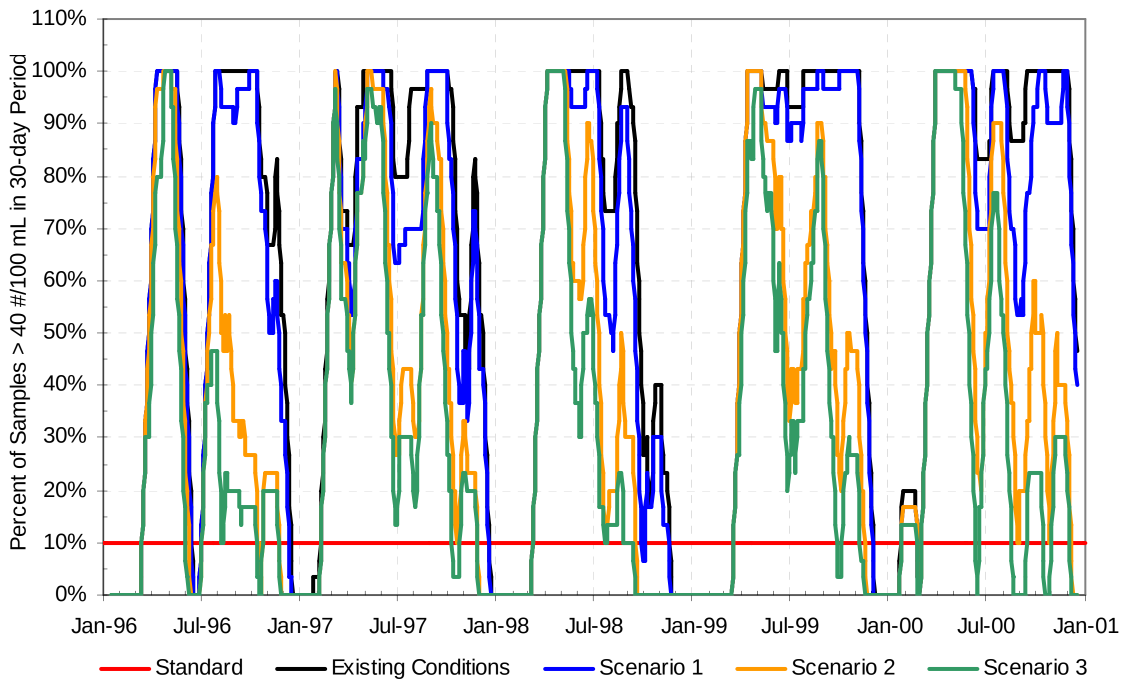



**Figure 6-6. Evaluation of the 30-day not-to-exceed standard at TMDL analysis point 350 on the South Fork of Chester Creek.**

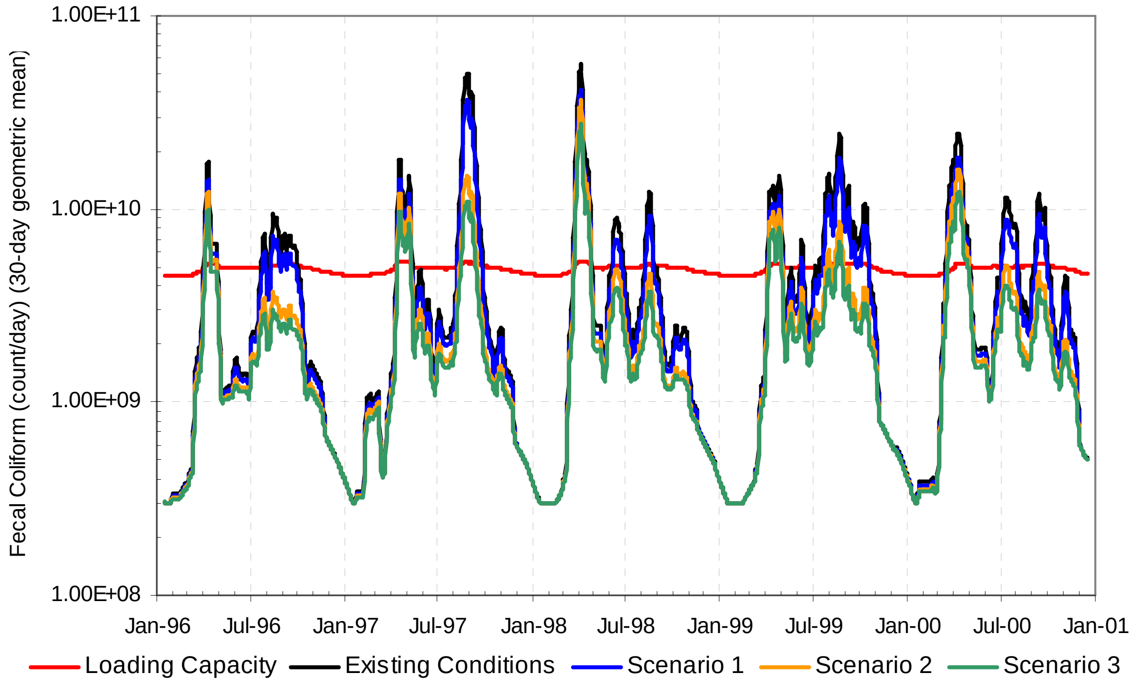



**Figure 6-7. Evaluation of the 30-day geometric mean standard at TMDL analysis point 101 on Chester Creek.**

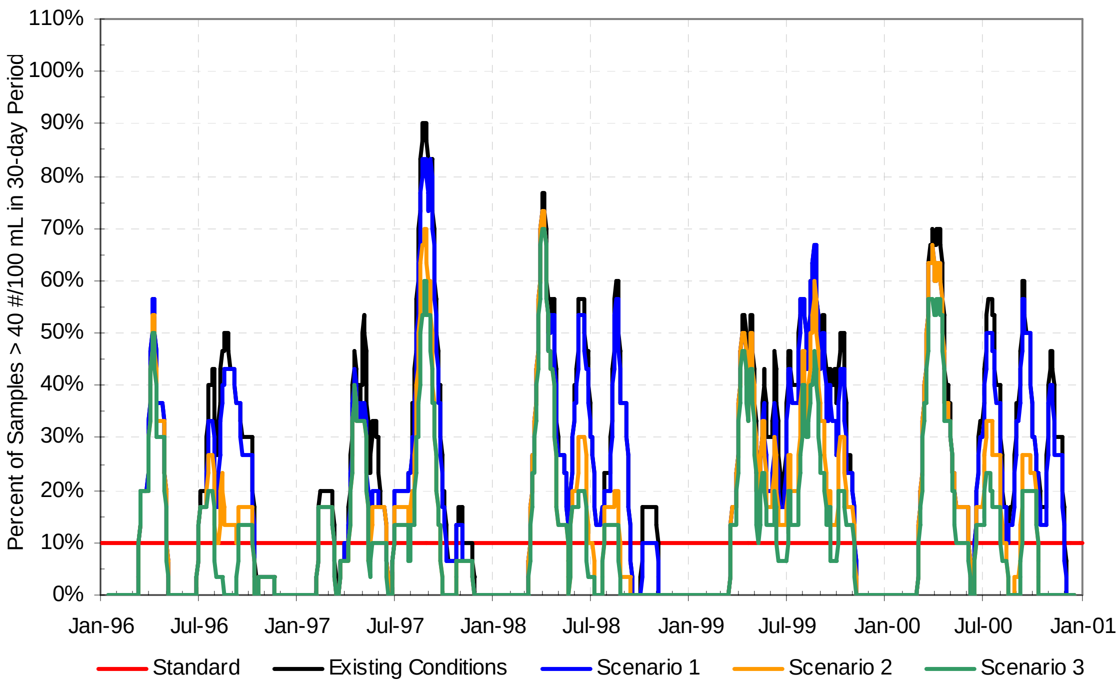



**Figure 6-8. Evaluation of the 30-day not-to-exceed standard at TMDL analysis point 101 on Chester Creek.**

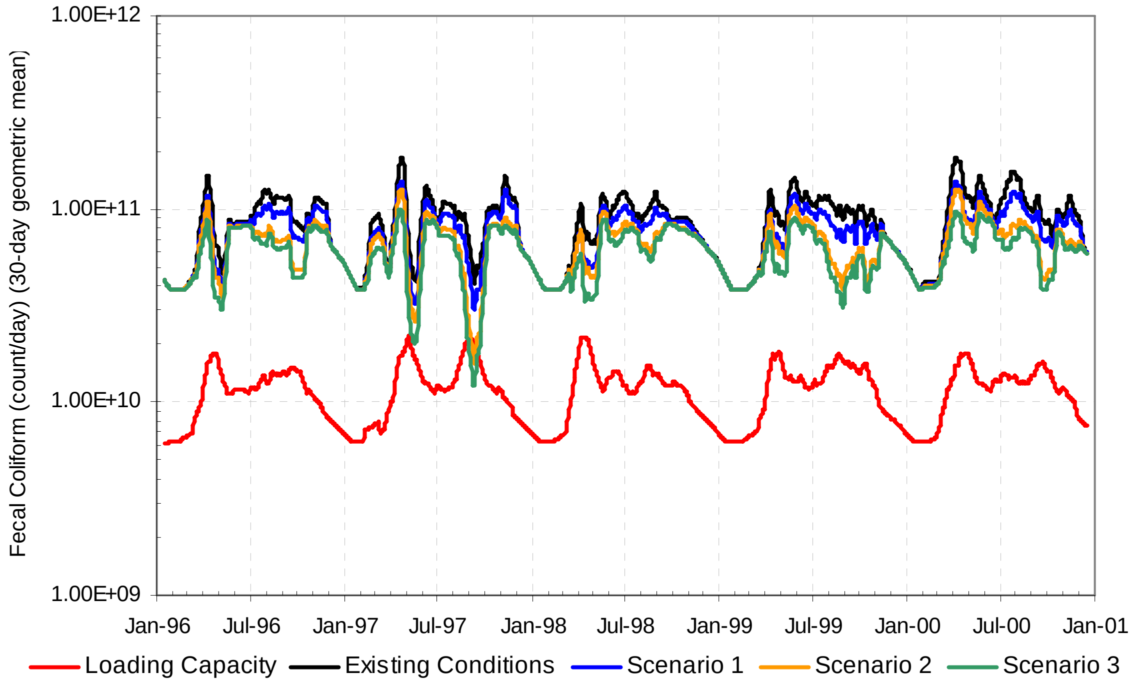



**Figure 6-9. Evaluation of the 30-day geometric mean standard at TMDL analysis point CH2 on Chester Creek.**

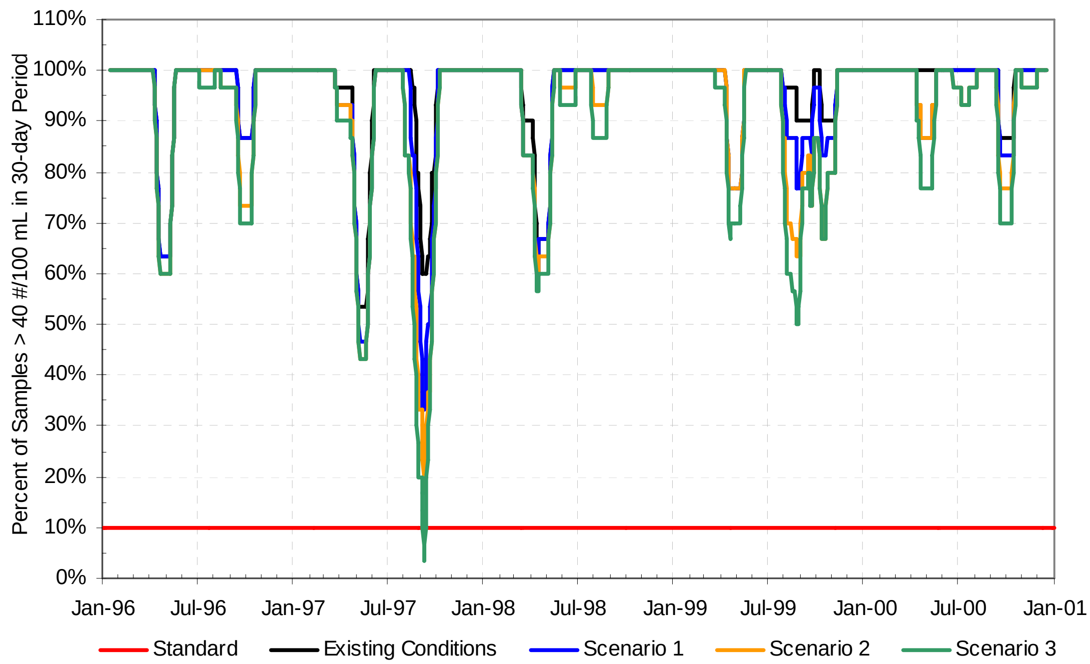



**Figure 6-10. Evaluation of the 30-day not-to-exceed standard at TMDL analysis point CH2 on Chester Creek.**

## 6.2 Load Allocation

Nonpoint sources are typically represented by loads carried to receiving waters through surface runoff resulting from precipitation events. However, because stormwater discharges in the MOA are regulated by a NPDES stormwater permit for municipal separate storm sewer systems (MS4), watershed loads delivered to Chester Creek through stormwater conveyances are addressed through the wasteload allocation component of this TMDL. Because the Chester Creek watershed includes only negligible loading from outside of the municipality that is essentially contributions from wildlife, a load allocation of zero has been set for this TMDL. In other words, all of the human sources of fecal coliform will be captured under the storm water permit and the wasteload allocation and that is why the load allocation is zero.

The rationale that loadings from outside the municipality are essentially natural background is based on previous studies (e.g., Dorava and Love, 1999; Frenzel and Couvillion, 2002), the 1988 to 1993 sampling that indicates geometric means of 5 to 8 counts/100 mL in this area, and more recent sampling at a site located on Fort Richardson. The Fort Richardson site (see Figure 3-1) has been sampled for fecal coliform 74 times over a 25-week period between July 1, 2004 and December 31, 2004 and the geometric mean of that data set is 4.38 FC/100ml. There are no known human sources of fecal coliform above the Fort Richardson site

## 6.3 Wasteload Allocation

The only permitted source of fecal coliform in the Chester Creek watershed is storm water runoff. The MOA is subject to an MS4 permit that regulates storm water discharges and EPA policy and regulation indicate that storm water runoff regulated by the NPDES program through an MS4 permit must be addressed through wasteload allocations in a TMDL (USEPA, 2002). Therefore, the Chester Creek TMDL establishes wasteload allocations for watershed loads of fecal coliform. The wasteload allocation is the loading capacity minus the margin of safety.

The fecal coliform wasteload allocations for Chester Creek, provided as monthly allocations for each the Chester Creek TMDL analysis points, are presented in Tables 6-1 to 6-5. As discussed previously, the tables present monthly wasteload allocations and required reductions for the most restrictive standard for each TMDL assessment point. For example, Table 6-1, representing TMDL analysis point 112, shows that the 10 percent not-to-exceed standard is more restrictive in the months of January, February, and December, and therefore, a greater level of reduction is required for these months relative to the 30-day geometric mean standard. The tables suggest that the greatest monthly fecal coliform loads to Chester Creek, and consequently the greatest required reductions, occur during the spring and summer months. The winter months represent the lowest fecal coliform loads to Chester Creek and also, therefore, require the lowest percent reductions from existing loads.

Future wasteload allocations are not established because ADEC does not anticipate any future permits for the discharge of fecal coliform to Chester Creek. Additionally, if data or information from future monitoring efforts can be used to identify and quantify stormwater or natural loads that are not delivered through the stormwater conveyances, the TMDL and its allocations will be revised accordingly.

**Table 6-1. Summary of the Middle Fork Chester Creek TMDL (Analysis Point 112).**

| Month | Existing (FC/month) | Loading Capacity (FC/month) | Margin of Safety (FC/month) | Waste Load Allocation (FC/month) | Required Reduction |
|---|---|---|---|---|---|
| **Jan** | **3.11E+09** | **2.90E+09** | **2.90E+08** | **2.61E+09** | **7%** |
| **Feb** | **1.45E+12** | **4.78E+11** | **4.78E+10** | **4.30E+11** | **67%** |
| Mar | 8.51E+11 | 3.21E+10 | 3.21E+09 | 2.89E+10 | 96% |
| Apr | 9.58E+12 | 8.85E+10 | 8.85E+09 | 7.96E+10 | 99% |
| May | 2.99E+12 | 6.75E+10 | 6.75E+09 | 6.08E+10 | 98% |
| Jun | 1.10E+12 | 6.44E+10 | 6.44E+09 | 5.80E+10 | 94% |
| Jul | 2.05E+12 | 6.55E+10 | 6.55E+09 | 5.90E+10 | 97% |
| Aug | 5.13E+12 | 8.10E+10 | 8.10E+09 | 7.29E+10 | 98% |
| Sep | 5.12E+12 | 8.07E+10 | 8.07E+09 | 7.26E+10 | 98% |
| Oct | 1.15E+12 | 6.69E+10 | 6.69E+09 | 6.02E+10 | 94% |
| Nov | 2.01E+11 | 4.23E+10 | 4.23E+09 | 3.81E+10 | 79% |
| **Dec** | **2.50E+10** | **1.80E+10** | **1.80E+09** | **1.62E+10** | **28%** |
| Annual | 2.82E+13 | 6.46E+11 | 6.46E+10 | 5.81E+11 | 98% |

Bold denotes monthly loading capacities identified using not-to-exceed standard.
Annual loads are given in FC/year.

**Table 6-2. Summary of the South Fork Chester Creek TMDL (Analysis Point 171).**

| Month | Existing (FC/month) | Loading Capacity (FC/month) | Margin of Safety (FC/month) | Waste Load Allocation (FC/month) | Required Reduction |
|---|---|---|---|---|---|
| Jan | 5.18E+11 | 3.63E+10 | 3.63E+09 | 3.27E+10 | 93% |
| Feb | 7.55E+11 | 3.75E+10 | 3.75E+09 | 3.38E+10 | 95% |
| Mar | 2.01E+12 | 7.25E+10 | 7.25E+09 | 6.53E+10 | 96% |
| Apr | 9.06E+12 | 1.97E+11 | 1.97E+10 | 1.77E+11 | 98% |
| May | 6.87E+12 | 1.66E+11 | 1.66E+10 | 1.49E+11 | 98% |
| Jun | 2.91E+12 | 1.46E+11 | 1.46E+10 | 1.32E+11 | 95% |
| Jul | 3.23E+12 | 1.43E+11 | 1.43E+10 | 1.28E+11 | 96% |
| Aug | 4.75E+12 | 1.74E+11 | 1.74E+10 | 1.56E+11 | 96% |
| Sep | 4.92E+12 | 1.78E+11 | 1.78E+10 | 1.60E+11 | 96% |
| Oct | 2.86E+12 | 1.52E+11 | 1.52E+10 | 1.37E+11 | 95% |
| Nov | 1.57E+12 | 9.81E+10 | 9.81E+09 | 8.83E+10 | 94% |
| Dec | 6.37E+11 | 5.80E+10 | 5.80E+09 | 5.22E+10 | 91% |
| Annual | 4.01E+13 | 1.46E+12 | 1.46E+11 | 1.31E+12 | 96% |

Annual loads are given in FC/year.

**Table 6-3. Summary of the South Fork Chester Creek TMDL (Analysis Point 350).**

| Month | Existing (FC/month) | Loading Capacity (FC/month) | Margin of Safety (FC/month) | Waste Load Allocation (FC/month) | Required Reduction |
|---|---|---|---|---|---|
| Jan | 6.42E+10 | 5.71E+10 | 5.71E+09 | 5.14E+10 | 11% |
| Feb | 1.32E+11 | 5.96E+10 | 5.96E+09 | 5.36E+10 | 55% |
| Mar | 9.09E+11 | 1.15E+11 | 1.15E+10 | 1.04E+11 | 87% |
| Apr | 4.66E+12 | 2.99E+11 | 2.99E+10 | 2.69E+11 | 94% |
| May | 2.88E+12 | 2.53E+11 | 2.53E+10 | 2.27E+11 | 91% |
| Jun | 1.08E+12 | 2.29E+11 | 2.29E+10 | 2.06E+11 | 79% |
| Jul | 1.26E+12 | 2.28E+11 | 2.28E+10 | 2.05E+11 | 82% |
| Aug | 2.28E+12 | 2.77E+11 | 2.77E+10 | 2.49E+11 | 88% |
| Sep | 2.22E+12 | 2.77E+11 | 2.77E+10 | 2.49E+11 | 88% |
| Oct | 1.15E+12 | 2.37E+11 | 2.37E+10 | 2.13E+11 | 79% |
| Nov | 5.77E+11 | 1.55E+11 | 1.55E+10 | 1.39E+11 | 73% |
| Dec | 1.28E+11 | 9.01E+10 | 9.01E+09 | 8.11E+10 | 30% |
| Annual | 1.73E+13 | 2.27E+12 | 2.27E+11 | 2.05E+12 | 87% |

Annual loads are given in FC/year.

**Table 6-4. Summary of the Chester Creek TMDL (Analysis Point 101).**

| Month | Existing (FC/month) | Loading Capacity (FC/month) | Margin of Safety (FC/month) | Waste Load Allocation (FC/month) | Required Reduction |
|---|---|---|---|---|---|
| **Jan** | **9.59E+09** | **8.69E+09** | **8.69E+08** | **7.82E+09** | **9%** |
| **Feb** | **1.26E+11** | **1.04E+11** | **1.04E+10** | **9.35E+10** | **18%** |
| **Mar** | **7.76E+11** | **4.02E+11** | **4.02E+10** | **3.62E+11** | **48%** |
| **Apr** | **4.28E+12** | **1.26E+12** | **1.26E+11** | **1.13E+12** | **71%** |
| **May** | **2.69E+11** | **1.50E+11** | **1.50E+10** | **1.35E+11** | **44%** |
| **Jun** | **2.69E+11** | **1.74E+11** | **1.74E+10** | **1.56E+11** | **36%** |
| **Jul** | **4.87E+11** | **2.76E+11** | **2.76E+10** | **2.49E+11** | **43%** |
| **Aug** | **9.51E+11** | **4.09E+11** | **4.09E+10** | **3.68E+11** | **57%** |
| **Sep** | **8.30E+11** | **3.89E+11** | **3.89E+10** | **3.51E+11** | **53%** |
| **Oct** | **2.85E+11** | **1.82E+11** | **1.82E+10** | **1.64E+11** | **36%** |
| **Nov** | **1.44E+11** | **1.01E+11** | **1.01E+10** | **9.11E+10** | **30%** |
| Dec | 1.63E+10 | 1.63E+10 | 1.63E+09 | 1.47E+10 | 0% |
| **Annual** | **8.44E+12** | **3.47E+12** | **3.47E+11** | **3.12E+12** | **59%** |

Bold denotes monthly loading capacities identified using not-to-exceed standard.
Annual loads are given in FC/year.

**Table 6-5. Summary of the Chester Creek TMDL (Analysis Point CH2).**

| Month | Existing (FC/month) | Loading Capacity (FC/month) | Margin of Safety (FC/month) | Waste Load Allocation (FC/month) | Required Reduction |
|---|---|---|---|---|---|
| Jan | 1.21E+12 | 1.80E+11 | 1.80E+10 | 1.62E+11 | 85% |
| Feb | 1.23E+12 | 1.85E+11 | 1.85E+10 | 1.66E+11 | 85% |
| Mar | 1.98E+12 | 2.75E+11 | 2.75E+10 | 2.48E+11 | 86% |
| Apr | 3.40E+12 | 5.03E+11 | 5.03E+10 | 4.53E+11 | 85% |
| May | 2.84E+12 | 4.39E+11 | 4.39E+10 | 3.95E+11 | 85% |
| Jun | 3.14E+12 | 3.73E+11 | 3.73E+10 | 3.35E+11 | 88% |
| Jul | 3.45E+12 | 3.87E+11 | 3.87E+10 | 3.49E+11 | 89% |
| Aug | 3.28E+12 | 4.58E+11 | 4.58E+10 | 4.12E+11 | 86% |
| Sep | 2.69E+12 | 4.55E+11 | 4.55E+10 | 4.09E+11 | 83% |
| Oct | 2.80E+12 | 3.91E+11 | 3.91E+10 | 3.52E+11 | 86% |
| Nov | 2.91E+12 | 2.91E+11 | 2.91E+10 | 2.62E+11 | 90% |
| Dec | 1.74E+12 | 2.13E+11 | 2.13E+10 | 1.92E+11 | 88% |
| Annual | 3.07E+13 | 4.15E+12 | 4.15E+11 | 3.73E+12 | 86% |

Annual loads are given in FC/year.

## 6.4 Margin of Safety

The margin of safety accounts for any uncertainty concerning the relationship between pollutant loading and receiving water quality and is a required component of a TMDL. The margin of safety can be implicit (e.g., incorporated into the TMDL analysis through conservative assumptions) or explicit (e.g., expressed in the TMDL as a portion of the loading) or a combination of both. For the Chester Creek TMDL, 10 percent of the loading capacity was explicitly reserved for the margin of safety.

## 6.5 Seasonal Variation

A TMDL must consider seasonal variation in the derivation of the allocation. By using continuous simulation (daily modeling), seasonal hydrologic and source loading variability was inherently considered. The fecal coliform counts simulated for each day of the modeling time period were compared to TMDL targets and an allocation that would meet these targets for every day was developed. Allowable loads were also specified by month. Modeling results agree with fecal coliform data collected within the Chester Creek watershed in that spring and summer months account for the greatest loading of fecal coliform to Chester Creek, and that winter months typically account for lower fecal coliform contributions to the creek.

## 6.6 Implementation Scenarios

Three implementation scenarios, selected with consultation with ADEC, were simulated with the calibrated SWMM model. These scenarios are:

- Scenario 1 – Public education. Informing the public about the benefits of “cleaning up” after their pets was assumed to result in a 30 percent decrease in the surface build up of fecal coliform on landscaped, street, directly connected, and indirectly connected impervious land cover types.

- Scenario 2 – Increased street sweeping frequency and efficiency. Street sweeping frequency was increased from monthly to weekly intervals and the efficiency was assumed to increase to eighty percent.

- Scenario 3 – A combination of Scenario 1 and Scenario 2.

Tables 6-6 through 6-15, and Figures 6-11 through 6-20 summarize the results of the implementation scenarios for each of the analysis points in Chester Creek. Table elements in bold type denote that the 10 percent no-to-exceed standard applies for the given month. The tables show that a combination of education and increased street sweeping frequency and efficiency (TMDL scenario 3) could have a significant impact in reducing fecal coliform loading to Chester Creek. Simulation results suggest that an annual percent reduction ranging from 74 percent at analysis point 112 to 29 percent at analysis point CH2 is possible with the implementation of TMDL scenario 3. For each TMDL analysis point, additional reduction in fecal coliform beyond that provided by the TMDL scenarios is required (see Tables 6-7, 6-9, 6-11, 6-13, and 6-15). For example, as presented in Table 6-15, TMDL analysis point CH2 requires an additional 58 percent reduction in fecal coliform on an annual basis to comply with the 30-day geometric mean standard. Significant additional monthly reductions are required at this site to meet water quality standards.

The tables also show decreasing fecal coliform reductions moving downstream in the watershed. This is due to the greater occurrence of lakes and wetlands in the middle to lower portion of the watershed and therefore a greater contribution of fecal coliform contribution from waterfowl relative to the upper portion of the basin. Since the scenarios simulate changes only to the urbanized areas in the watershed they do not impact loadings from wetlands, lakes or forested areas.

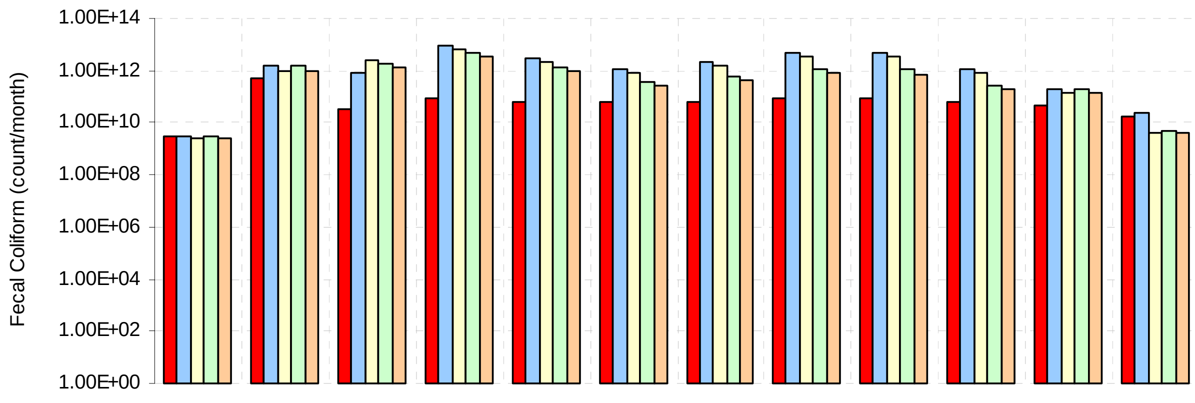
**Table 6-6. Implementation Scenarios for TMDL Analysis Point 112, Middle Fork Chester Creek.**

| ***Scenario 1*** | | | |
|---|---|---|---|
| **Month** | **Existing (FC/month)** | **Post-Scenario (FC/month)** | **Percent Reduction** |
| **January** | **3.11E+09** | **2.52E+09** | **19%** |
| **February** | **1.45E+12** | **1.01E+12** | **30%** |
| March | 8.51E+11 | 6.06E+11 | 29% |
| April | 9.58E+12 | 6.69E+12 | 30% |
| May | 2.99E+12 | 2.10E+12 | 30% |
| June | 1.10E+12 | 7.78E+11 | 29% |
| July | 2.05E+12 | 1.45E+12 | 30% |
| August | 5.13E+12 | 3.60E+12 | 30% |
| September | 5.12E+12 | 3.58E+12 | 30% |
| October | 1.15E+12 | 8.13E+11 | 29% |
| November | 2.01E+11 | 1.47E+11 | 27% |
| **December** | **2.50E+10** | **1.78E+10** | **29%** |
| Annual | 2.82E+13 | 1.98E+13 | 30% |
| ***Scenario 2*** | | | |
| **Month** | **Existing (FC/month)** | **Post-Scenario (FC/month)** | **Percent Reduction** |
| **January** | **3.11E+09** | **3.11E+09** | **0%** |
| **February** | **1.45E+12** | **1.45E+12** | **0%** |
| March | 8.51E+11 | 4.49E+11 | 47% |
| April | 9.58E+12 | 4.87E+12 | 49% |
| May | 2.99E+12 | 1.43E+12 | 52% |
| June | 1.10E+12 | 3.92E+11 | 64% |
| July | 2.05E+12 | 5.78E+11 | 72% |
| August | 5.13E+12 | 1.20E+12 | 77% |
| September | 5.12E+12 | 1.06E+12 | 79% |
| October | 1.15E+12 | 2.50E+11 | 78% |
| November | 2.01E+11 | 2.01E+11 | 0% |
| **December** | **2.50E+10** | **2.50E+10** | **0%** |
| Annual | 2.82E+13 | 1.04E+13 | 63% |
| ***Scenario 3*** | | | |
| **Month** | **Existing (FC/month)** | **Post-Scenario (FC/month)** | **Percent Reduction** |
| January | **3.11E+09** | **2.52E+09** | **19%** |
| February | **1.45E+12** | **1.01E+12** | **30%** |
| March | 8.51E+11 | 3.21E+11 | 62% |
| April | 9.58E+12 | 3.40E+12 | 64% |
| May | 2.99E+12 | 1.00E+12 | 66% |
| June | 1.10E+12 | 2.78E+11 | 75% |
| July | 2.05E+12 | 4.10E+11 | 80% |
| August | 5.13E+12 | 8.46E+11 | 84% |
| September | 5.12E+12 | 7.43E+11 | 85% |
| October | 1.15E+12 | 1.78E+11 | 85% |
| November | 2.01E+11 | 1.47E+11 | 27% |
| December | **2.50E+10** | **1.78E+10** | **29%** |
| Annual | 2.82E+13 | 7.33E+12 | 74% |

**Table 6-7. Summary of TMDL Scenarios for TMDL Analysis Point 112, Middle Fork Chester Creek.**

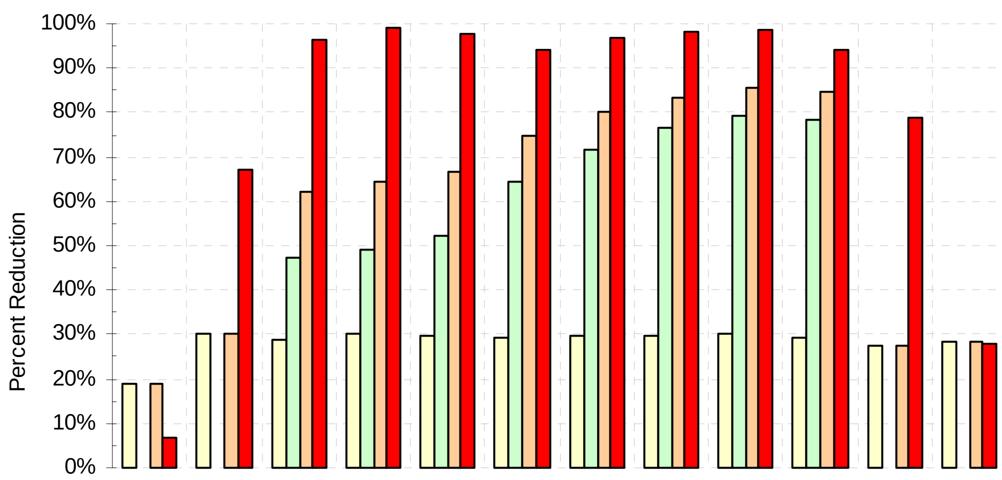
| Month | Required Reduction | Scenario 1 Reduction | Scenario 2 Reduction | Scenario 3 Reduction | Additional Reduction |
|---|---|---|---|---|---|
| **Jan** | **7%** | **19%** | **0%** | **19%** | **0%** |
| **Feb** | **67%** | **30%** | **0%** | **30%** | **37%** |
| Mar | 96% | 29% | 47% | 62% | 34% |
| Apr | 99% | 30% | 49% | 64% | 35% |
| May | 98% | 30% | 52% | 66% | 31% |
| Jun | 94% | 29% | 64% | 75% | 19% |
| Jul | 97% | 30% | 72% | 80% | 17% |
| Aug | 98% | 30% | 77% | 84% | 15% |
| Sep | 98% | 30% | 79% | 85% | 13% |
| Oct | 94% | 29% | 78% | 85% | 10% |
| Nov | 79% | 27% | 0% | 27% | 52% |
| **Dec** | **28%** | **29%** | **0%** | **29%** | **0%** |
| Annual | 98% | 30% | 63% | 74% | 24% |

Bold type indicates that the 10 percent not-to-exceed standard applies for the month.
Annual loads are given in FC/year.




| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Loading Capacity | 2.90E+09 | 4.78E+11 | 3.21E+10 | 8.85E+10 | 6.75E+10 | 6.44E+10 | 6.55E+10 | 8.10E+10 | 8.07E+10 | 6.69E+10 | 4.23E+10 | 1.80E+10 |
| Existing Conditions | 3.11E+09 | 1.45E+12 | 8.51E+11 | 9.58E+12 | 2.99E+12 | 1.10E+12 | 2.05E+12 | 5.13E+12 | 5.12E+12 | 1.15E+12 | 2.01E+11 | 2.50E+10 |
| Scenario 1 | 2.52E+09 | 1.01E+12 | 2.70E+12 | 6.69E+12 | 2.10E+12 | 7.78E+11 | 1.45E+12 | 3.60E+12 | 3.58E+12 | 8.13E+11 | 1.47E+11 | 4.19E+09 |
| Scenario 2 | 3.11E+09 | 1.45E+12 | 1.93E+12 | 4.87E+12 | 1.43E+12 | 3.92E+11 | 5.78E+11 | 1.20E+12 | 1.06E+12 | 2.50E+11 | 2.01E+11 | 4.88E+09 |
| Scenario 3 | 2.52E+09 | 1.01E+12 | 1.35E+12 | 3.40E+12 | 1.00E+12 | 2.78E+11 | 4.10E+11 | 8.46E+11 | 7.43E+11 | 1.78E+11 | 1.47E+11 | 4.19E+09 |

**Figure 6-11. Comparison of monthly loading capacities evaluated by the most restrictive standard to existing loads and TMDL scenario loads at TMDL analysis point 112 on the Middle Fork of Chester Creek.**




| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Scenario 1 | 19% | 30% | 29% | 30% | 30% | 29% | 30% | 30% | 30% | 29% | 27% | 29% |
| Scenario 2 | 0% | 0% | 47% | 49% | 52% | 64% | 72% | 77% | 79% | 78% | 0% | 0% |
| Scenario 3 | 19% | 30% | 62% | 64% | 66% | 75% | 80% | 84% | 85% | 85% | 27% | 29% |
| Required Reduction | 7% | 67% | 96% | 99% | 98% | 94% | 97% | 98% | 98% | 94% | 79% | 28% |

**Figure 6-12. Comparison of monthly loading reductions provided by the TMDL scenarios and loading reductions required by the most restrictive standard at TMDL analysis point 112 on the Middle Fork of Chester Creek.**

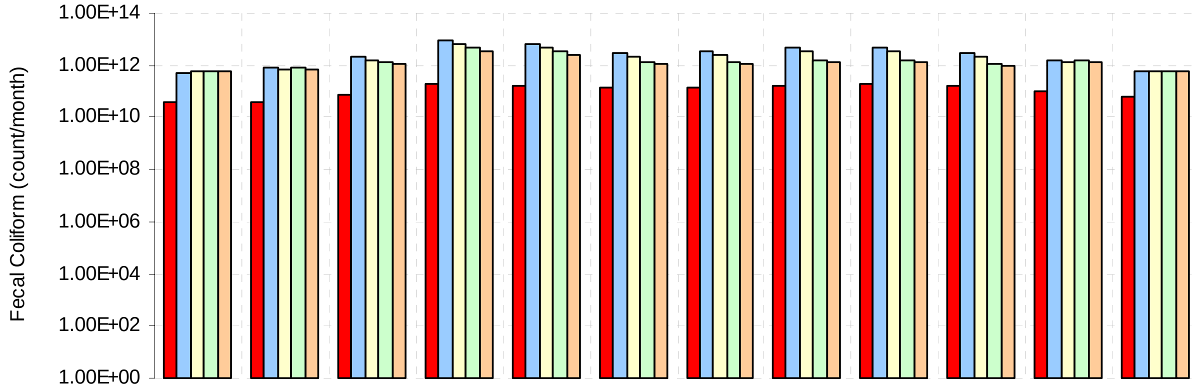
**Table 6-8. Implementation Scenarios for TMDL Analysis Point 171, South Fork Chester Creek.**

| ***Scenario 1*** **Month** | **Existing (FC/month)** | **Post-Scenario (FC/month)** | **Percent Reduction** |
|---|---|---|---|
| January | 5.18E+11 | 5.14E+11 | 1% |
| February | 7.55E+11 | 6.93E+11 | 8% |
| March | 2.01E+12 | 1.64E+12 | 18% |
| April | 9.06E+12 | 6.50E+12 | 28% |
| May | 6.87E+12 | 4.97E+12 | 28% |
| June | 2.91E+12 | 2.22E+12 | 24% |
| July | 3.23E+12 | 2.46E+12 | 24% |
| August | 4.75E+12 | 3.50E+12 | 26% |
| September | 4.92E+12 | 3.60E+12 | 27% |
| October | 2.86E+12 | 2.20E+12 | 23% |
| November | 1.57E+12 | 1.30E+12 | 17% |
| December | 6.37E+11 | 6.12E+11 | 4% |
| Annual | 4.01E+13 | 3.02E+13 | 25% |
| ***Scenario 2*** **Month** | **Existing (FC/month)** | **Post-Scenario (FC/month)** | **Percent Reduction** |
| January | 5.18E+11 | 5.18E+11 | 0% |
| February | 7.55E+11 | 7.55E+11 | 0% |
| March | 2.01E+12 | 1.36E+12 | 32% |
| April | 9.06E+12 | 4.50E+12 | 50% |
| May | 6.87E+12 | 3.24E+12 | 53% |
| June | 2.91E+12 | 1.42E+12 | 51% |
| July | 3.23E+12 | 1.39E+12 | 57% |
| August | 4.75E+12 | 1.61E+12 | 66% |
| September | 4.92E+12 | 1.52E+12 | 69% |
| October | 2.86E+12 | 1.19E+12 | 58% |
| November | 1.57E+12 | 1.57E+12 | 0% |
| December | 6.37E+11 | 6.37E+11 | 0% |
| Annual | 4.01E+13 | 1.95E+13 | 51% |
| ***Scenario 3*** **Month** | **Existing (FC/month)** | **Post-Scenario (FC/month)** | **Percent Reduction** |
| January | 5.18E+11 | 5.14E+11 | 1% |
| February | 7.55E+11 | 6.93E+11 | 8% |
| March | 2.01E+12 | 1.16E+12 | 42% |
| April | 9.06E+12 | 3.29E+12 | 64% |
| May | 6.87E+12 | 2.44E+12 | 65% |
| June | 2.91E+12 | 1.17E+12 | 60% |
| July | 3.23E+12 | 1.15E+12 | 64% |
| August | 4.75E+12 | 1.29E+12 | 73% |
| September | 4.92E+12 | 1.22E+12 | 75% |
| October | 2.86E+12 | 1.02E+12 | 64% |
| November | 1.57E+12 | 1.30E+12 | 17% |
| December | 6.37E+11 | 6.12E+11 | 4% |
| Annual | 4.01E+13 | 1.57E+13 | 61% |

**Table 6-9. Summary of TMDL Scenarios for TMDL Analysis Point 171, South Fork Chester Creek.**

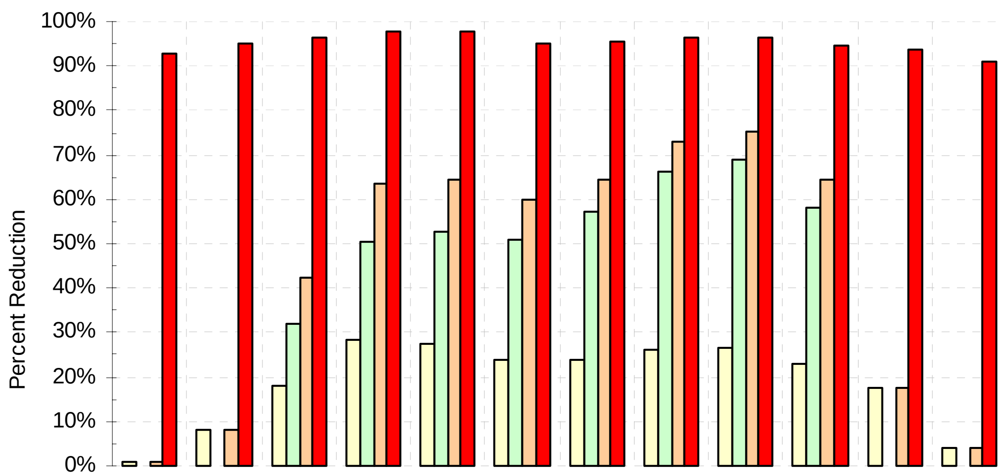
| Month | Required Reduction | Scenario 1 Reduction | Scenario 2 Reduction | Scenario 3 Reduction | Additional Reduction |
|---|---|---|---|---|---|
| January | 93% | 1% | 0% | 1% | 92% |
| February | 95% | 8% | 0% | 8% | 87% |
| March | 96% | 18% | 32% | 42% | 54% |
| April | 98% | 28% | 50% | 64% | 34% |
| May | 98% | 28% | 53% | 65% | 33% |
| June | 95% | 24% | 51% | 60% | 35% |
| July | 96% | 24% | 57% | 64% | 31% |
| August | 96% | 26% | 66% | 73% | 23% |
| September | 96% | 27% | 69% | 75% | 21% |
| October | 95% | 23% | 58% | 64% | 30% |
| November | 94% | 17% | 0% | 17% | 76% |
| December | 91% | 4% | 0% | 4% | 87% |
| Annual | 96% | 25% | 51% | 61% | 36% |

Annual loads are given in FC/year.




| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Loading Capacity | 3.63E+10 | 3.75E+10 | 7.25E+10 | 1.97E+11 | 1.66E+11 | 1.46E+11 | 1.43E+11 | 1.74E+11 | 1.78E+11 | 1.52E+11 | 9.81E+10 | 5.80E+10 |
| Existing Conditions | 5.18E+11 | 7.55E+11 | 2.01E+12 | 9.06E+12 | 6.87E+12 | 2.91E+12 | 3.23E+12 | 4.75E+12 | 4.92E+12 | 2.86E+12 | 1.57E+12 | 6.37E+11 |
| Scenario 1 | 5.58E+11 | 6.93E+11 | 1.64E+12 | 6.50E+12 | 4.97E+12 | 2.22E+12 | 2.46E+12 | 3.50E+12 | 3.60E+12 | 2.20E+12 | 1.30E+12 | 6.12E+11 |
| Scenario 2 | 5.60E+11 | 7.55E+11 | 1.36E+12 | 4.50E+12 | 3.24E+12 | 1.42E+12 | 1.39E+12 | 1.61E+12 | 1.52E+12 | 1.19E+12 | 1.57E+12 | 6.37E+11 |
| Scenario 3 | 5.58E+11 | 6.93E+11 | 1.16E+12 | 3.29E+12 | 2.44E+12 | 1.17E+12 | 1.15E+12 | 1.29E+12 | 1.22E+12 | 1.02E+12 | 1.30E+12 | 6.12E+11 |

**Figure 6-13. Comparison of monthly loading capacities evaluated by the most restrictive standard to existing loads and TMDL scenario loads at TMDL analysis point 171 on the South Fork of Chester Creek.**




| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Scenario 1 | 1% | 8% | 18% | 28% | 28% | 24% | 24% | 26% | 27% | 23% | 17% | 4% |
| Scenario 2 | 0% | 0% | 32% | 50% | 53% | 51% | 57% | 66% | 69% | 58% | 0% | 0% |
| Scenario 3 | 1% | 8% | 42% | 64% | 65% | 60% | 64% | 73% | 75% | 64% | 17% | 4% |
| Required Reduction | 93% | 95% | 96% | 98% | 98% | 95% | 96% | 96% | 96% | 95% | 94% | 91% |

**Figure 6-14. Comparison of monthly loading reductions provided by the TMDL scenarios and loading reductions required by the most restrictive standard at TMDL analysis point 171 on the South Fork of Chester Creek.**

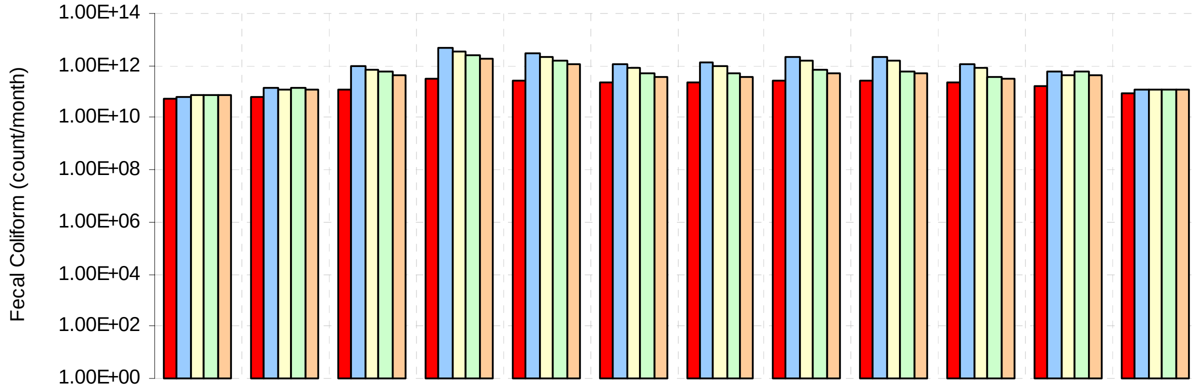
Table 6-10. Implementation Scenarios for TMDL Analysis Point 350, South Fork Chester Creek.

| Month | Existing (FC/month) | Post-Scenario (FC/month) | Percent Reduction |
|---|---|---|---|
| ***Scenario 1*** | | | |
| January | 6.42E+10 | 6.34E+10 | 1% |
| February | 1.32E+11 | 1.15E+11 | 13% |
| March | 9.09E+11 | 6.97E+11 | 23% |
| April | 4.66E+12 | 3.31E+12 | 29% |
| May | 2.88E+12 | 2.04E+12 | 29% |
| June | 1.08E+12 | 7.96E+11 | 27% |
| July | 1.26E+12 | 9.28E+11 | 26% |
| August | 2.28E+12 | 1.63E+12 | 28% |
| September | 2.22E+12 | 1.59E+12 | 28% |
| October | 1.15E+12 | 8.44E+11 | 26% |
| November | 5.77E+11 | 4.45E+11 | 23% |
| December | 1.28E+11 | 1.16E+11 | 10% |
| Annual | 1.73E+13 | 1.26E+13 | 27% |
| ***Scenario 2*** | | | |
| **Month** | **Existing (FC/month)** | **Post-Scenario (FC/month)** | **Percent Reduction** |
| January | 6.42E+10 | 6.42E+10 | 0% |
| February | 1.32E+11 | 1.32E+11 | 0% |
| March | 9.09E+11 | 5.92E+11 | 35% |
| April | 4.66E+12 | 2.63E+12 | 44% |
| May | 2.88E+12 | 1.45E+12 | 50% |
| June | 1.08E+12 | 4.96E+11 | 54% |
| July | 1.26E+12 | 4.95E+11 | 61% |
| August | 2.28E+12 | 7.03E+11 | 69% |
| September | 2.22E+12 | 6.17E+11 | 72% |
| October | 1.15E+12 | 3.94E+11 | 66% |
| November | 5.77E+11 | 5.77E+11 | 0% |
| December | 1.28E+11 | 1.28E+11 | 0% |
| Annual | 1.73E+13 | 8.19E+12 | 53% |
| ***Scenario 3*** | | | |
| **Month** | **Existing (FC/month)** | **Post-Scenario (FC/month)** | **Percent Reduction** |
| January | 6.42E+10 | 6.34E+10 | 1% |
| February | 1.32E+11 | 1.15E+11 | 13% |
| March | 9.09E+11 | 4.64E+11 | 49% |
| April | 4.66E+12 | 1.89E+12 | 59% |
| May | 2.88E+12 | 1.05E+12 | 63% |
| June | 1.08E+12 | 3.84E+11 | 65% |
| July | 1.26E+12 | 3.87E+11 | 69% |
| August | 2.28E+12 | 5.31E+11 | 77% |
| September | 2.22E+12 | 4.68E+11 | 79% |
| October | 1.15E+12 | 3.17E+11 | 72% |
| November | 5.77E+11 | 4.45E+11 | 23% |
| December | 1.28E+11 | 1.16E+11 | 10% |
| Annual | 1.73E+13 | 6.16E+12 | 64% |

**Table 6-11. Summary of TMDL Scenarios for TMDL Analysis Point 350 on the South Fork Chester Creek.**

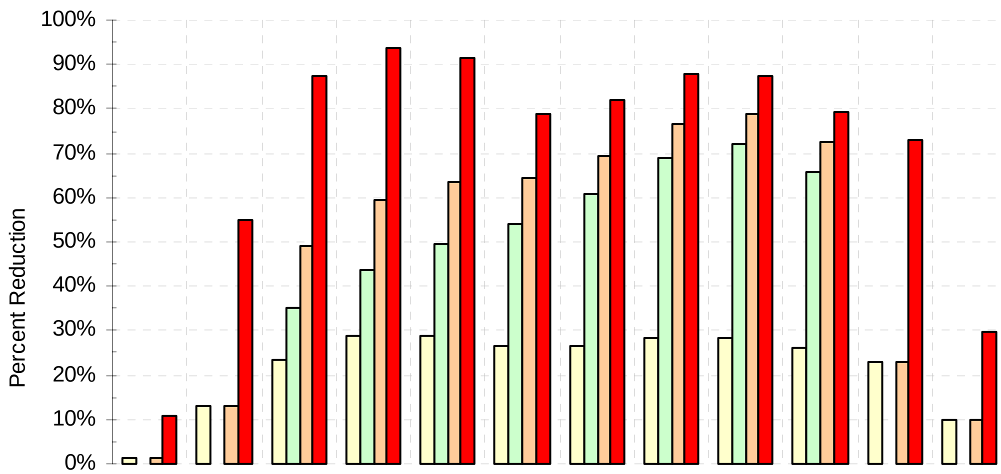
| Month | Required Reduction | Scenario 1 Reduction | Scenario 2 Reduction | Scenario 3 Reduction | Additional Reduction |
|---|---|---|---|---|---|
| January | 11% | 1% | 0% | 1% | 10% |
| February | 55% | 13% | 0% | 13% | 42% |
| March | 87% | 23% | 35% | 49% | 38% |
| April | 94% | 29% | 44% | 59% | 34% |
| May | 91% | 29% | 50% | 63% | 28% |
| June | 79% | 27% | 54% | 65% | 14% |
| July | 82% | 26% | 61% | 69% | 13% |
| August | 88% | 28% | 69% | 77% | 11% |
| September | 88% | 28% | 72% | 79% | 9% |
| October | 79% | 26% | 66% | 72% | 7% |
| November | 73% | 23% | 0% | 23% | 50% |
| December | 30% | 10% | 0% | 10% | 20% |
| Annual | 87% | 27% | 53% | 64% | 22% |

Annual loads are given in FC/year.




| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Loading Capacity | 5.71E+10 | 5.96E+10 | 1.15E+11 | 2.99E+11 | 2.53E+11 | 2.29E+11 | 2.28E+11 | 2.77E+11 | 2.77E+11 | 2.37E+11 | 1.55E+11 | 9.01E+10 |
| Existing Conditions | 6.42E+10 | 1.32E+11 | 9.09E+11 | 4.66E+12 | 2.88E+12 | 1.08E+12 | 1.26E+12 | 2.28E+12 | 2.22E+12 | 1.15E+12 | 5.77E+11 | 1.28E+11 |
| Scenario 1 | 6.83E+10 | 1.15E+11 | 6.97E+11 | 3.31E+12 | 2.04E+12 | 7.96E+11 | 9.28E+11 | 1.63E+12 | 1.59E+12 | 8.44E+11 | 4.45E+11 | 1.16E+11 |
| Scenario 2 | 6.88E+10 | 1.32E+11 | 5.92E+11 | 2.63E+12 | 1.45E+12 | 4.96E+11 | 4.95E+11 | 7.03E+11 | 6.17E+11 | 3.94E+11 | 5.77E+11 | 1.28E+11 |
| Scenario 3 | 6.83E+10 | 1.15E+11 | 4.64E+11 | 1.89E+12 | 1.05E+12 | 3.84E+11 | 3.87E+11 | 5.31E+11 | 4.68E+11 | 3.17E+11 | 4.45E+11 | 1.16E+11 |

**Figure 6-15. Comparison of monthly loading capacities evaluated by the most restrictive standard to existing loads and TMDL scenario loads at TMDL analysis point 350 on the South Fork of Chester Creek.**




| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Scenario 1 | 1% | 13% | 23% | 29% | 29% | 27% | 26% | 28% | 28% | 26% | 23% | 10% |
| Scenario 2 | 0% | 0% | 35% | 44% | 50% | 54% | 61% | 69% | 72% | 66% | 0% | 0% |
| Scenario 3 | 1% | 13% | 49% | 59% | 63% | 65% | 69% | 77% | 79% | 72% | 23% | 10% |
| Required Reduction | 11% | 55% | 87% | 94% | 91% | 79% | 82% | 88% | 88% | 79% | 73% | 30% |

**Figure 6-16. Comparison of monthly loading reductions provided by the TMDL scenarios and loading reductions required by the most restrictive standard at TMDL analysis point 350 on the South Fork of Chester Creek.**

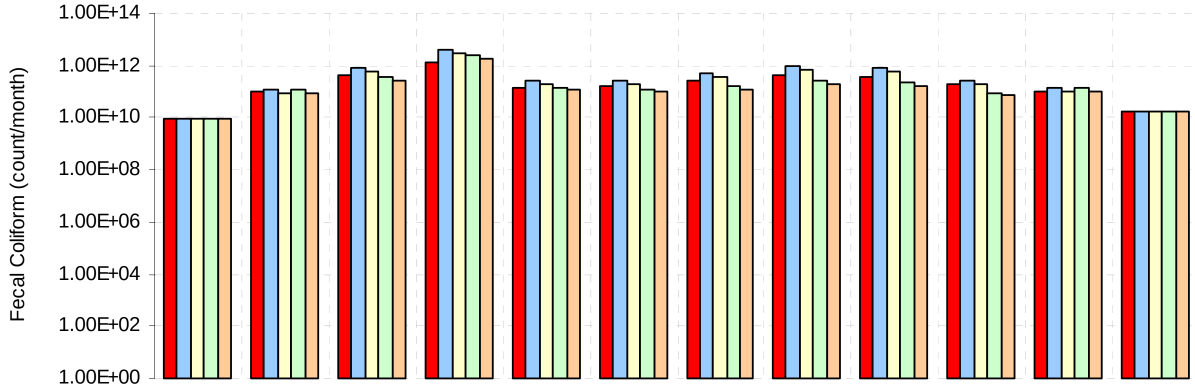
**Table 6-12. Implementation Scenarios for TMDL Analysis Point 101 on Chester Creek.**

| *Scenario 1* Month | Existing (FC/month) | Post-Scenario (FC/month) | Percent Reduction |
|---|---|---|---|
| January | 9.59E+09 | 9.58E+09 | 0% |
| February | 1.26E+11 | 9.07E+10 | 28% |
| March | 7.76E+11 | 5.45E+11 | 30% |
| April | 4.28E+12 | 2.99E+12 | 30% |
| May | 2.69E+11 | 1.96E+11 | 27% |
| June | 2.69E+11 | 1.97E+11 | 27% |
| July | 4.87E+11 | 3.48E+11 | 29% |
| August | 9.51E+11 | 6.73E+11 | 29% |
| September | 8.30E+11 | 5.89E+11 | 29% |
| October | 2.85E+11 | 2.08E+11 | 27% |
| November | 1.44E+11 | 1.07E+11 | 26% |
| December | 1.46E+10 | 1.45E+10 | 1% |
| Annual | 8.44E+12 | 5.97E+12 | 29% |
| *Scenario 2* Month | Existing (FC/month) | Post-Scenario (FC/month) | Percent Reduction |
| January | 9.59E+09 | 9.59E+09 | 0% |
| February | 1.26E+11 | 1.26E+11 | 0% |
| March | 7.76E+11 | 3.87E+11 | 50% |
| April | 4.28E+12 | 2.58E+12 | 40% |
| May | 2.69E+11 | 1.48E+11 | 45% |
| June | 2.69E+11 | 1.22E+11 | 55% |
| July | 4.87E+11 | 1.69E+11 | 65% |
| August | 9.51E+11 | 2.72E+11 | 71% |
| September | 8.30E+11 | 2.18E+11 | 74% |
| October | 2.85E+11 | 8.43E+10 | 70% |
| November | 1.44E+11 | 1.44E+11 | 0% |
| December | 1.46E+10 | 1.46E+10 | 0% |
| Annual | 8.44E+12 | 4.27E+12 | 49% |
| *Scenario 3* Month | Existing (FC/month) | Post-Scenario (FC/month) | Percent Reduction |
| January | 9.59E+09 | 9.58E+09 | 0% |
| February | 1.26E+11 | 9.07E+10 | 28% |
| March | 7.76E+11 | 2.74E+11 | 65% |
| April | 4.28E+12 | 1.81E+12 | 58% |
| May | 2.69E+11 | 1.12E+11 | 58% |
| June | 2.69E+11 | 9.45E+10 | 65% |
| July | 4.87E+11 | 1.26E+11 | 74% |
| August | 9.51E+11 | 1.99E+11 | 79% |
| September | 8.30E+11 | 1.62E+11 | 81% |
| October | 2.85E+11 | 6.83E+10 | 76% |
| November | 1.44E+11 | 1.07E+11 | 26% |
| December | 1.46E+10 | 1.45E+10 | 1% |
| Annual | 8.44E+12 | 3.06E+12 | 64% |

**Table 6-13. Summary of TMDL Scenarios for TMDL Analysis Point 101 on Chester Creek.**

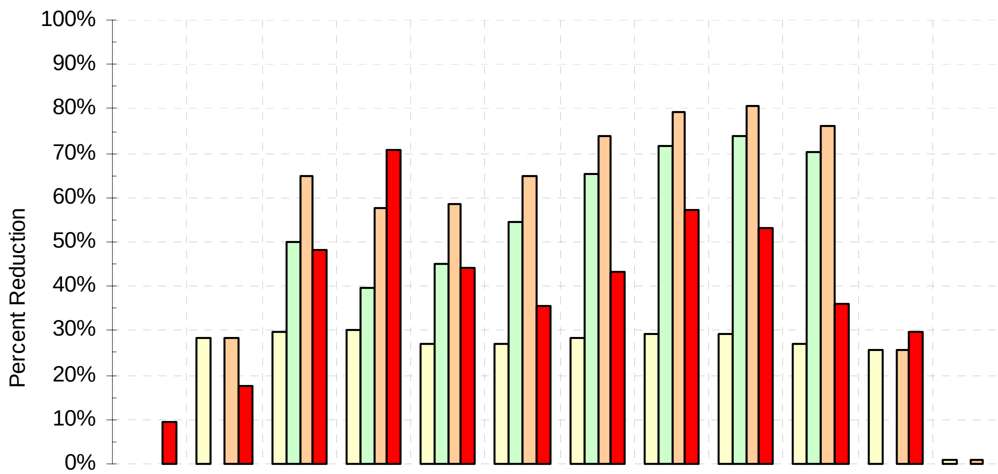
| Month | Required Reduction | Scenario 1 Reduction | Scenario 2 Reduction | Scenario 3 Reduction | Additional Reduction |
|---|---|---|---|---|---|
| **January** | **9%** | **0%** | **0%** | **0%** | **9%** |
| **February** | **18%** | **28%** | **0%** | **28%** | **0%** |
| **March** | **48%** | **30%** | **50%** | **65%** | **0%** |
| **April** | **71%** | **30%** | **40%** | **58%** | **13%** |
| **May** | **44%** | **27%** | **45%** | **58%** | **0%** |
| **June** | **36%** | **27%** | **55%** | **65%** | **0%** |
| **July** | **43%** | **29%** | **65%** | **74%** | **0%** |
| **August** | **57%** | **29%** | **71%** | **79%** | **0%** |
| **September** | **53%** | **29%** | **74%** | **81%** | **0%** |
| **October** | **36%** | **27%** | **70%** | **76%** | **0%** |
| **November** | **30%** | **26%** | **0%** | **26%** | **4%** |
| December | 0% | 1% | 0% | 1% | 0% |
| **Annual** | **59%** | **29%** | **49%** | **64%** | **0%** |

Bold type indicates that the 10 percent not-to-exceed standard applies for the month.
Annual loads are given in FC/year.




| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Loading Capacity | 8.69E+09 | 1.04E+11 | 4.02E+11 | 1.26E+12 | 1.50E+11 | 1.74E+11 | 2.76E+11 | 4.09E+11 | 3.89E+11 | 1.82E+11 | 1.01E+11 | 1.63E+10 |
| Existing Conditions | 9.59E+09 | 1.26E+11 | 7.76E+11 | 4.28E+12 | 2.69E+11 | 2.69E+11 | 4.87E+11 | 9.51E+11 | 8.30E+11 | 2.85E+11 | 1.44E+11 | 1.63E+10 |
| Scenario 1 | 9.58E+09 | 9.07E+10 | 5.45E+11 | 2.99E+12 | 1.96E+11 | 1.97E+11 | 3.48E+11 | 6.73E+11 | 5.89E+11 | 2.08E+11 | 1.07E+11 | 1.62E+10 |
| Scenario 2 | 9.59E+09 | 1.26E+11 | 3.87E+11 | 2.58E+12 | 1.48E+11 | 1.22E+11 | 1.69E+11 | 2.72E+11 | 2.18E+11 | 8.43E+10 | 1.44E+11 | 1.63E+10 |
| Scenario 3 | 9.58E+09 | 9.07E+10 | 2.74E+11 | 1.81E+12 | 1.12E+11 | 9.45E+10 | 1.26E+11 | 1.99E+11 | 1.62E+11 | 6.83E+10 | 1.07E+11 | 1.62E+10 |

**Figure 6-17. Comparison of monthly loading capacities evaluated by the most restrictive standard to existing loads and TMDL scenario loads at TMDL analysis point 101 on the South Fork of Chester Creek.**




| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Scenario 1 | 0% | 28% | 30% | 30% | 27% | 27% | 29% | 29% | 29% | 27% | 26% | 1% |
| Scenario 2 | 0% | 0% | 50% | 40% | 45% | 55% | 65% | 71% | 74% | 70% | 0% | 0% |
| Scenario 3 | 0% | 28% | 65% | 58% | 58% | 65% | 74% | 79% | 81% | 76% | 26% | 1% |
| Required Reduction | 9% | 18% | 48% | 71% | 44% | 36% | 43% | 57% | 53% | 36% | 30% | 0% |

**Figure 6-18. Comparison of monthly loading reductions provided by the TMDL scenarios and loading reductions required by the most restrictive standard at TMDL analysis point 101 on the South Fork of Chester Creek.**

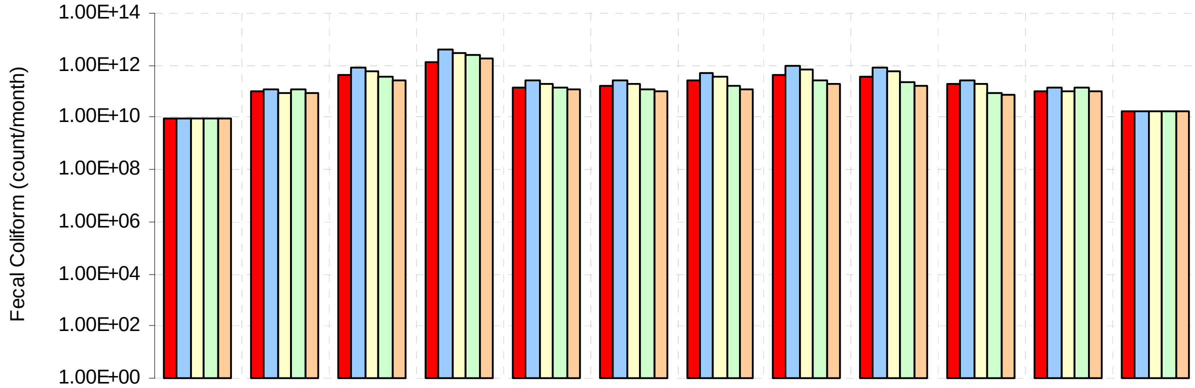
**Table 6-14. Implementation Scenarios for TMDL Analysis Point CH2, Chester Creek.**

| ***Scenario 1*** | | | |
|---|---|---|---|
| **Month** | **Existing (FC/month)** | **Post-Scenario (FC/month)** | **Percent Reduction** |
| January | 1.21E+12 | 1.21E+12 | 0% |
| February | 1.23E+12 | 1.18E+12 | 4% |
| March | 1.98E+12 | 1.78E+12 | 10% |
| April | 3.40E+12 | 2.61E+12 | 23% |
| May | 2.84E+12 | 2.35E+12 | 17% |
| June | 3.14E+12 | 2.81E+12 | 11% |
| July | 3.45E+12 | 2.96E+12 | 14% |
| August | 3.28E+12 | 2.72E+12 | 17% |
| September | 2.69E+12 | 2.27E+12 | 16% |
| October | 2.80E+12 | 2.53E+12 | 10% |
| November | 2.91E+12 | 2.66E+12 | 9% |
| December | 1.74E+12 | 1.72E+12 | 1% |
| Annual | 3.07E+13 | 2.68E+13 | 13% |
| ***Scenario 2*** | | | |
| **Month** | **Existing (FC/month)** | **Post-Scenario (FC/month)** | **Percent Reduction** |
| January | 1.21E+12 | 1.21E+12 | 0% |
| February | 1.23E+12 | 1.23E+12 | 0% |
| March | 1.98E+12 | 1.73E+12 | 13% |
| April | 3.40E+12 | 2.44E+12 | 28% |
| May | 2.84E+12 | 2.13E+12 | 25% |
| June | 3.14E+12 | 2.53E+12 | 20% |
| July | 3.45E+12 | 2.39E+12 | 31% |
| August | 3.28E+12 | 1.99E+12 | 39% |
| September | 2.69E+12 | 1.65E+12 | 39% |
| October | 2.80E+12 | 2.14E+12 | 24% |
| November | 2.91E+12 | 2.91E+12 | 0% |
| December | 1.74E+12 | 1.74E+12 | 0% |
| Annual | 3.07E+13 | 2.40E+13 | 22% |
| ***Scenario 3*** | | | |
| **Month** | **Existing (FC/month)** | **Post-Scenario (FC/month)** | **Percent Reduction** |
| January | 1.21E+12 | 1.21E+12 | 0% |
| February | 1.23E+12 | 1.18E+12 | 4% |
| March | 1.98E+12 | 1.58E+12 | 20% |
| April | 3.40E+12 | 1.91E+12 | 44% |
| May | 2.84E+12 | 1.84E+12 | 35% |
| June | 3.14E+12 | 2.36E+12 | 25% |
| July | 3.45E+12 | 2.18E+12 | 37% |
| August | 3.28E+12 | 1.78E+12 | 46% |
| September | 2.69E+12 | 1.52E+12 | 44% |
| October | 2.80E+12 | 2.04E+12 | 27% |
| November | 2.91E+12 | 2.66E+12 | 9% |
| December | 1.74E+12 | 1.72E+12 | 1% |
| Annual | 3.07E+13 | 2.19E+13 | 29% |

**Table 6-15. Summary of TMDL Scenarios for TMDL Analysis Point CH2, Chester Creek.**

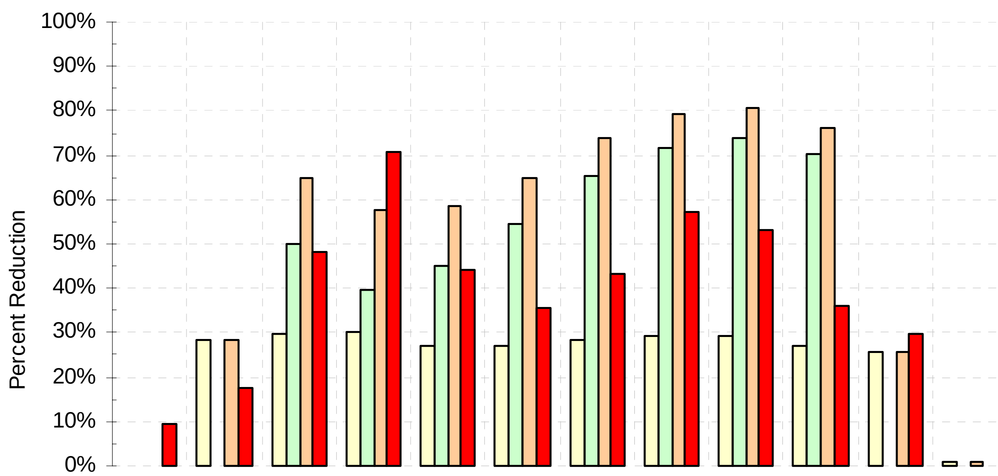
| Month | Required Reduction | Scenario 1 Reduction | Scenario 2 Reduction | Scenario 3 Reduction | Additional Reduction |
|---|---|---|---|---|---|
| January | 85% | 0% | 0% | 0% | 85% |
| February | 85% | 4% | 0% | 4% | 81% |
| March | 86% | 10% | 13% | 20% | 66% |
| April | 85% | 23% | 28% | 44% | 42% |
| May | 85% | 17% | 25% | 35% | 49% |
| June | 88% | 11% | 20% | 25% | 63% |
| July | 89% | 14% | 31% | 37% | 52% |
| August | 86% | 17% | 39% | 46% | 40% |
| September | 83% | 16% | 39% | 44% | 39% |
| October | 86% | 10% | 24% | 27% | 59% |
| November | 90% | 9% | 0% | 9% | 81% |
| December | 88% | 1% | 0% | 1% | 87% |
| Annual | 86% | 13% | 22% | 29% | 58% |

Annual loads are given in FC/year.




| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Loading Capacity | 8.69E+09 | 1.04E+11 | 4.02E+11 | 1.26E+12 | 1.50E+11 | 1.74E+11 | 2.76E+11 | 4.09E+11 | 3.89E+11 | 1.82E+11 | 1.01E+11 | 1.63E+10 |
| Existing Conditions | 9.59E+09 | 1.26E+11 | 7.76E+11 | 4.28E+12 | 2.69E+11 | 2.69E+11 | 4.87E+11 | 9.51E+11 | 8.30E+11 | 2.85E+11 | 1.44E+11 | 1.63E+10 |
| Scenario 1 | 9.58E+09 | 9.07E+10 | 5.45E+11 | 2.99E+12 | 1.96E+11 | 1.97E+11 | 3.48E+11 | 6.73E+11 | 5.89E+11 | 2.08E+11 | 1.07E+11 | 1.62E+10 |
| Scenario 2 | 9.59E+09 | 1.26E+11 | 3.87E+11 | 2.58E+12 | 1.48E+11 | 1.22E+11 | 1.69E+11 | 2.72E+11 | 2.18E+11 | 8.43E+10 | 1.44E+11 | 1.63E+10 |
| Scenario 3 | 9.58E+09 | 9.07E+10 | 2.74E+11 | 1.81E+12 | 1.12E+11 | 9.45E+10 | 1.26E+11 | 1.99E+11 | 1.62E+11 | 6.83E+10 | 1.07E+11 | 1.62E+10 |

**Figure 6-19. Comparison of monthly loading capacities evaluated by the most restrictive standard to existing loads and TMDL scenario loads at TMDL analysis point CH2 on the South Fork of Chester Creek.**




| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Scenario 1 | 0% | 28% | 30% | 30% | 27% | 27% | 29% | 29% | 29% | 27% | 26% | 1% |
| Scenario 2 | 0% | 0% | 50% | 40% | 45% | 55% | 65% | 71% | 74% | 70% | 0% | 0% |
| Scenario 3 | 0% | 28% | 65% | 58% | 58% | 65% | 74% | 79% | 81% | 76% | 26% | 1% |
| Required Reduction | 9% | 18% | 48% | 71% | 44% | 36% | 43% | 57% | 53% | 36% | 30% | 0% |

**Figure 6-20. Comparison of monthly loading reductions provided by the TMDL scenarios and loading reductions required by the most restrictive standard at TMDL analysis point CH2 on the South Fork of Chester Creek.**

# 7.0 UNIVERSITY LAKE ALLOCATION ANALYSIS

## 7.1 Identification of Allowable Loads

The calibrated SWMM model was used to determine existing and allowable loads of fecal coliform for the University Lake TMDL analysis points 171 and ULO (see Figures 5-3 and 5-5). The results of the modeling runs are summarized in Figures 7-1 to 7-4 and Tables 7-1 and 7-2.

Figures 7-1 through 7-4 and Tables 7-1 and 7-2 show that the 30-day geometric mean standard is always more restrictive than the 10 percent not-to-exceed standard. Therefore the final TMDL results (presented below) are based on the reductions necessary to achieve the 30-day geometric mean standard.

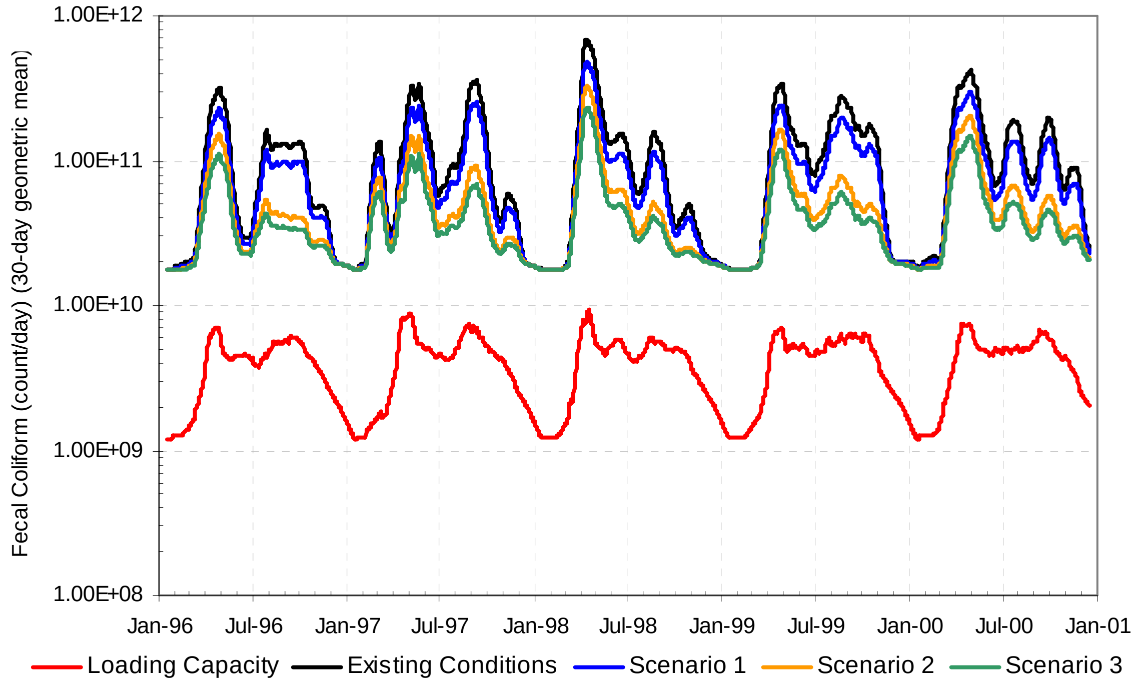



**Figure 7-1. Evaluation of the 30-day geometric mean standard at TMDL analysis point 171, located just above University Lake.**

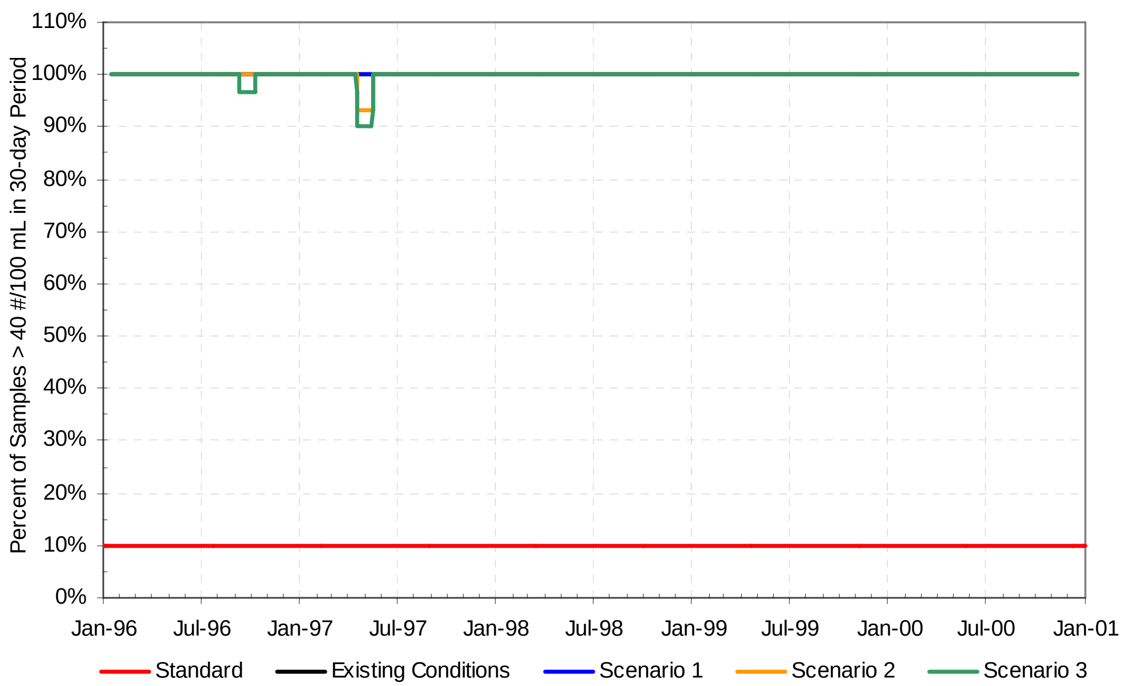



**Figure 7-2. Evaluation of the 30-day not-to-exceed standard at TMDL analysis point 171, located just above University Lake.**

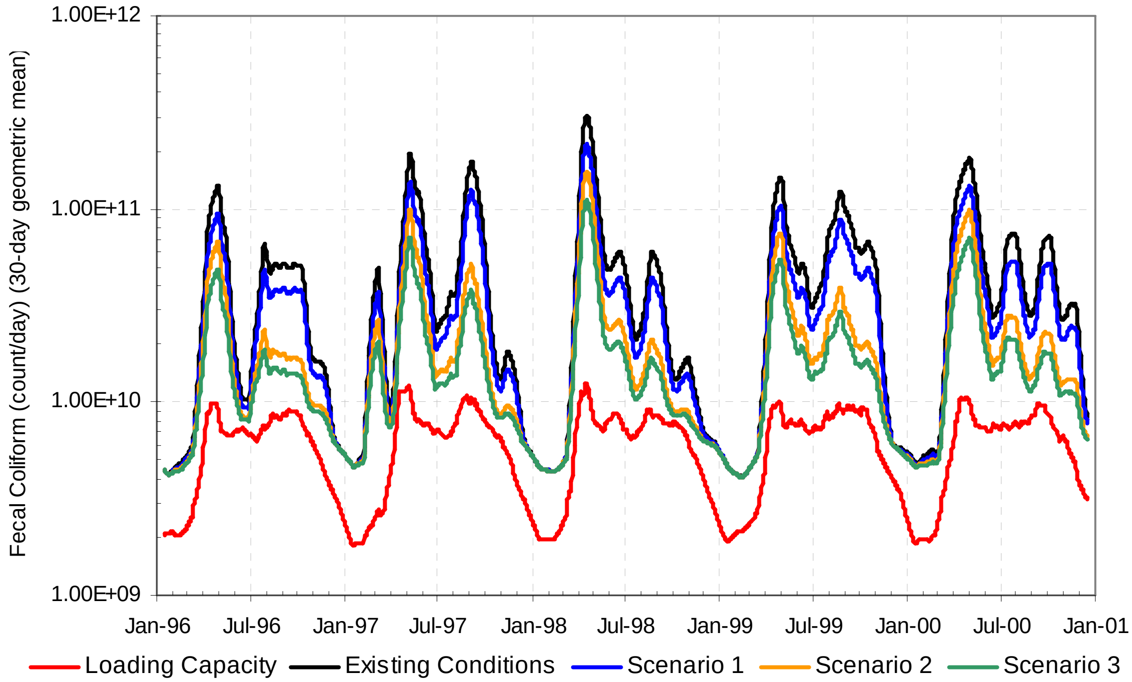



**Figure 7-3. Evaluation of the 30-day geometric mean standard at TMDL analysis point ULO, located just below University Lake.**

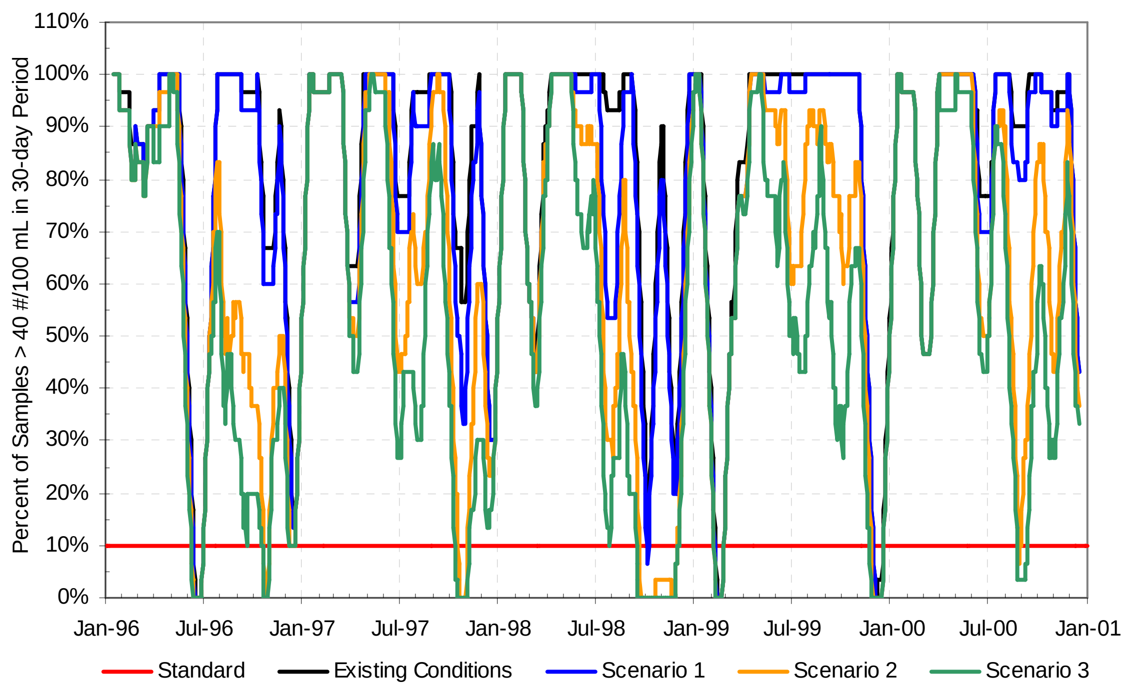



**Figure 7-4. Evaluation of the 30-day not-to-exceed standard at TMDL analysis point ULO, located just below University Lake.**

## 7.2 Load Allocation

Nonpoint sources are typically represented by loads carried to receiving waters through surface runoff resulting from precipitation events. However, because stormwater discharges in the MOA are regulated by a NPDES stormwater permit for municipal separate storm sewer systems (MS4), watershed loads delivered to Chester Creek through stormwater conveyances are addressed through the wasteload allocation component of this TMDL. Because the Chester Creek watershed includes only negligible loading from outside of the municipality that is essentially contributions from wildlife, a load allocation of zero has been set for this TMDL.

## 7.3 Wasteload Allocation

The only permitted source of fecal coliform in the Chester Creek watershed is storm water runoff. The MOA is subject to an MS4 permit that regulates storm water discharges and EPA policy and regulation indicate that storm water runoff regulated by the NPDES program through an MS4 permit must be addressed through wasteload allocations in a TMDL (USEPA, 2002). Therefore, the Chester Creek TMDL establishes wasteload allocations for watershed loads of fecal coliform. The wasteload allocation is the loading capacity minus the margin of safety.

The fecal coliform wasteload allocations for Chester Creek, provided as monthly allocations for the University Lake TMDL analysis points 171 and ULO, are presented in Tables 7-1 and 7-2, respectively. Table 7-1 (TMDL analysis point 171) suggests that fecal coliform loadings to University Lake are large throughout the year, and that the greatest monthly fecal coliform loads occurs during the spring and summer months. Consequently, the greatest required monthly reductions for TMDL analysis point 171 occur during spring and summer months. The winter months represent the lowest fecal coliform loads upstream of University Lake and, therefore, require the lowest percent reductions from existing loads.

Allocations are not established for future loads because ADEC does not anticipate any future permits for the discharge of fecal coliform to Chester Creek. Additionally, if data or information from future monitoring efforts can be used to identify and quantify stormwater or natural loads that are not delivered through the stormwater conveyances, the TMDL and its allocations will be revised accordingly.
The fecal coliform wasteload allocations and a margin of safety for University Lake are provided as seasonal and annual allocations for both of the University Lake TMDL analysis points and are presented in Tables 7-1 and 7-2.

**Table 7-1. Summary of the University Lake TMDL, Analysis Point 171.**

| Month | Existing (FC/month) | Loading Capacity (FC/month) | Margin of Safety (FC/month) | Waste Load Allocation (FC/month) | Required Reduction |
|---|---|---|---|---|---|
| Jan | 5.18E+11 | 3.63E+10 | 3.63E+09 | 3.27E+10 | 93% |
| Feb | 7.55E+11 | 3.75E+10 | 3.75E+09 | 3.38E+10 | 95% |
| Mar | 2.01E+12 | 7.25E+10 | 7.25E+09 | 6.53E+10 | 96% |
| Apr | 9.06E+12 | 1.97E+11 | 1.97E+10 | 1.77E+11 | 98% |
| May | 6.87E+12 | 1.66E+11 | 1.66E+10 | 1.49E+11 | 98% |
| Jun | 2.91E+12 | 1.46E+11 | 1.46E+10 | 1.32E+11 | 95% |
| Jul | 3.23E+12 | 1.43E+11 | 1.43E+10 | 1.28E+11 | 96% |
| Aug | 4.75E+12 | 1.74E+11 | 1.74E+10 | 1.56E+11 | 96% |
| Sep | 4.92E+12 | 1.78E+11 | 1.78E+10 | 1.60E+11 | 96% |
| Oct | 2.86E+12 | 1.52E+11 | 1.52E+10 | 1.37E+11 | 95% |
| Nov | 1.57E+12 | 9.81E+10 | 9.81E+09 | 8.83E+10 | 94% |
| Dec | 6.37E+11 | 5.80E+10 | 5.80E+09 | 5.22E+10 | 91% |
| Annual | 4.01E+13 | 1.46E+12 | 1.46E+11 | 1.31E+12 | 96% |

Annual loads are given in FC/year.

**Table 7-2. Summary of the University Lake TMDL, Analysis Point ULO.**

| Month | Existing (FC/month) | Loading Capacity (FC/month) | Margin of Safety (FC/month) | Waste Load Allocation (FC/month) | Required Reduction |
|---|---|---|---|---|---|
| Jan | 1.35E+11 | 5.71E+10 | 5.71E+09 | 5.14E+10 | 58% |
| Feb | 2.02E+11 | 5.95E+10 | 5.95E+09 | 5.36E+10 | 71% |
| Mar | 5.97E+11 | 1.10E+11 | 1.10E+10 | 9.92E+10 | 82% |
| Apr | 3.67E+12 | 2.80E+11 | 2.80E+10 | 2.52E+11 | 92% |
| May | 3.05E+12 | 2.48E+11 | 2.48E+10 | 2.23E+11 | 92% |
| Jun | 1.15E+12 | 2.25E+11 | 2.25E+10 | 2.02E+11 | 80% |
| Jul | 1.24E+12 | 2.21E+11 | 2.21E+10 | 1.99E+11 | 82% |
| Aug | 1.97E+12 | 2.65E+11 | 2.65E+10 | 2.39E+11 | 87% |
| Sep | 2.05E+12 | 2.68E+11 | 2.68E+10 | 2.41E+11 | 87% |
| Oct | 1.14E+12 | 2.32E+11 | 2.32E+10 | 2.09E+11 | 80% |
| Nov | 5.60E+11 | 1.53E+11 | 1.53E+10 | 1.38E+11 | 73% |
| Dec | 2.06E+11 | 9.00E+10 | 9.00E+09 | 8.10E+10 | 56% |
| Annual | 1.60E+13 | 2.21E+12 | 2.21E+11 | 1.99E+12 | 86% |

Annual loads are given in FC/year.

### 7.4 Implementation Scenarios

The same three implementation scenarios discussed above for the Chester Creek TMDL were used to assess conditions in University Lake.

Tables 7-3 through 7-6 summarize the results of the implementation scenarios for the University Lake analysis points. The tables show that a combination of education and increased street sweeping frequency and efficiency applied to all urbanized areas in the watershed has a significant impact in the reduction of fecal coliform loading to University Lake, with an annual fecal coliform percent reduction of 61 percent. However, significant additional reductions beyond TMDL scenario 3 are required for both TMDL analysis sites in order to comply with both components of the standard.

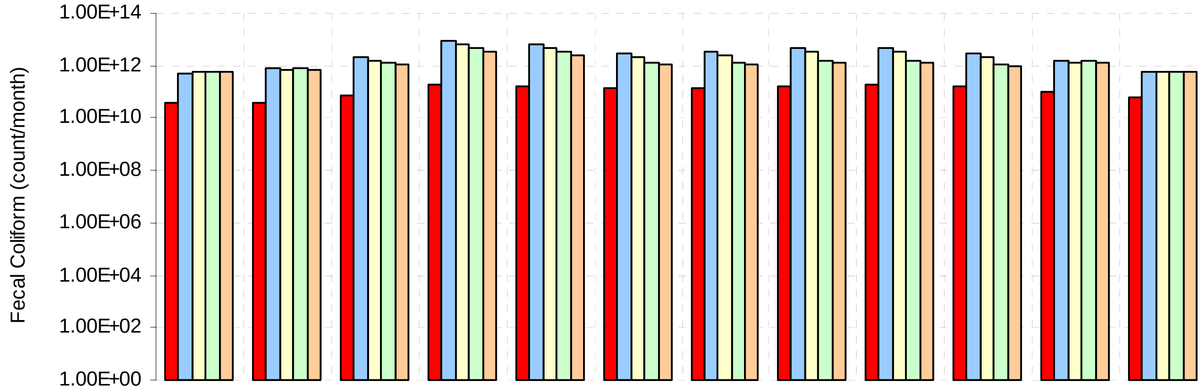
**Table 7-3. Implementation Scenarios for University Lake, Analysis Point 171.**

| Month | Existing (FC/month) | Post-Scenario (FC/month) | Percent Reduction |
|---|---|---|---|
| ***Scenario 1*** | | | |
| **Month** | **Existing (FC/month)** | **Post-Scenario (FC/month)** | **Percent Reduction** |
| January | 5.18E+11 | 5.14E+11 | 1% |
| February | 7.55E+11 | 6.93E+11 | 8% |
| March | 2.01E+12 | 1.64E+12 | 18% |
| April | 9.06E+12 | 6.50E+12 | 28% |
| May | 6.87E+12 | 4.97E+12 | 28% |
| June | 2.91E+12 | 2.22E+12 | 24% |
| July | 3.23E+12 | 2.46E+12 | 24% |
| August | 4.75E+12 | 3.50E+12 | 26% |
| September | 4.92E+12 | 3.60E+12 | 27% |
| October | 2.86E+12 | 2.20E+12 | 23% |
| November | 1.57E+12 | 1.30E+12 | 17% |
| December | 6.37E+11 | 6.12E+11 | 4% |
| Annual | 4.01E+13 | 3.02E+13 | 25% |
| ***Scenario 2*** | | | |
| **Month** | **Existing (FC/month)** | **Post-Scenario (FC/month)** | **Percent Reduction** |
| January | 5.18E+11 | 5.18E+11 | 0% |
| February | 7.55E+11 | 7.55E+11 | 0% |
| March | 2.01E+12 | 1.36E+12 | 32% |
| April | 9.06E+12 | 4.50E+12 | 50% |
| May | 6.87E+12 | 3.24E+12 | 53% |
| June | 2.91E+12 | 1.42E+12 | 51% |
| July | 3.23E+12 | 1.39E+12 | 57% |
| August | 4.75E+12 | 1.61E+12 | 66% |
| September | 4.92E+12 | 1.52E+12 | 69% |
| October | 2.86E+12 | 1.19E+12 | 58% |
| November | 1.57E+12 | 1.57E+12 | 0% |
| December | 6.37E+11 | 6.37E+11 | 0% |
| Annual | 4.01E+13 | 1.95E+13 | 51% |
| ***Scenario 3*** | | | |
| **Month** | **Existing (FC/month)** | **Post-Scenario (FC/month)** | **Percent Reduction** |
| January | 5.18E+11 | 5.14E+11 | 1% |
| February | 7.55E+11 | 6.93E+11 | 8% |
| March | 2.01E+12 | 1.16E+12 | 42% |
| April | 9.06E+12 | 3.29E+12 | 64% |
| May | 6.87E+12 | 2.44E+12 | 65% |
| June | 2.91E+12 | 1.17E+12 | 60% |
| July | 3.23E+12 | 1.15E+12 | 64% |
| August | 4.75E+12 | 1.29E+12 | 73% |
| September | 4.92E+12 | 1.22E+12 | 75% |
| October | 2.86E+12 | 1.02E+12 | 64% |
| November | 1.57E+12 | 1.30E+12 | 17% |
| December | 6.37E+11 | 6.12E+11 | 4% |
| Annual | 4.01E+13 | 1.57E+13 | 61% |

**Table 7-4. Summary of TMDL Scenarios for University Lake, Analysis Point 171.**

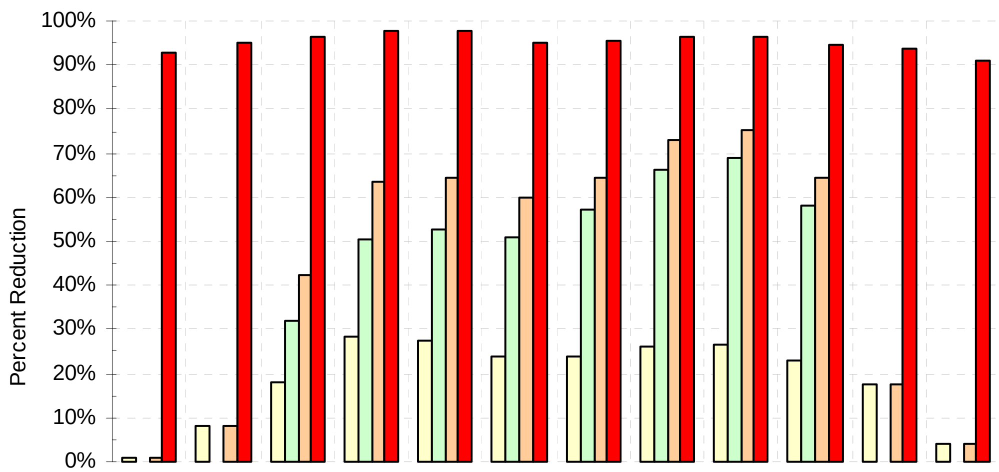
| Month | Required Reduction | Scenario 1 Reduction | Scenario 2 Reduction | Scenario 3 Reduction | Additional Reduction |
|---|---|---|---|---|---|
| January | 93% | 1% | 0% | 1% | 92% |
| February | 95% | 8% | 0% | 8% | 87% |
| March | 96% | 18% | 32% | 42% | 54% |
| April | 98% | 28% | 50% | 64% | 34% |
| May | 98% | 28% | 53% | 65% | 33% |
| June | 95% | 24% | 51% | 60% | 35% |
| July | 96% | 24% | 57% | 64% | 31% |
| August | 96% | 26% | 66% | 73% | 23% |
| September | 96% | 27% | 69% | 75% | 21% |
| October | 95% | 23% | 58% | 64% | 30% |
| November | 94% | 17% | 0% | 17% | 76% |
| December | 91% | 4% | 0% | 4% | 87% |
| Annual | 96% | 25% | 51% | 61% | 36% |

Annual loads are given in FC/year.




| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Loading Capacity | 3.63E+10 | 3.75E+10 | 7.25E+10 | 1.97E+11 | 1.66E+11 | 1.46E+11 | 1.43E+11 | 1.74E+11 | 1.78E+11 | 1.52E+11 | 9.81E+10 | 5.80E+10 |
| Existing Conditions | 5.18E+11 | 7.55E+11 | 2.01E+12 | 9.06E+12 | 6.87E+12 | 2.91E+12 | 3.23E+12 | 4.75E+12 | 4.92E+12 | 2.86E+12 | 1.57E+12 | 6.37E+11 |
| Scenario 1 | 5.58E+11 | 6.93E+11 | 1.64E+12 | 6.50E+12 | 4.97E+12 | 2.22E+12 | 2.46E+12 | 3.50E+12 | 3.60E+12 | 2.20E+12 | 1.30E+12 | 6.12E+11 |
| Scenario 2 | 5.60E+11 | 7.55E+11 | 1.36E+12 | 4.50E+12 | 3.24E+12 | 1.42E+12 | 1.39E+12 | 1.61E+12 | 1.52E+12 | 1.19E+12 | 1.57E+12 | 6.37E+11 |
| Scenario 3 | 5.58E+11 | 6.93E+11 | 1.16E+12 | 3.29E+12 | 2.44E+12 | 1.17E+12 | 1.15E+12 | 1.29E+12 | 1.22E+12 | 1.02E+12 | 1.30E+12 | 6.12E+11 |

**Figure 7-5. Comparison of monthly loading capacities evaluated by the most restrictive standard to existing loads and TMDL scenario loads at TMDL analysis point 171 on the South Fork of Chester Creek.**




| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Scenario 1 | 1% | 8% | 18% | 28% | 28% | 24% | 24% | 26% | 27% | 23% | 17% | 4% |
| Scenario 2 | 0% | 0% | 32% | 50% | 53% | 51% | 57% | 66% | 69% | 58% | 0% | 0% |
| Scenario 3 | 1% | 8% | 42% | 64% | 65% | 60% | 64% | 73% | 75% | 64% | 17% | 4% |
| Required Reduction | 93% | 95% | 96% | 98% | 98% | 95% | 96% | 96% | 96% | 95% | 94% | 91% |

**Figure 7-6. Comparison of monthly loading reductions provided by the TMDL scenarios and loading reductions required by the most restrictive standard at TMDL analysis point 171 on the South Fork of Chester Creek.**

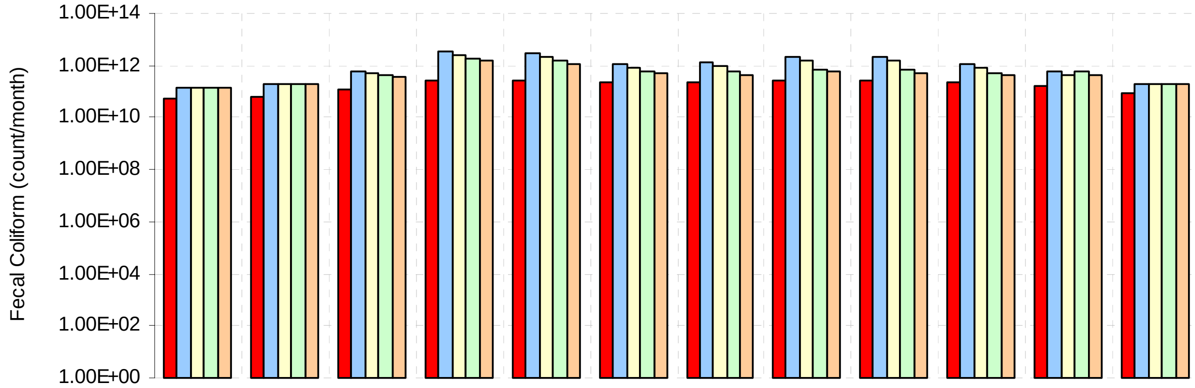
**Table 7-5. Implementation Scenarios for University Lake, Analysis Point ULO.**

| ***Scenario 1*** | | | |
|---|---|---|---|
| **Month** | **Existing (FC/month)** | **Post-Scenario (FC/month)** | **Percent Reduction** |
| January | 1.35E+11 | 1.34E+11 | 1% |
| February | 2.02E+11 | 1.84E+11 | 9% |
| March | 5.97E+11 | 4.87E+11 | 19% |
| April | 3.67E+12 | 2.64E+12 | 28% |
| May | 3.05E+12 | 2.20E+12 | 28% |
| June | 1.15E+12 | 8.72E+11 | 24% |
| July | 1.24E+12 | 9.43E+11 | 24% |
| August | 1.97E+12 | 1.45E+12 | 27% |
| September | 2.05E+12 | 1.50E+12 | 27% |
| October | 1.14E+12 | 8.69E+11 | 24% |
| November | 5.60E+11 | 4.57E+11 | 18% |
| December | 2.06E+11 | 1.95E+11 | 6% |
| Annual | 1.60E+13 | 1.19E+13 | 25% |
| ***Scenario 2*** | | | |
| **Month** | **Existing (FC/month)** | **Post-Scenario (FC/month)** | **Percent Reduction** |
| January | 1.35E+11 | 1.35E+11 | 0% |
| February | 2.02E+11 | 2.02E+11 | 0% |
| March | 5.97E+11 | 4.12E+11 | 31% |
| April | 3.67E+12 | 1.95E+12 | 47% |
| May | 3.05E+12 | 1.52E+12 | 50% |
| June | 1.15E+12 | 5.74E+11 | 50% |
| July | 1.24E+12 | 5.59E+11 | 55% |
| August | 1.97E+12 | 7.18E+11 | 64% |
| September | 2.05E+12 | 6.63E+11 | 68% |
| October | 1.14E+12 | 4.72E+11 | 59% |
| November | 5.60E+11 | 5.60E+11 | 0% |
| December | 2.06E+11 | 2.06E+11 | 0% |
| Annual | 1.60E+13 | 7.90E+12 | 51% |
| ***Scenario 3*** | | | |
| **Month** | **Existing (FC/month)** | **Post-Scenario (FC/month)** | **Percent Reduction** |
| January | 1.35E+11 | 1.34E+11 | 1% |
| February | 2.02E+11 | 1.84E+11 | 9% |
| March | 5.97E+11 | 3.49E+11 | 42% |
| April | 3.67E+12 | 1.43E+12 | 61% |
| May | 3.05E+12 | 1.13E+12 | 63% |
| June | 1.15E+12 | 4.67E+11 | 59% |
| July | 1.24E+12 | 4.59E+11 | 63% |
| August | 1.97E+12 | 5.69E+11 | 71% |
| September | 2.05E+12 | 5.27E+11 | 74% |
| October | 1.14E+12 | 3.98E+11 | 65% |
| November | 5.60E+11 | 4.57E+11 | 18% |
| December | 2.06E+11 | 1.95E+11 | 6% |
| Annual | 1.60E+13 | 6.24E+12 | 61% |

**Table 7-6. Summary of TMDL Scenarios for University Lake, Analysis Point ULO.**

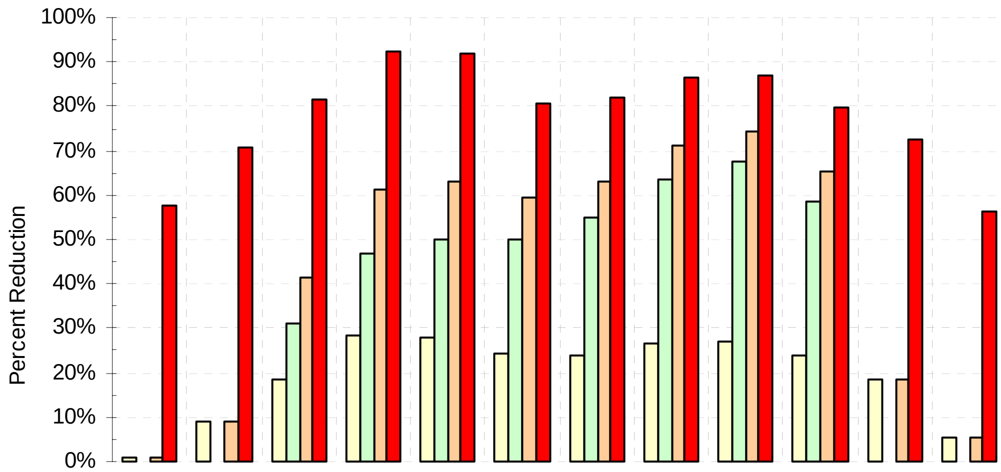
| Month | Required Reduction | Scenario 1 Reduction | Scenario 2 Reduction | Scenario 3 Reduction | Additional Reduction |
|---|---|---|---|---|---|
| January | 58% | 1% | 0% | 1% | 57% |
| February | 71% | 9% | 0% | 9% | 62% |
| March | 82% | 19% | 31% | 42% | 40% |
| April | 92% | 28% | 47% | 61% | 31% |
| May | 92% | 28% | 50% | 63% | 29% |
| June | 80% | 24% | 50% | 59% | 21% |
| July | 82% | 24% | 55% | 63% | 19% |
| August | 87% | 27% | 64% | 71% | 15% |
| September | 87% | 27% | 68% | 74% | 13% |
| October | 80% | 24% | 59% | 65% | 15% |
| November | 73% | 18% | 0% | 18% | 54% |
| December | 56% | 6% | 0% | 6% | 51% |
| Annual | 86% | 25% | 51% | 61% | 25% |

Annual loads are given in FC/year.




| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Loading Capacity | 5.71E+10 | 5.95E+10 | 1.10E+11 | 2.80E+11 | 2.48E+11 | 2.25E+11 | 2.21E+11 | 2.65E+11 | 2.68E+11 | 2.32E+11 | 1.53E+11 | 9.00E+10 |
| Existing Conditions | 1.35E+11 | 2.02E+11 | 5.97E+11 | 3.67E+12 | 3.05E+12 | 1.15E+12 | 1.24E+12 | 1.97E+12 | 2.05E+12 | 1.14E+12 | 5.60E+11 | 2.06E+11 |
| Scenario 1 | 1.45E+11 | 1.84E+11 | 4.87E+11 | 2.64E+12 | 2.20E+12 | 8.72E+11 | 9.43E+11 | 1.45E+12 | 1.50E+12 | 8.69E+11 | 4.57E+11 | 1.95E+11 |
| Scenario 2 | 1.46E+11 | 2.02E+11 | 4.12E+11 | 1.95E+12 | 1.52E+12 | 5.74E+11 | 5.59E+11 | 7.18E+11 | 6.63E+11 | 4.72E+11 | 5.60E+11 | 2.06E+11 |
| Scenario 3 | 1.45E+11 | 1.84E+11 | 3.49E+11 | 1.43E+12 | 1.13E+12 | 4.67E+11 | 4.59E+11 | 5.69E+11 | 5.27E+11 | 3.98E+11 | 4.57E+11 | 1.95E+11 |

**Figure 7-7. Comparison of monthly loading capacities evaluated by the most restrictive standard to existing loads and TMDL scenario loads at TMDL analysis point ULO on the South Fork of Chester Creek.**




| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Scenario 1 | 1% | 9% | 19% | 28% | 28% | 24% | 24% | 27% | 27% | 24% | 18% | 6% |
| Scenario 2 | 0% | 0% | 31% | 47% | 50% | 50% | 55% | 64% | 68% | 59% | 0% | 0% |
| Scenario 3 | 1% | 9% | 42% | 61% | 63% | 59% | 63% | 71% | 74% | 65% | 18% | 6% |
| Required Reduction | 58% | 71% | 82% | 92% | 92% | 80% | 82% | 87% | 87% | 80% | 73% | 56% |

**Figure 7-8. Comparison of monthly loading reductions provided by the TMDL scenarios and loading reductions required by the most restrictive standard at TMDL analysis point ULO on the South Fork of Chester Creek.**

# 8.0 WESTCHESTER LAGOONS ALLOCATION ANALYSIS

## 8.1 Identification of Allowable Loads

The calibrated SWMM model was used to determine existing and allowable loads of fecal coliform for the Westchester Lagoons TMDL analysis points CH2 and CL2 (see Figures 5-1, and 5-5). The results of the modeling runs are summarized in Figures 8-1 to 8-4 and Tables 8-1 and 8-2.

Figures 8-1 through 8-4 and Tables 8-1 through 8-2 show that the 30-day geometric mean standard is typically more restrictive than the 10 percent not-to-exceed standard. However, during January and March at CL2 the 10 percent not-to-exceed standard is more restrictive. Therefore the final TMDL results (presented below) are based on the not-to-exceed reductions for these two months. All other reductions are based on meeting the 30 day geometric mean standard.

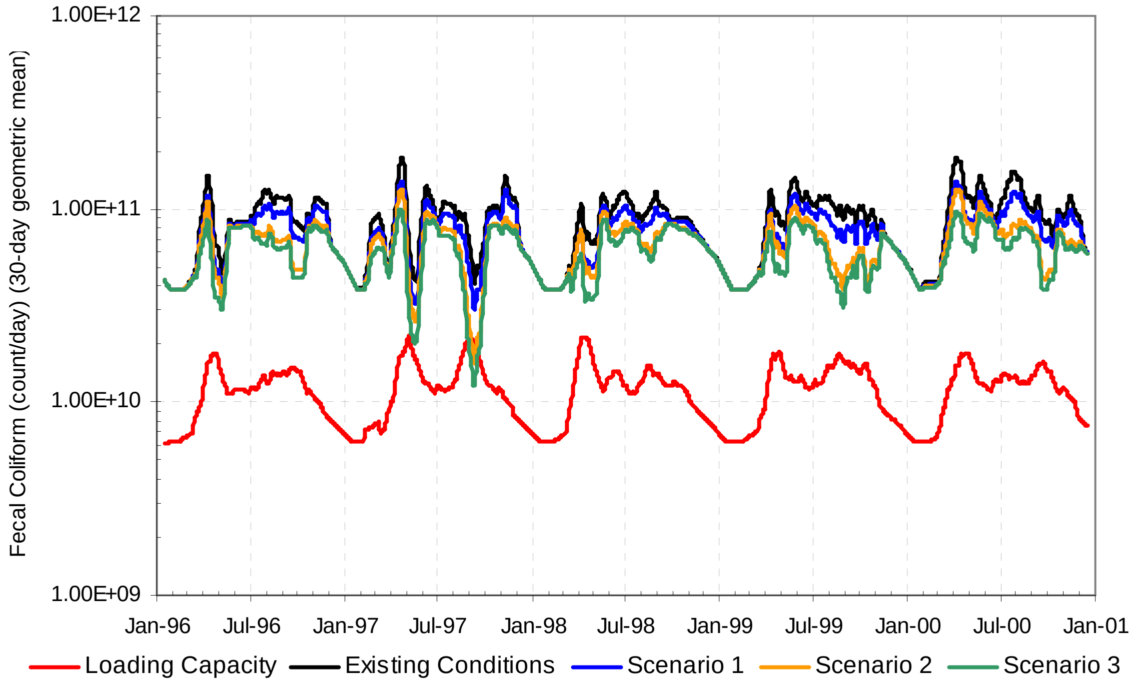



**Figure 8-1. Evaluation of the 30-day geometric mean standard at TMDL analysis point CH2.**

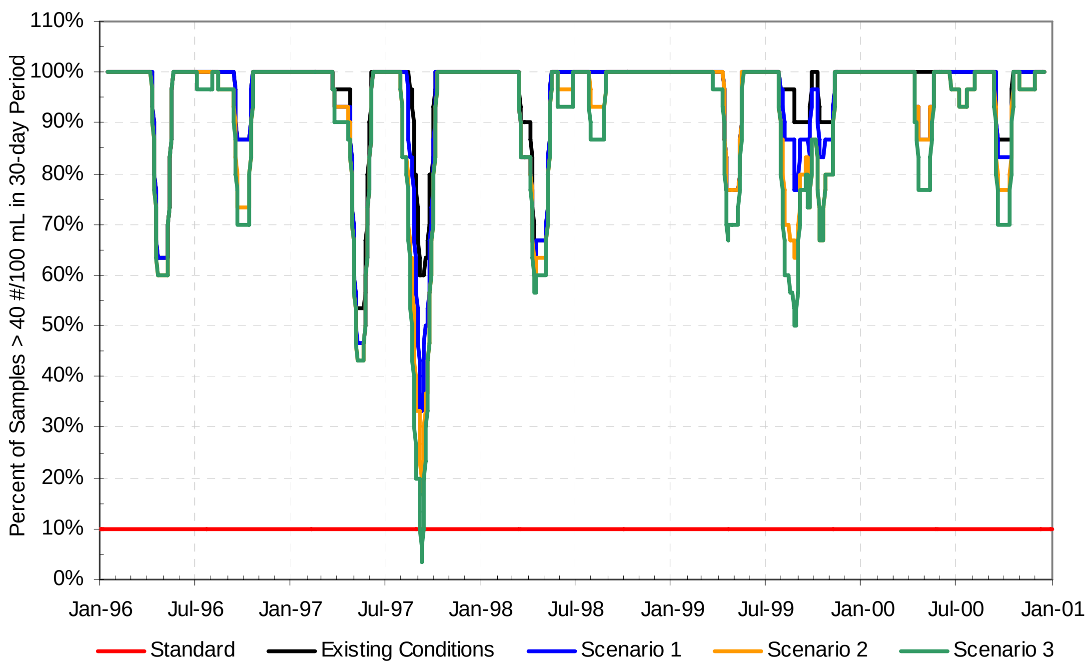



**Figure 8-2. Evaluation of the 30-day not-to-exceed standard at TMDL analysis point CH2.**

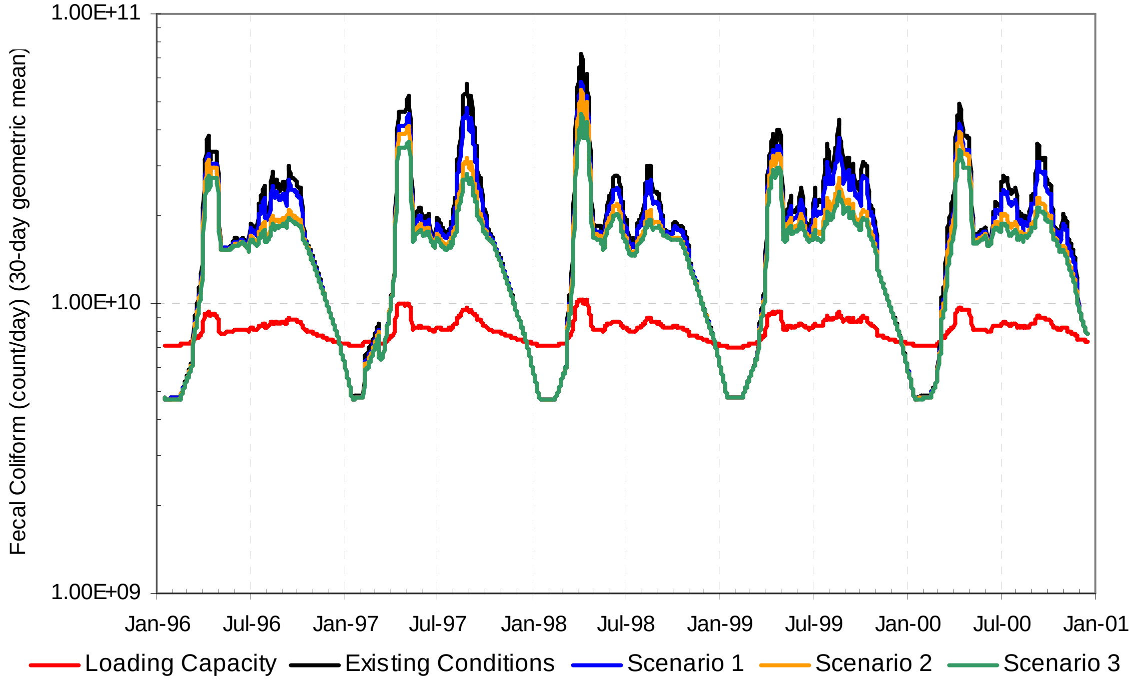



**Figure 8-3. Evaluation of the 30-day geometric mean at TMDL analysis point CL2.**

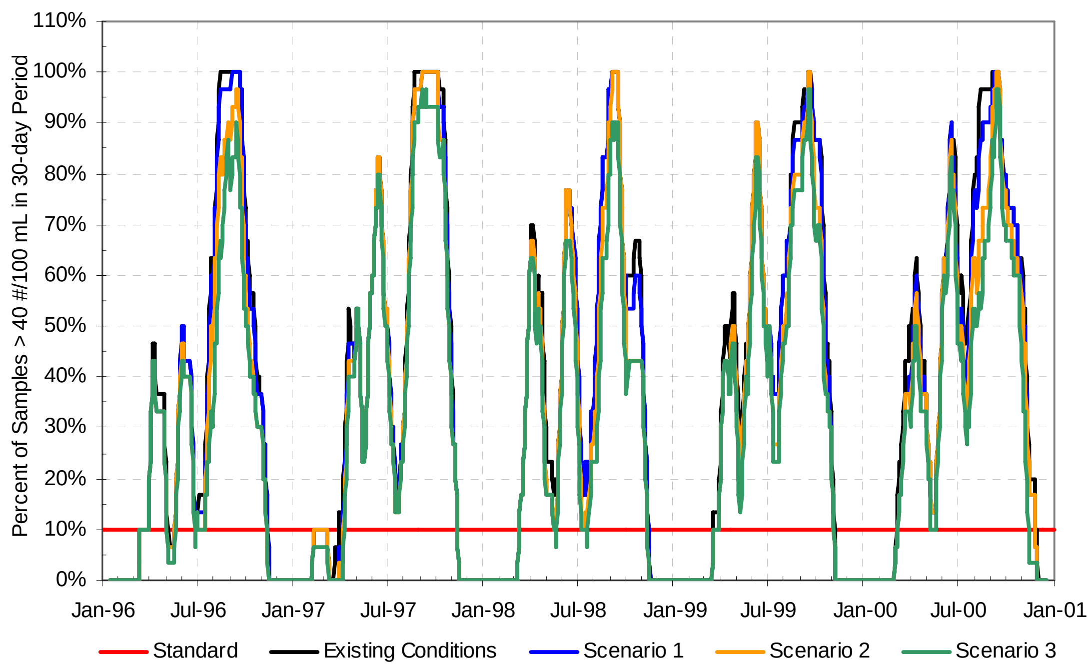



**Figure 8-4. Evaluation of the not-to-exceed standard at TMDL analysis point CL2.**

## 8.2 Load Allocation

Nonpoint sources are typically represented by loads carried to receiving waters through surface runoff resulting from precipitation events. However, because stormwater discharges in the MOA are regulated by a NPDES stormwater permit for municipal separate storm sewer systems (MS4), watershed loads delivered to Chester Creek through stormwater conveyances are addressed through the wasteload allocation component of this TMDL. Because the Chester Creek watershed includes loading from outside of the municipality that is essentially contributions from wildlife and are considered natural background, a load allocation of zero has been set for this TMDL.

## 8.3 Wasteload Allocation

The only permitted source of fecal coliform in the Chester Creek watershed is storm water runoff. The MOA is subject to an MS4 permit that regulates storm water discharges and EPA policy and regulation indicate that storm water runoff regulated by the NPDES program through an MS4 permit must be addressed through wasteload allocations in a TMDL (USEPA, 2002). Therefore, the Chester Creek TMDL establishes wasteload allocations for watershed loads of fecal coliform. The wasteload allocation is the loading capacity minus the margin of safety.

The fecal coliform wasteload allocations for Westchester Lagoon, provided as seasonal and annual allocations for the TMDL analysis points CH2 and CL2, are presented in Tables 8-1 and 8-2, respectively. Table 8-1 (TMDL analysis point CH2) suggests that fecal coliform loadings to Westchester Lagoon are large throughout the year, and that the greatest monthly fecal coliform loads occurs during the spring and summer months. Consequently, the greatest required monthly reductions for TMDL analysis point CH2 occur during spring and summer months. The winter months represent the lowest fecal coliform loads upstream of Westchester Lagoon and, therefore, require the lowest percent reductions from existing loads.

Allocations are not established for future loads because ADEC does not anticipate any future permits for the discharge of fecal coliform to Chester Creek. Additionally, if data or information from future monitoring efforts can be used to identify and quantify stormwater or natural loads that are not delivered through the stormwater conveyances, the TMDL and its allocations will be revised accordingly.
The fecal coliform wasteload allocations and a margin of safety for Westchester Lagoon are provided as seasonal and annual allocations for both of the Westchester Lagoon TMDL analysis points and are presented in Tables 8-1 and 8-2.

The fecal coliform wasteload and load allocations and a margin of safety for Westchester Lagoon are provided as seasonal allocations for both of the analysis points and are presented in Tables 8-1 and 8-2.

**Table 8-1. Summary of the Westchester Lagoon TMDL, Analysis Point CH2.**

| Month | Existing (FC/month) | Loading Capacity (FC/month) | Margin of Safety (FC/month) | Waste Load Allocation (FC/month) | Required Reduction |
|---|---|---|---|---|---|
| Jan | 1.21E+12 | 1.80E+11 | 1.80E+10 | 1.62E+11 | 85% |
| Feb | 1.23E+12 | 1.85E+11 | 1.85E+10 | 1.66E+11 | 85% |
| Mar | 1.98E+12 | 2.75E+11 | 2.75E+10 | 2.48E+11 | 86% |
| Apr | 3.40E+12 | 5.03E+11 | 5.03E+10 | 4.53E+11 | 85% |
| May | 2.84E+12 | 4.39E+11 | 4.39E+10 | 3.95E+11 | 85% |
| Jun | 3.14E+12 | 3.73E+11 | 3.73E+10 | 3.35E+11 | 88% |
| Jul | 3.45E+12 | 3.87E+11 | 3.87E+10 | 3.49E+11 | 89% |
| Aug | 3.28E+12 | 4.58E+11 | 4.58E+10 | 4.12E+11 | 86% |
| Sep | 2.69E+12 | 4.55E+11 | 4.55E+10 | 4.09E+11 | 83% |
| Oct | 2.80E+12 | 3.91E+11 | 3.91E+10 | 3.52E+11 | 86% |
| Nov | 2.91E+12 | 2.91E+11 | 2.91E+10 | 2.62E+11 | 90% |
| Dec | 1.74E+12 | 2.13E+11 | 2.13E+10 | 1.92E+11 | 88% |
| Annual | 3.07E+13 | 4.15E+12 | 4.15E+11 | 3.73E+12 | 86% |

Annual loads are given in FC/year.

**Table 8-2. Summary of the Westchester Lagoon TMDL, Analysis Point CL2.**

| Month | Existing (FC/month) | Loading Capacity (FC/month) | Margin of Safety (FC/month) | Waste Load Allocation (FC/month) | Required Reduction |
|---|---|---|---|---|---|
| **Jan** | **1.48E+11** | **1.34E+11** | **1.34E+10** | **1.21E+11** | **9%** |
| Feb | 2.14E+11 | 2.14E+11 | 2.14E+10 | 1.93E+11 | 0% |
| **Mar** | **5.41E+11** | **3.34E+11** | **3.34E+10** | **3.01E+11** | **38%** |
| Apr | 1.13E+12 | 2.80E+11 | 2.80E+10 | 2.52E+11 | 75% |
| May | 6.53E+11 | 2.58E+11 | 2.58E+10 | 2.33E+11 | 60% |
| Jun | 6.00E+11 | 2.49E+11 | 2.49E+10 | 2.24E+11 | 59% |
| Jul | 6.64E+11 | 2.59E+11 | 2.59E+10 | 2.33E+11 | 61% |
| Aug | 8.94E+11 | 2.71E+11 | 2.71E+10 | 2.44E+11 | 70% |
| Sep | 8.25E+11 | 2.62E+11 | 2.62E+10 | 2.36E+11 | 68% |
| Oct | 6.14E+11 | 2.58E+11 | 2.58E+10 | 2.32E+11 | 58% |
| Nov | 3.79E+11 | 2.33E+11 | 2.33E+10 | 2.10E+11 | 39% |
| Dec | 2.24E+11 | 2.08E+11 | 2.08E+10 | 1.87E+11 | 7% |
| Annual | 6.63E+12 | 2.92E+12 | 2.92E+11 | 2.63E+12 | 56% |

Bold type indicates that the 10 percent not-to-exceed standard applies for the month.
Annual loads are given in FC/year.

## 8.4 Implementation Scenarios

Three implementation scenarios, selected with consultation with ADEC, were simulated with the calibrated SWMM model. These scenarios are:

- Scenario 1 – Public education. Informing the public about the benefits of "cleaning up" after their pets was assumed to result in a 30 percent decrease in the surface build up of fecal coliform on landscaped, street, directly connected, and indirectly connected impervious land cover types.

- Scenario 2 – Increased street sweeping frequency and efficiency. Street sweeping frequency was increased from monthly to weekly intervals and the efficiency was assumed to increase to eighty percent efficiency.

- Scenario 3 – A combination of Scenario 1 and Scenario 2.

Tables 8-3 through 8-6 summarize the results of the implementation scenarios for the Westchester Lagoons analysis points. The tables show that a combination of education and increased street sweeping frequency and efficiency applied to all urbanized areas in the watershed has the greatest impact in the reduction of fecal coliform loading to Westchester Lagoons, with a maximum annual fecal coliform percent reduction of 29 percent for TMDL analysis point CH2.

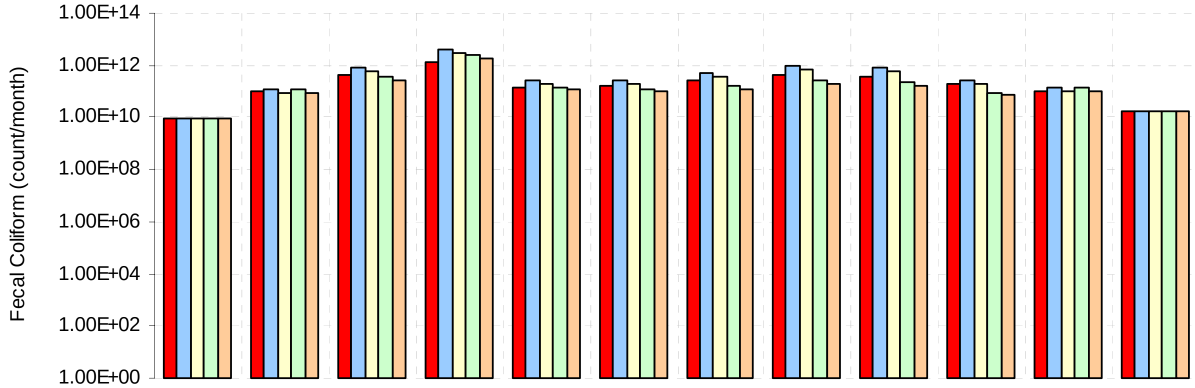
**Table 8-3. Implementation Scenarios for Westchester Lagoon, TMDL Analysis Point CH2.**

| ***Scenario 1*** | | | |
|---|---|---|---|
| **Month** | **Existing (FC/month)** | **Post-Scenario (FC/month)** | **Percent Reduction** |
| January | 1.21E+12 | 1.21E+12 | 0% |
| February | 1.23E+12 | 1.18E+12 | 4% |
| March | 1.98E+12 | 1.78E+12 | 10% |
| April | 3.40E+12 | 2.61E+12 | 23% |
| May | 2.84E+12 | 2.35E+12 | 17% |
| June | 3.14E+12 | 2.81E+12 | 11% |
| July | 3.45E+12 | 2.96E+12 | 14% |
| August | 3.28E+12 | 2.72E+12 | 17% |
| September | 2.69E+12 | 2.27E+12 | 16% |
| October | 2.80E+12 | 2.53E+12 | 10% |
| November | 2.91E+12 | 2.66E+12 | 9% |
| December | 1.74E+12 | 1.72E+12 | 1% |
| Annual | 3.07E+13 | 2.68E+13 | 13% |
| ***Scenario 2*** | | | |
| **Month** | **Existing (FC/month)** | **Post-Scenario (FC/month)** | **Percent Reduction** |
| January | 1.21E+12 | 1.21E+12 | 0% |
| February | 1.23E+12 | 1.23E+12 | 0% |
| March | 1.98E+12 | 1.73E+12 | 13% |
| April | 3.40E+12 | 2.44E+12 | 28% |
| May | 2.84E+12 | 2.13E+12 | 25% |
| June | 3.14E+12 | 2.53E+12 | 20% |
| July | 3.45E+12 | 2.39E+12 | 31% |
| August | 3.28E+12 | 1.99E+12 | 39% |
| September | 2.69E+12 | 1.65E+12 | 39% |
| October | 2.80E+12 | 2.14E+12 | 24% |
| November | 2.91E+12 | 2.91E+12 | 0% |
| December | 1.74E+12 | 1.74E+12 | 0% |
| Annual | 3.07E+13 | 2.40E+13 | 22% |
| ***Scenario 3*** | | | |
| **Month** | **Existing (FC/month)** | **Post-Scenario (FC/month)** | **Percent Reduction** |
| January | 1.21E+12 | 1.21E+12 | 0% |
| February | 1.23E+12 | 1.18E+12 | 4% |
| March | 1.98E+12 | 1.58E+12 | 20% |
| April | 3.40E+12 | 1.91E+12 | 44% |
| May | 2.84E+12 | 1.84E+12 | 35% |
| June | 3.14E+12 | 2.36E+12 | 25% |
| July | 3.45E+12 | 2.18E+12 | 37% |
| August | 3.28E+12 | 1.78E+12 | 46% |
| September | 2.69E+12 | 1.52E+12 | 44% |
| October | 2.80E+12 | 2.04E+12 | 27% |
| November | 2.91E+12 | 2.66E+12 | 9% |
| December | 1.74E+12 | 1.72E+12 | 1% |
| Annual | 3.07E+13 | 2.19E+13 | 29% |

**Table 8-4. Summary of TMDL Scenarios for Westchester Lagoon, TMDL Analysis Point CH2.**

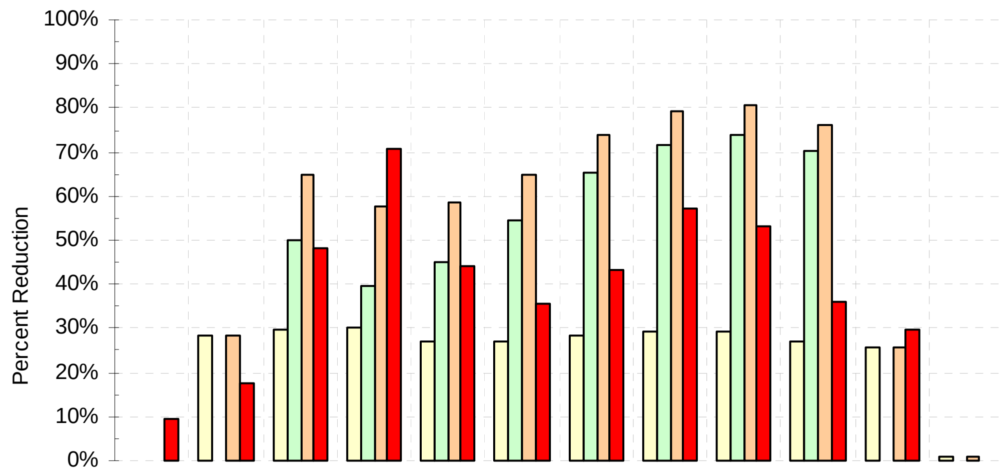
| Month | Required Reduction | Scenario 1 Reduction | Scenario 2 Reduction | Scenario 3 Reduction | Additional Reduction |
|---|---|---|---|---|---|
| January | 85% | 0% | 0% | 0% | 85% |
| February | 85% | 4% | 0% | 4% | 81% |
| March | 86% | 10% | 13% | 20% | 66% |
| April | 85% | 23% | 28% | 44% | 42% |
| May | 85% | 17% | 25% | 35% | 49% |
| June | 88% | 11% | 20% | 25% | 63% |
| July | 89% | 14% | 31% | 37% | 52% |
| August | 86% | 17% | 39% | 46% | 40% |
| September | 83% | 16% | 39% | 44% | 39% |
| October | 86% | 10% | 24% | 27% | 59% |
| November | 90% | 9% | 0% | 9% | 81% |
| December | 88% | 1% | 0% | 1% | 87% |
| Annual | 86% | 13% | 22% | 29% | 58% |

Annual loads are given in FC/year.




| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Loading Capacity | 8.69E+09 | 1.04E+11 | 4.02E+11 | 1.26E+12 | 1.50E+11 | 1.74E+11 | 2.76E+11 | 4.09E+11 | 3.89E+11 | 1.82E+11 | 1.01E+11 | 1.63E+10 |
| Existing Conditions | 9.59E+09 | 1.26E+11 | 7.76E+11 | 4.28E+12 | 2.69E+11 | 2.69E+11 | 4.87E+11 | 9.51E+11 | 8.30E+11 | 2.85E+11 | 1.44E+11 | 1.63E+10 |
| Scenario 1 | 9.58E+09 | 9.07E+10 | 5.45E+11 | 2.99E+12 | 1.96E+11 | 1.97E+11 | 3.48E+11 | 6.73E+11 | 5.89E+11 | 2.08E+11 | 1.07E+11 | 1.62E+10 |
| Scenario 2 | 9.59E+09 | 1.26E+11 | 3.87E+11 | 2.58E+12 | 1.48E+11 | 1.22E+11 | 1.69E+11 | 2.72E+11 | 2.18E+11 | 8.43E+10 | 1.44E+11 | 1.63E+10 |
| Scenario 3 | 9.58E+09 | 9.07E+10 | 2.74E+11 | 1.81E+12 | 1.12E+11 | 9.45E+10 | 1.26E+11 | 1.99E+11 | 1.62E+11 | 6.83E+10 | 1.07E+11 | 1.62E+10 |

**Figure 8-5. Comparison of monthly loading capacities evaluated by the most restrictive standard to existing loads and TMDL scenario loads at TMDL analysis point CH2 on the South Fork of Chester Creek.**




| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Scenario 1 | 0% | 28% | 30% | 30% | 27% | 27% | 29% | 29% | 29% | 27% | 26% | 1% |
| Scenario 2 | 0% | 0% | 50% | 40% | 45% | 55% | 65% | 71% | 74% | 70% | 0% | 0% |
| Scenario 3 | 0% | 28% | 65% | 58% | 58% | 65% | 74% | 79% | 81% | 76% | 26% | 1% |
| Required Reduction | 9% | 18% | 48% | 71% | 44% | 36% | 43% | 57% | 53% | 36% | 30% | 0% |

**Figure 8-6. Comparison of monthly loading reductions provided by the TMDL scenarios and loading reductions required by the most restrictive standard at TMDL analysis point CH2 on the South Fork of Chester Creek.**

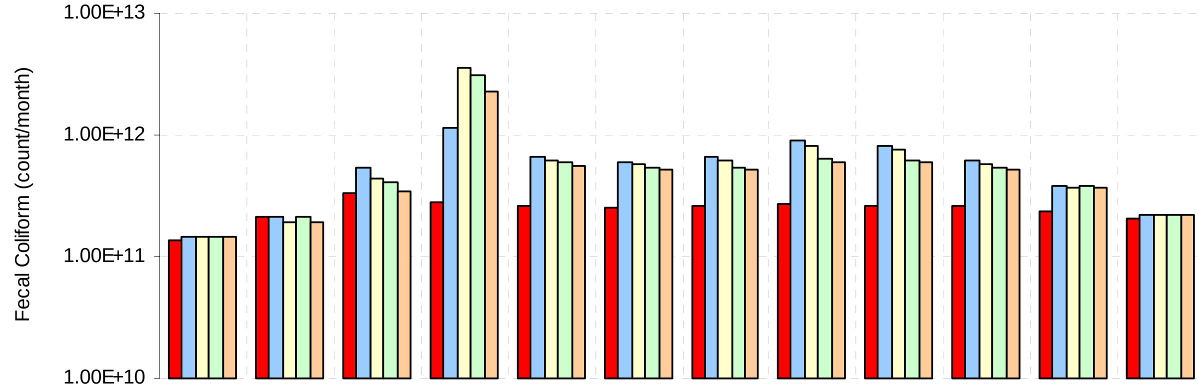
**Table 8-5. Implementation Scenarios for Westchester Lagoon, Analysis Point CL2.**

| *Scenario 1* Month | Existing (FC/month) | Post-Scenario (FC/month) | Percent Reduction |
|---|---|---|---|
| **January** | **1.48E+11** | **1.48E+11** | **0%** |
| February | 1.49E+11 | 1.47E+11 | 1% |
| **March** | **5.41E+11** | **4.38E+11** | **19%** |
| April | 1.13E+12 | 9.97E+11 | 12% |
| May | 6.53E+11 | 6.17E+11 | 6% |
| June | 6.00E+11 | 5.71E+11 | 5% |
| July | 6.64E+11 | 6.17E+11 | 7% |
| August | 8.94E+11 | 8.02E+11 | 10% |
| September | 8.25E+11 | 7.53E+11 | 9% |
| October | 6.14E+11 | 5.85E+11 | 5% |
| November | 3.79E+11 | 3.72E+11 | 2% |
| December | 2.24E+11 | 2.23E+11 | 0% |
| Annual | 6.63E+12 | 6.15E+12 | 7% |
| ***Scenario 2*** | | | |
| **Month** | **Existing (FC/month)** | **Post-Scenario (FC/month)** | **Percent Reduction** |
| January | **1.48E+11** | **1.48E+11** | **0%** |
| February | 1.49E+11 | 1.49E+11 | 0% |
| March | **5.41E+11** | **4.03E+11** | **25%** |
| April | 1.13E+12 | 9.48E+11 | 16% |
| May | 6.53E+11 | 5.92E+11 | 9% |
| June | 6.00E+11 | 5.37E+11 | 11% |
| July | 6.64E+11 | 5.44E+11 | 18% |
| August | 8.94E+11 | 6.50E+11 | 27% |
| September | 8.25E+11 | 6.20E+11 | 25% |
| October | 6.14E+11 | 5.31E+11 | 13% |
| November | 3.79E+11 | 3.79E+11 | 0% |
| December | 2.24E+11 | 2.24E+11 | 0% |
| Annual | 6.63E+12 | 5.63E+12 | 15% |
| ***Scenario 3*** | | | |
| **Month** | **Existing (FC/month)** | **Post-Scenario (FC/month)** | **Percent Reduction** |
| **January** | **1.48E+11** | **1.48E+11** | **0%** |
| February | 1.49E+11 | 1.47E+11 | 1% |
| **March** | **5.41E+11** | **3.42E+11** | **37%** |
| April | 1.13E+12 | 8.43E+11 | 26% |
| May | 6.53E+11 | 5.66E+11 | 13% |
| June | 6.00E+11 | 5.19E+11 | 13% |
| July | 6.64E+11 | 5.19E+11 | 22% |
| August | 8.94E+11 | 6.07E+11 | 32% |
| September | 8.25E+11 | 5.89E+11 | 29% |
| October | 6.14E+11 | 5.18E+11 | 16% |
| November | 3.79E+11 | 3.72E+11 | 2% |
| December | 2.24E+11 | 2.23E+11 | 0% |
| Annual | 6.63E+12 | 5.34E+12 | 19% |

**Table 8-6. Summary of TMDL Scenarios for Westchester Lagoon, TMDL Analysis Point CL2.**

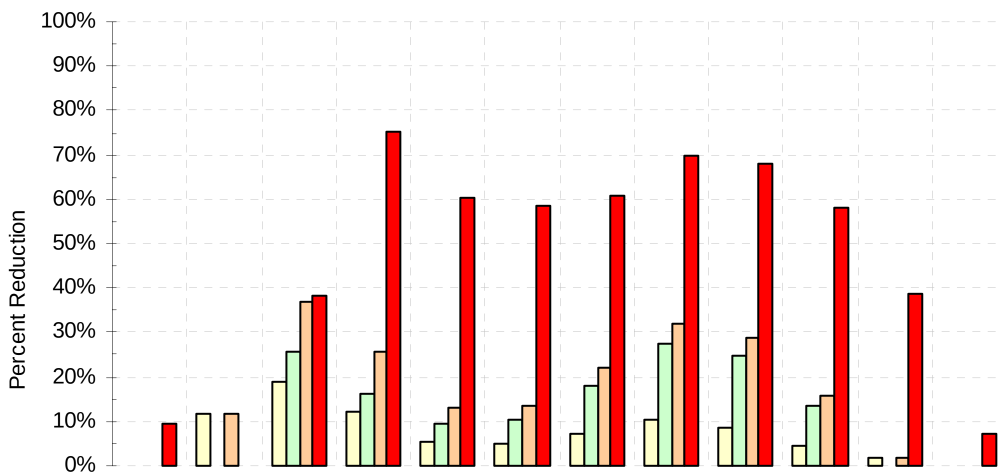
| Month | Required Reduction | Scenario 1 Reduction | Scenario 2 Reduction | Scenario 3 Reduction | Additional Reduction |
|---|---|---|---|---|---|
| **Jan** | **9%** | **0%** | **0%** | **0%** | **9%** |
| Feb | 0% | 12% | 0% | 12% | 0% |
| **Mar** | **38%** | **19%** | **25%** | **37%** | **1%** |
| Apr | 75% | 12% | 16% | 26% | 50% |
| May | 60% | 6% | 9% | 13% | 47% |
| Jun | 59% | 5% | 11% | 13% | 45% |
| Jul | 61% | 7% | 18% | 22% | 39% |
| Aug | 70% | 10% | 27% | 32% | 38% |
| Sep | 68% | 9% | 25% | 29% | 40% |
| Oct | 58% | 5% | 13% | 16% | 42% |
| Nov | 39% | 2% | 0% | 2% | 37% |
| Dec | 7% | 0% | 0% | 0% | 7% |
| Annual | 56% | 7% | 15% | 19% | 36% |

Bold type indicates that the 10 percent not-to-exceed standard applies for the month.
Annual loads are given in FC/year.




| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Loading Capacity | 1.34E+11 | 2.14E+11 | 3.34E+11 | 2.80E+11 | 2.58E+11 | 2.49E+11 | 2.59E+11 | 2.71E+11 | 2.62E+11 | 2.58E+11 | 2.33E+11 | 2.08E+11 |
| Existing Conditions | 1.48E+11 | 2.14E+11 | 5.41E+11 | 1.13E+12 | 6.53E+11 | 6.00E+11 | 6.64E+11 | 8.94E+11 | 8.25E+11 | 6.14E+11 | 3.79E+11 | 2.24E+11 |
| Scenario 1 | 1.48E+11 | 1.90E+11 | 4.38E+11 | 3.58E+12 | 6.17E+11 | 5.71E+11 | 6.17E+11 | 8.02E+11 | 7.53E+11 | 5.85E+11 | 3.72E+11 | 2.23E+11 |
| Scenario 2 | 1.48E+11 | 2.14E+11 | 4.03E+11 | 3.08E+12 | 5.92E+11 | 5.37E+11 | 5.44E+11 | 6.50E+11 | 6.20E+11 | 5.31E+11 | 3.79E+11 | 2.24E+11 |
| Scenario 3 | 1.48E+11 | 1.90E+11 | 3.42E+11 | 2.27E+12 | 5.66E+11 | 5.19E+11 | 5.19E+11 | 6.07E+11 | 5.89E+11 | 5.18E+11 | 3.72E+11 | 2.23E+11 |

**Figure 8-7. Comparison of monthly loading capacities evaluated by the most restrictive standard to existing loads and TMDL scenario loads at TMDL analysis point CL2 on Westchester Lagoon.**




| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Scenario 1 | 0% | 12% | 19% | 12% | 6% | 5% | 7% | 10% | 9% | 5% | 2% | 0% |
| Scenario 2 | 0% | 0% | 25% | 16% | 9% | 11% | 18% | 27% | 25% | 13% | 0% | 0% |
| Scenario 3 | 0% | 12% | 37% | 26% | 13% | 13% | 22% | 32% | 29% | 16% | 2% | 0% |
| Required Reduction | 9% | 0% | 38% | 75% | 60% | 59% | 61% | 70% | 68% | 58% | 39% | 7% |

**Figure 8-8. Comparison of monthly loading reductions provided by the TMDL scenarios and loading reductions required by the most restrictive standard at TMDL analysis point CL2 on Westchester Lagoon.**

## 9.0 IMPLEMENTATION

According to EPA policy on addressing regulated storm water in TMDLs (USEPA, 2002), wasteload allocations can be translated to effluent limitations in the applicable permit through the use of best management practices (BMPs). The following discussion summarizes information contained in USEPA (2002).

NPDES permits must contain effluent limits and conditions consistent with the requirements and assumptions of the wasteload allocations in the relevant approved TMDL. Typically, those effluent limitations to control the discharge of pollutants are expressed in numerical form. However, because storm water discharges are due to storm events that are highly variable in frequency and duration and are not easily characterized, EPA's policy recognizes that only in rare cases will it be feasible or appropriate to establish numeric limits for municipal and small construction storm water discharges. Therefore, EPA recommends that for NPDES-regulated municipal and small construction storm water discharges effluent limits should be expressed as BMPs or other similar requirements, rather than as numeric effluent limits. The policy recognizes the need for an iterative approach to control pollutants in storm water discharges. Specifically, the policy anticipates that a suite of BMPs will be used in the initial rounds of permits and that these BMPs will be tailored in subsequent rounds.

Appropriate BMPs will be identified for implementation in the Chester Creek watershed in the relevant storm water permit. Information on the applicability of the BMPs for removal of fecal coliform and on the feasibility of implementation in the Chester Creek watershed will be taken into account when identifying BMPs.

The National Storm water Best Management Practices database (http://www.bmpdatabase.org/) provides access to BMP performance data in a standardized format for over 190 BMP studies conducted over the past fifteen years. The database was developed by the Urban Water Resources Research Council (UWRRC) of American Society of Civil Engineers (ASCE) under a cooperative agreement with the U.S. Environmental Protection Agency.

Some studies on BMP effectiveness have evaluated the ability of certain BMPs to remove fecal coliform and other bacteria. The Center for Watershed Protection has compiled a storm water treatment database containing information from studies conducted from 1990 to the present. Schueler (2000) provides a summary of the information in the database. The included studies do not provide sufficient fecal coliform data to statistically evaluate the effectiveness of BMPs in removing bacteria from urban runoff, but Schueler (2000) indicates that mean fecal coliform removal rates typically range from 65 to 75 percent from ponds and wetlands and 55 percent for filters. Schueler (2000) and SMRC (2000) also reports that water quality swales (including biofilters and wet and dry swales) consistently exported bacteria. Although it is possible that the bacteria thrive in the warm swale soils, the studies do not account for potential sources of bacteria directly to the swales, such as wildlife and domestic pets. Table 9-1 provides examples of BMP removal efficiencies for bacteria. Because information on BMP efficiency for fecal coliform is limited, information in Table 9-1 should be applied with consideration of local knowledge of the environmental conditions and BMP performance in the Anchorage area.

CWP (1997) discusses the use and effectiveness of BMPs in cold climates. Due to the characteristics such as freezing temperatures and snowmelt events, some BMPs are not appropriate or require modifications for use in cold climates. Table 9-2 provides a summary of the applicability of BMPs to colder climates.

**Table 9-1. Fecal coliform removal for various BMPs.**

| BMP Type | Fecal Coliform Bacteria Removal (%) |
|---|---|
| Detention and Dry Extended Detention Ponds | 78 |
| Wet Ponds | 70 |
| Shallow Marsh Wetland | 76 |
| Submerged Gravel Wetland | 78 |
| Filters (excluding vertical sand filters) | 37 |
| Infiltration Basins | 90 |
| Ditches | 5 |

Adapted from Schueler (2000) and SMRC (2000)

**Table 9-2. Applicability of BMPs to cold climate conditions (CWP, 1997).**

| Type | BMP | Classification | Notes |
|---|---|---|---|
| **Ponds** | Wet Pond | □ | Can be effective, but needs modifications to prevent freezing of outlet pipes. Limited by reduced treatment volume and biological activity in the permanent pool during ice cover. |
| | Wet ED Pond | □ | Some modifications to conveyance structures needed. Extended detention storage provides treatment during the winter season. |
| | Dry ED Pond | □ | Few modifications needed. Although this practice is easily adapted to cold climates, it is not highly recommended overall because of its relatively poor warm season performance. |
| **Wetlands** | Shallow Marsh | □ | In climates where significant ice formation occurs, shallow marshes are not effective winter BMPs. Most of the treatment storage is taken up by ice, and the system is bypassed. |
| | Pond/Wetland System | □ | Pond/Wetland systems can be effective, especially if some ED storage is provided. Modifications for both pond and wetland systems apply to these BMPs. This includes changes in wetland plant selection and planting. |
| | ED Wetland | □ | See Wet ED Pond. Also needs modifications to wetland plant species. |
| **Infiltration** | Porous Pavement | □ | This practice is restricted in cold climates. It cannot be used on any pavement that is sanded, because the pavement will clog. |
| | Infiltration Trench | □ | Can be effective, but may be restricted by groundwater quality concerns related to infiltrating chlorides. Also, frozen ground conditions may inhibit the infiltration capacity of the ground. |
| | Infiltration Basin | □ | See infiltration trench. |

| Type | BMP | Classification | Notes |
|---|---|---|---|
| **Filtering Systems** | Surface Sand Filter | □ | Frozen ground considerations, combined with frost heave concerns, make this type of system relatively ineffective during the winter season. |
| | Underground Sand Filter | □ | When placed below the frost line, these systems can function effectively in cold climates. |
| | Perimeter Sand Filter | □ | See Surface Sand Filter. |
| | Bioretention | □ | Problems functioning during the winter season because of reduced infiltration. It has some value for snow storage on parking lots, however. |
| | Submerged Gravel Wetlands | □ | Some concerns of bypass during winter flows. Has been used in relatively cold regions with success., but not tested in a wide range of conditions. |
| **Open Channel Systems** | Grassed Channel | □ | Reduced effectiveness in the winter season because of dormant vegetation and reduced infiltration. Valuable for snow storage. |
| | Dry Swale | □ | Reduced effectiveness in the winter season because of dormant vegetation and reduced infiltration. Very valuable for snow storage and meltwater infiltration. |
| | Wet Swale | □ | Reduced effectiveness in the winter season because of dormant vegetation. Can be valuable for snow storage. |
| | Vegetated Filter Strip | □ | See Dry Swale. |

ED: Extended Detention
□ Easily applied to cold climates; can be effective during the winter season.
□ Can be used in cold climates with significant modifications; moderately effective during the winter season.
□ Very difficult to use in cold climates. Generally not recommended.

## 10.0 MONITORING

Follow-up monitoring for a TMDL is important in tracking the progress of TMDL implementation and subsequent water quality response as well as in evaluating any assumptions made during TMDL development. Monitoring results can be used to support any necessary future TMDL revisions and to track BMP effectiveness. Most importantly, monitoring will track the water quality of Chester Creek to evaluate future attainment of water quality standards.

USEPA (2002) outlines EPA regulatory requirements for and provides guidance on establishing WLAs for storm water in TMDLs. The memorandum also provides information on the implementation of effluent limitations through NPDES permits consistent with the TMDL WLAs. The policy outlined affirms the appropriateness of an iterative, adaptive management BMP approach, whereby permits include effluent limits (e.g., a combination of structural and non-structural BMPs) that address storm water discharges, implement mechanisms to evaluate the performance of such controls, and make adjustments (i.e., more stringent controls or specific BMPs) as necessary to protect water quality.

USEPA (2002) indicates that where BMPs are used to implement the WLAs, the NPDES permit should require the monitoring necessary to assess if the expected load reductions attributed to BMP implementation are achieved (e.g., BMP performance data), although the permitting authority has the discretion under EPA's regulations to decide the frequency of such monitoring. EPA recommends that such permits require collecting data on the performance of the BMPs. The monitoring data can provide a basis for revised management measures and indicate any necessary adjustments to the BMPs. Any monitoring for storm water required as part of the permit should be consistent with the state's overall assessment and monitoring strategy.

## 11.0 PUBLIC COMMENTS AND RESPONSIVENESS SUMMARY

The fecal coliform bacteria Total Maximum Daily Load (TMDL) for the Chester Creek watershed, including University Lake and Westchester Lagoon, was developed over several years with extensive opportunity for feedback from affected parties. In 1993, Alaska's Department of Environmental Conservation (DEC) published an assessment of Chester Creek, based on consultation with the Municipality of Anchorage (MOA) and others. This assessment assembled much of the information on the watershed that was used develoing this document. In 1999, DEC developed, with the Environmental Protection Agency (EPA) and its contractor (Tetratech) and through consulting with MOA, an approach for developing fecal coliform bacteria TMDLs that would be appropriate for Anchorage area streams. Using this document, DEC consulted with the MOA, Alaska Department of Transportation (ADOT), and the University of Alaska to finalize the approach for developing the Chester Creek TMDL, along with TMDLs for six other Anchorage streams. TMDL development began in July 2002. Drafts were shared with the MOA and other key stakeholders for feedback through emails, meetings, and phone conversations. To the extent possible and relevant, DEC revised the TMDLs based on the stakeholder comments. TMDLs on the other six Anchorage Streams were submitted in May 2004. The Chester Creek TMDL was not submitted at that time as DEC determined it was more appropriate to complete it in conjunction with University Lake and Westchester Lagoon TMDLs, which did not begin development until June 2004.

DEC completed the public draft TMDL for Chester Creek, University Lake and Westchester Lagoon in March 2005. Copies were provided to the MOA, Alaska Department of Transportation and others (University of Alaska). ADEC published a public notice on these TMDLs on the State of Alaska's website on April 7, 2005 and in the Anchorage Daily News, on April 10, 2005. A fact sheet describing the TMDL was also posted on ADEC's website, along with the draft TMDL. The public comment period was open from April 7, 2005 through May 6, 2005, and a public meeting was held on April 22, 2005 at the Anchorage DEC office. In addition, DEC sent electronic copies of the draft TMDL to the MOA, ADOT, and all relevant federal, state, and local agencies, and the major citizen group involved with Anchorage water quality issues (Anchorage Waterways Council) which has cooperated with DEC and MOA in monitoring fecal coliform in Chester Creek and other Anchorage Streams.

The TMDL process had extensive stakeholder involvement early and throughout the process, which accounts for the limited amount of public comment received during the public notice period. The only comments received during the public notice period were via email and phone conversations from the Municipality of Anchorage. To the extent practical, these comments were addressed and incorporated into the Final TMDL. DEC responded to MOA's comments in a letter of May 2005 (included in submittal packet). As indicated in the letter, DEC revised the TMDL to better describe the process used to identify fecal coliform bacteria sources. The MOA also commented on the appropriateness of Alaska's Water Quality Standards. This comment was passed on to DEC's Standards Program for consideration in future changes to the standards. In regards to a MOA comment on load allocations, DEC responded that the TMDL assigns the maximum waste load allocation possible to the municipal storm water system, providing the Municipality the most flexibility in Best Management Practices (BMPs) implementation. In regards to a MOA comment on technical assumptions, DEC explained that the TMDL used the best data and models available; and shares the Municipality's desire to continue to improve data and models used in developing and implementing the TDML.

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# APPENDIX A: SWMM CALIBRATION

## Introduction

The Storm Water Management Model (SWMM) simulates real storm events based on rainfall and other meteorological inputs, such as evaporation and temperature, and watershed transport, storage and management practices to predict runoff quantity and quality. At the subwatershed scale, SWMM provides for evaluation of in-stream conditions, which allows for the direct comparison with relevant water quality standards.

SWMM is comprised of several computational blocks, or modules, of which the Rain, Temperature, Runoff and Transport blocks were used for the Chester Creek study. These modules essentially generate surface runoff and route it to the stream channel based on user-defined inputs such as precipitation, land use, and topography. Various hydrologic, pollutant buildup/washoff, and in-channel parameters must also be specified by the user. SWMM represents the stream network system as a series of links and nodes with the links representing stream or channel segments and nodes representing contributing subcatchment inlet points. Consequently, the model represents Chester Creek as a series of hydrologically connected subwatersheds.

Hydrologic and water quality simulations of the watershed were performed for Chester Creek. The modeling approach included continuous simulation of rainfall and runoff, as well as in-stream fecal coliform counts. Calibration of the Storm Water Management Model (SWMM) consisted of calibrating hydrologic response and water quality. This appendix describes the calibration of these two components.

## Model Configuration

To simulate watershed loadings and resulting counts of fecal coliform, the Chester Creek watershed was divided into numerous modeling subcatchments using spatial (map) data and tabular data provided by MOA. The modeling subcatchments for the lower and upper Chester Creek subwatersheds are shown in Section 5 of the main report. Figures 5-2 and 5-4 display the impervious land cover classes found in the lower and upper Chester Creek subwatersheds, respectively. Hydrology and fecal coliform for the headwaters subwatershed of the Chester Creek basin was not simulated in SWMM. Estimated stream flow and observed fecal coliform concentration discharging from the headwaters subwatershed, referred to as boundary conditions, were instead used as input into the model.

Required input data for each subcatchment include area, imperviousness, slope, Manning’s roughness coefficient, a conceptual subcatchment width (total width of overland flow), depression storage, and infiltration parameters. These data were previously estimated by MOA for SWMM modeling applications of Chester Creek. The MOA SWMM parameter values were compiled for each land cover class within each subcatchment in the Chester Creek watershed. The land cover classes reflect the degree of imperviousness for a given cover type. Watershed parameters were lumped, that is spatially weighted or averaged, for each modeling subcatchment. Since information about the storm drain network’s hydraulic characteristics (such as pipe diameter and roughness characteristics) were not available, the Runoff block was set up to “route” runoff to each subcatchment outlet.

Daily precipitation and temperature data, available from the National Climatic Data Center (NCDC) weather station at the Ted Stevens International Airport from 1952 through 2003, were used for the Chester Creek watershed SWMM modeling.

**Hydrologic Calibration**

The hydrologic calibration involved a comparison of model results to in-stream flow observations recorded at the USGS stream gage (15275100) located near Arctic Boulevard (see Figure 3-1 in the main report). This is the only operative stream gage in the entire Chester Creek watershed. This gage recorded daily mean flow from June 17, 1966 through September 30, 1993, and from October 1, 1998 to September 30, 2000. The stream gage was not operational from October 1, 1993 to September 30, 1998. The period of hydrologic calibration was therefore selected as July 1, 1987 to September 30, 1993. This period is deemed sufficient to calibrate the hydrologic response of Chester Creek to rainfall events. The results of the hydrologic calibration are shown in Figures A-1 through A-4. Figure A-1 shows a comparison of the observed versus simulated average monthly stream flow for the calibration period, and displays a very good level of agreement ($R^2 = 0.99$).

Graphical comparisons of observed versus simulated mean monthly streamflow are presented in Figures A-2 and A-3. These figures show a good level of agreement between observed and simulated mean monthly streamflow. Additionally, an observed versus simulated flow duration analysis is presented in Figure A-4. With the exception of the very lowest flows, the model adequately describes flow variability within the Chester Creek watershed.

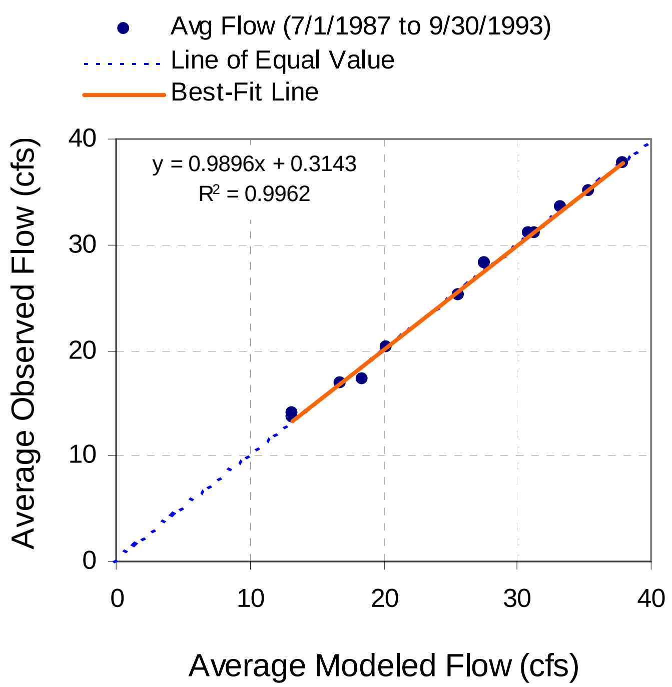


**Figure A-1. Statistical comparison between observed versus simulated mean monthly stream flow, 1987 – 1993.**

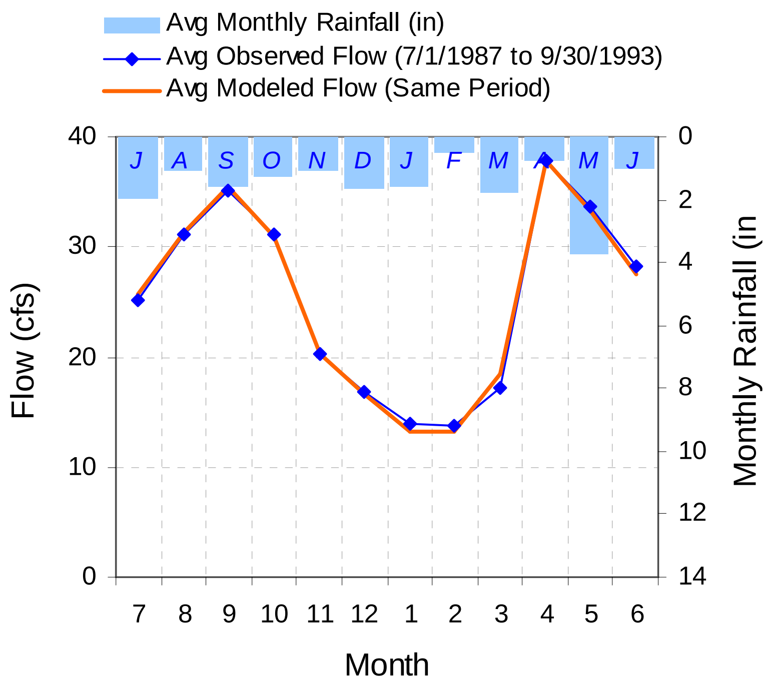


**Figure A-2. Observed versus simulated mean monthly stream flow, 1987 - 1993.**

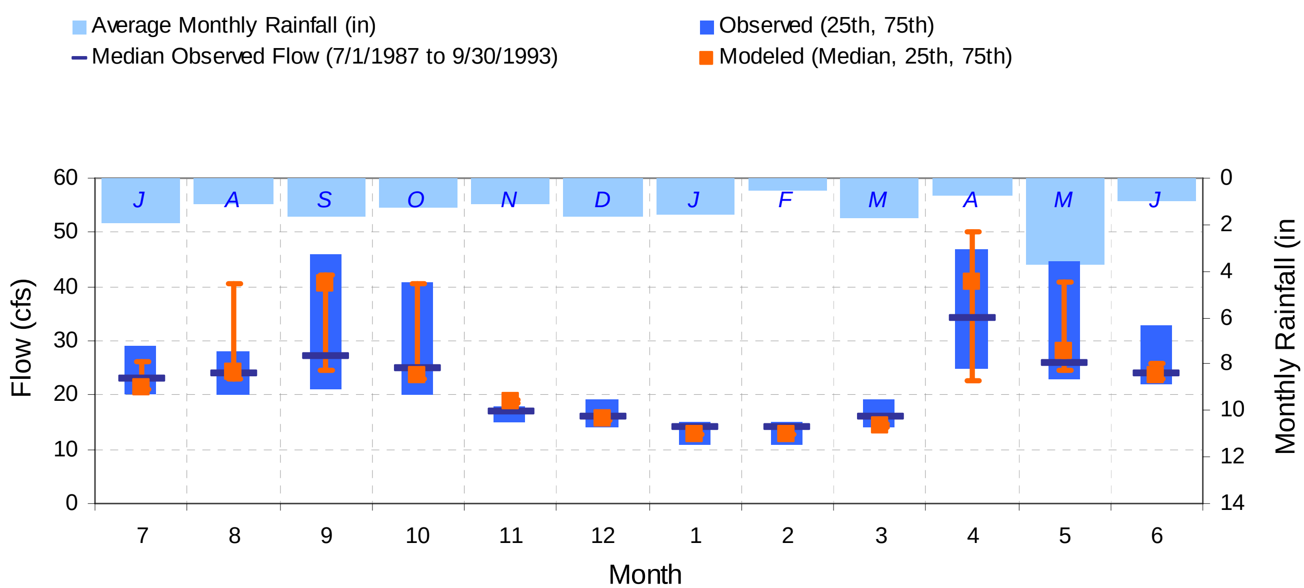


**Figure A-3. Observed versus simulated 25th percentile, 75th percentile, and median monthly streamflow, 1987 - 1993.**

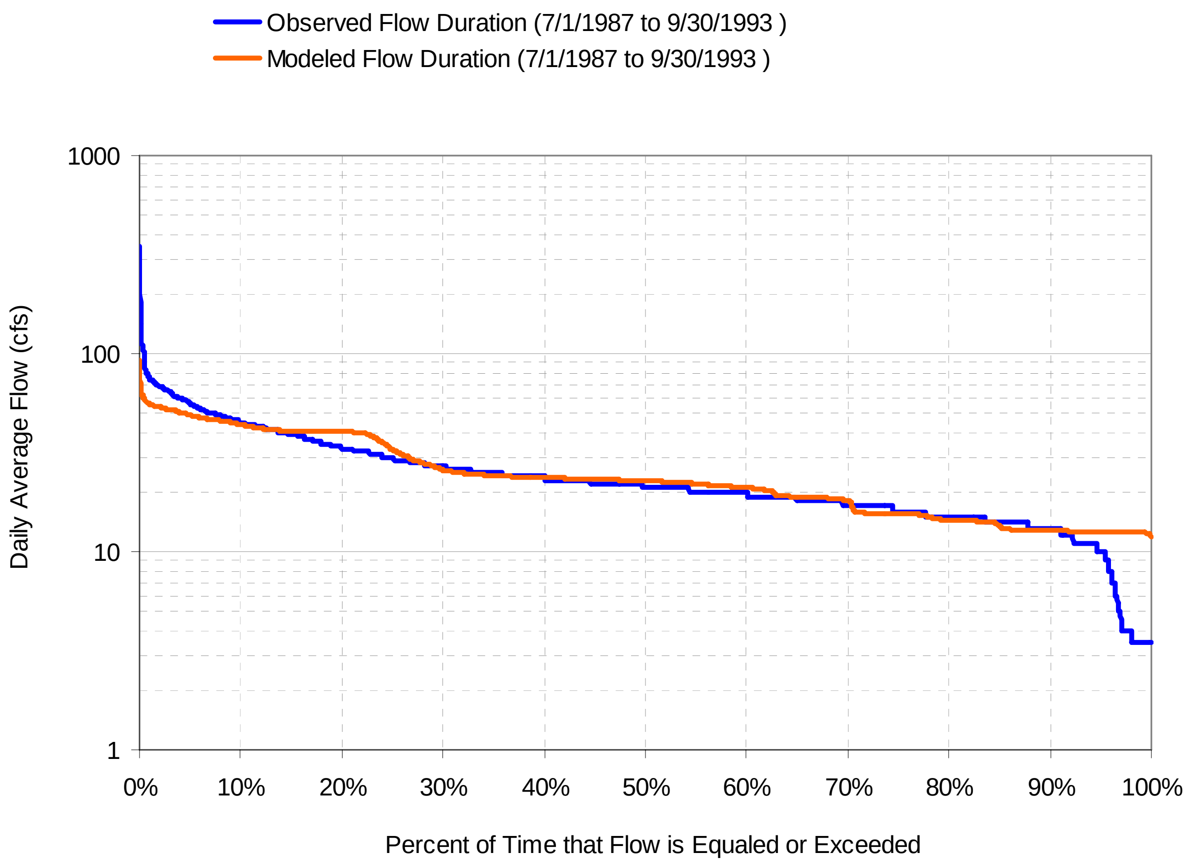


**Figure A-4. Observed versus simulated flow duration, 1987 - 1993.**

Seasonal and annual differences between observed versus simulated stream flow are summarized in Tables A-1 and A-2. Table A-1 shows that simulated flow for the calibration period agrees well with observed stream flow data. A statistical summary of the hydrologic calibration is presented in Table A-2. Table A-2 shows that the greatest errors occur in simulated summer storm volumes, yet these errors are within recommended calibration parameters (Lumb et al., 1994). Over all, the hydrologic calibration appears adequate in that it reflects the total water yield, annual variability, and magnitude of individual storm events in the basin. All recommended criteria are met except for the 10 percent highest flow criteria, which is underestimated by the SWMM. This error is most likely related to the precipitation record, where larger, more intense storms may have occurred somewhere within the watershed buy may not have not been recorded by the rain gage.

**Table A-1. Comparison of Observed and Simulated Monthly Flow Statistics.**

| MONTH | OBSERVED FLOW (CFS) | | | | MODELED FLOW (CFS) | | | |
|---|---|---|---|---|---|---|---|---|
| | MEAN | MEDIAN | 25TH | 75TH | MEAN | MEDIAN | 25TH | 75TH |
| Jul | 25.17 | 23.00 | 20.00 | 29.00 | 25.64 | 21.50 | 21.00 | 26.20 |
| Aug | 31.10 | 24.00 | 20.00 | 28.00 | 31.36 | 24.20 | 23.10 | 40.50 |
| Sep | 35.13 | 27.00 | 21.00 | 46.00 | 35.39 | 40.60 | 24.60 | 42.20 |
| Oct | 31.14 | 25.00 | 20.00 | 40.75 | 30.92 | 23.70 | 23.10 | 40.50 |
| Nov | 20.33 | 17.00 | 15.00 | 18.00 | 20.24 | 18.80 | 18.60 | 19.10 |
| Dec | 16.86 | 16.00 | 14.00 | 19.00 | 16.72 | 15.50 | 15.40 | 15.60 |
| Jan | 13.97 | 14.00 | 11.00 | 15.00 | 13.19 | 12.80 | 12.70 | 12.80 |
| Feb | 13.68 | 14.00 | 11.00 | 15.00 | 13.18 | 12.70 | 12.70 | 12.80 |
| Mar | 17.25 | 16.00 | 14.00 | 19.00 | 18.40 | 14.40 | 14.20 | 14.70 |
| Apr | 37.77 | 34.00 | 25.00 | 47.00 | 37.84 | 40.70 | 22.50 | 50.15 |
| May | 33.62 | 26.00 | 23.00 | 44.75 | 33.22 | 28.15 | 24.60 | 40.90 |
| Jun | 28.28 | 24.00 | 22.00 | 33.00 | 27.60 | 23.55 | 23.10 | 25.88 |

**Table A-2. Statistical Summary of Hydrologic Calibration for USGS Station 15275100, at Arctic Boulevard, Anchorage, Alaska (MOA Fecal Monitoring Site CH2).**

| 6.25-Year Analysis Period: 7/1/1987 to 9/30/1993<br>Flow volumes are (inches/year) for upstream drainage area | | | |
|---|---|---|---|
| Total Simulated In-stream Flow: | **0.936** | Total Observed In-stream Flow: | **0.937** |
| | | | |
| Total of simulated highest 10% flows: | **0.184** | Total of Observed highest 10% flows: | **0.227** |
| Total of Simulated lowest 50% flows: | **0.304** | Total of Observed Lowest 50% flows: | **0.285** |
| | | | |
| Simulated Summer Flow Volume (months 7-9): | **0.317** | Observed Summer Flow Volume (7-9): | **0.314** |
| Simulated Fall Flow Volume (months 10-12): | **0.200** | Observed Fall Flow Volume (10-12): | **0.202** |
| Simulated Winter Flow Volume (months 1-3): | **0.130** | Observed Winter Flow Volume (1-3): | **0.130** |
| Simulated Spring Flow Volume (months 4-6): | **0.288** | Observed Spring Flow Volume (4-6): | **0.291** |
| | | | |
| Total Simulated Storm Volume: | **0.154** | Total Observed Storm Volume: | **0.153** |
| Simulated Summer Storm Volume (7-9): | **0.065** | Observed Summer Storm Volume (7-9): | **0.079** |
| *Errors (Simulated-Observed)* | *Error Statistics* | *Recommended Criteria* | |
| Error in total volume: | **-0.13** | **10** | |
| Error in 50% lowest flows: | **6.44** | **10** | |
| Error in 10% highest flows: | **-23.51** | **15** | |
| Seasonal volume error - Summer: | **1.08** | **30** | |
| Seasonal volume error - Fall: | **-0.68** | **30** | |
| Seasonal volume error - Winter: | **-0.22** | **30** | |
| Seasonal volume error - Spring: | **-1.02** | **30** | |
| Error in storm volumes: | **0.31** | **30** | |
| Error in summer storm volumes: | **-20.94** | **50** | |
| | | | |

**Water Quality Calibration**

After hydrology was sufficiently calibrated, water quality calibration was performed. Modeled versus observed in-stream concentrations were directly compared during model calibration. The water quality calibration consisted of executing the watershed model, comparing water quality time series output to available water quality observation data, and adjusting pollutant loading and in-stream water quality parameters within a reasonable range. The objective was to best simulate the observed data, as well as to obtain modeling output within the range of all observations (i.e., the observed minimum and maximum water quality concentrations should be within the range of the simulated minimum and maximums). The adequacy of the water quality calibration was assessed through comparison to observed water quality data.

Simulation of fecal coliform bacteria concentrations often presents a challenge for watershed modeling. Observed concentrations tend to be highly variable in both space and time - due to both natural variability and analytical uncertainty. Further, instream concentrations may be elevated by sources which cannot explicitly be included in the model (e.g., illicit connections to storm sewers or illegal dumping into storm drain systems), or which may be included in the model in a general way, but have large and unmonitored variability (e.g., wildlife sources). The watershed models represent average loads from the land surface as a washoff process. In addition, background loading is represented as a ground water concentration. In fact, the load attributed to ground water includes both true ground water load and other unmodeled sources of loading that are not flow-dependent.

Adjusted water quality parameters within the model included the daily surface fecal coliform accumulation factors (called QFACT1, QFACT2, and QFACT3), surface washoff factors (called WASHPO, and RCOEFF), and the instream decay rate coefficient.

A power-linear function was used to estimate the daily build up of fecal coliform, and is given in the expression below:

$$\text{PSHED} = \text{QFACT3} \times t^{(\text{QFACT2})}$$

where,

PSHED = fecal accumulation rate, #FC/ac
QFACT3 = third build up factor, FC/acre
QFACT2 = second build up factor, dimensionless
t = time interval, day

Fecal coliform washoff is dependent upon the amount of fecal coliform available to be removed during a runoff event, and may be expressed as an exponential function as:

$$\text{POFF} = -\text{RCOEF} \times R^{(\text{WASHPO})} \times \text{PSHED}$$

where,

POFF = fecal coliform load washed off at time t, quantity/second
PSHED = quantity of fecal coliform available for washoff at time t
RCOEF = washoff coefficient
R = runoff rate in inches/hour.

The calibrated SWMM water quality parameters are presented in Table A-3 according to impervious land cover type.

**Table A-3. SWMM Water Quality Parameters Used in the Chester Creek Watershed.**

| MOA Impervious Classification | QFACT1 | QFACT2 | QFACT3 | WASHPO | RCOEF | REFF[1] |
|---|---|---|---|---|---|---|
| Barren | 1.37E8 | 0.6 | 1.70E6 | 1.9 | 0.7 | 0.5 |
| ICI | 1.70E8 | 0.7 | 1.50E6 | 1.9 | 0.7 | 0.5 |
| DCI | 6.26E8 | 0.7 | 2.00E5 | 1.9 | 0.7 | 0.5 |
| Street | 2.00E7 | 0.7 | 2.00E5 | 1.9 | 0.7 | 0.5 |
| Wetland | 8.35E10 | 0.8 | 3.10E6 | 1.9 | 0.7 | 0 |
| Lake | 1.75E7 | 0.8 | 2.00E5 | 1.9 | 0.7 | 0 |
| Landscape | 1.67E9 | 0.8 | 3.67E7 | 1.9 | 0.7 | 0.5 |
| Forest | 8.23E9 | 0.8 | 5.19E6 | 1.9 | 0.7 | 0 |

[1]REFF is the efficiency fraction of street sweeping practices. A value of 0.5 is equal to 50 % efficiency.

The values of WASHPO and RCOEF given in Table A-3 are representative of long duration, low intensity rainfall events that are characteristic of the storm events that typically occur within Anchorage, Alaska.

Water quality calibration adequacy was primarily assessed through review of time-series plots. Looking at a time series plot of modeled versus observed data provides more insight into the nature of the system and is more useful in water quality calibration than a statistical comparison. Flow (or rainfall) and water quality can be compared simultaneously, and thus can provide insight into conditions during the monitoring period (dry period versus storm event). The response of the model to storm events can be studied and compared to observations (data permitting). Ensuring that the storm events are represented within the range of the data over time is the most practical and meaningful means of assessing the quality of a calibration. Furthermore, due to the relative lack of water quality monitoring data, it was not possible to make statistical comparisons of the predicted and observed data.

Water quality calibration involved the examination of observed and predicted data at eight calibration sites, as shown in Figure 3-1 in the main report. These sites correspond to the following MOA fecal coliform water quality monitoring stations: CH7, CH9, ULI, ULO, CH6, CH2, CL3, and CL2.

Figures A-5 through A-12 present the results of the model calibration for each of the MOA fecal coliform monitoring stations. Simulation results show a reasonable general agreement between observed and simulated fecal coliform concentrations and the model is deemed suitable for use in TMDL development.

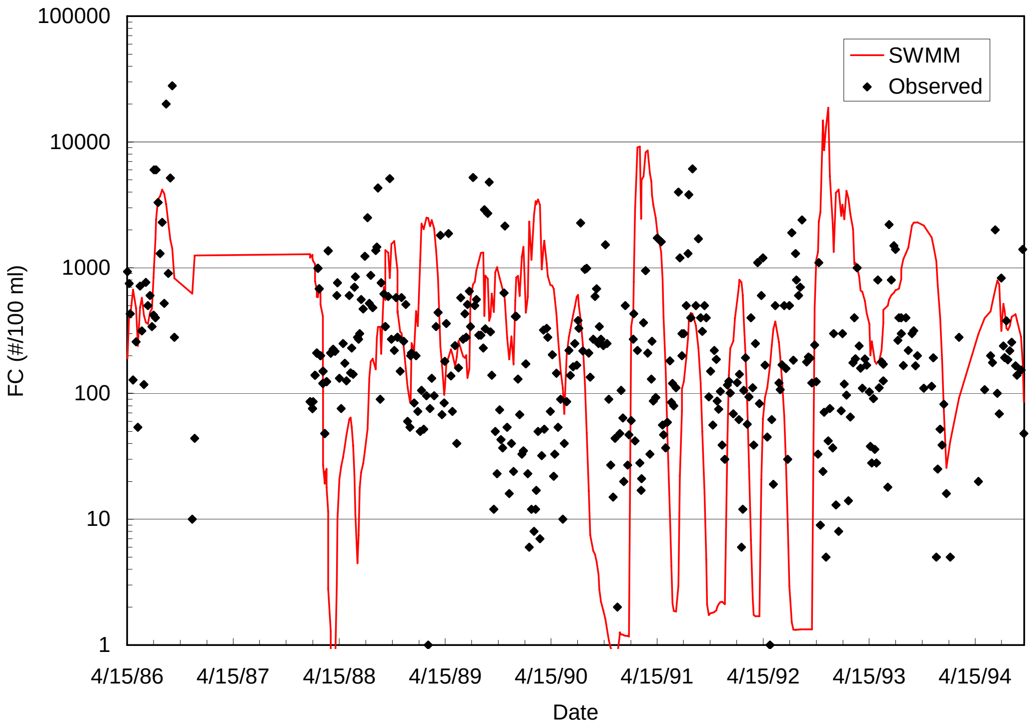


**Figure A-5. Observed versus simulated fecal coliform at monitoring station CH7.**

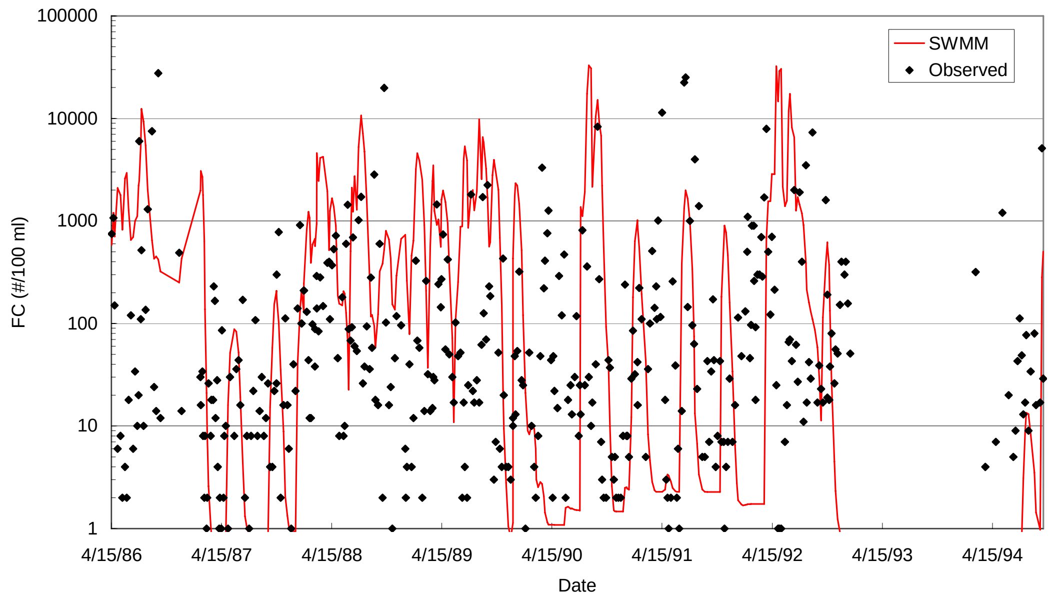


**Figure A-6. Observed versus simulated fecal coliform at monitoring station CH9.**

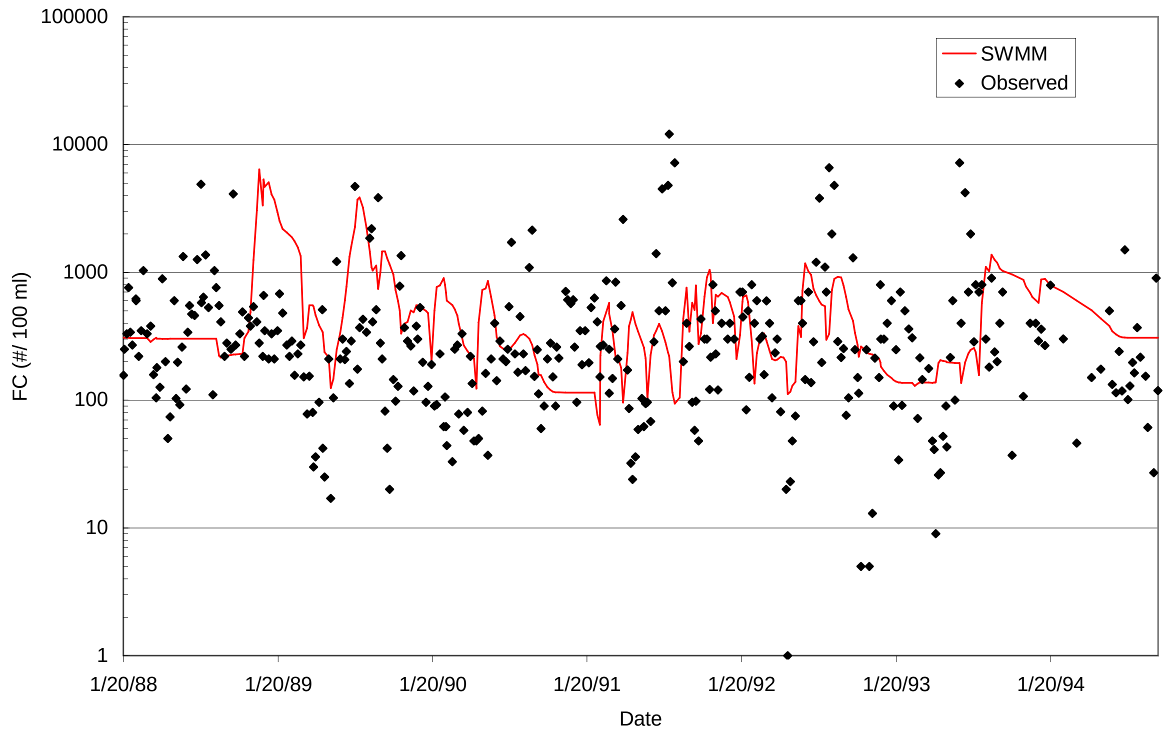


**Figure A-7. Observed versus simulated fecal coliform at monitoring station ULI.**

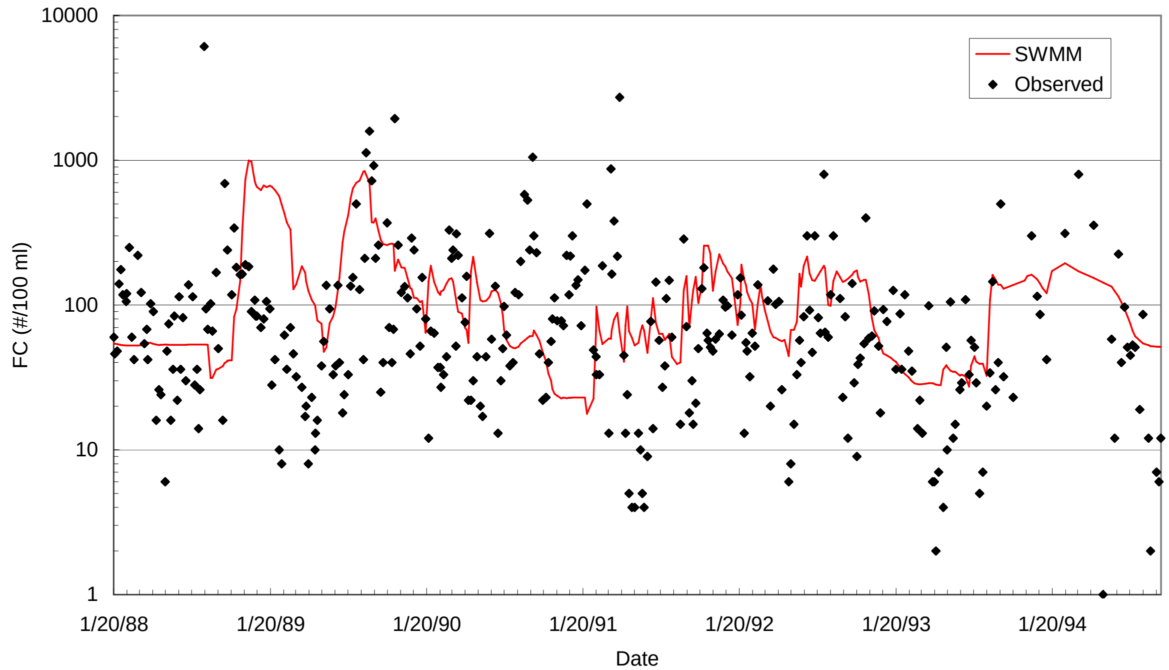


**Figure A-8. Observed versus simulated fecal coliform at monitoring station ULO.**

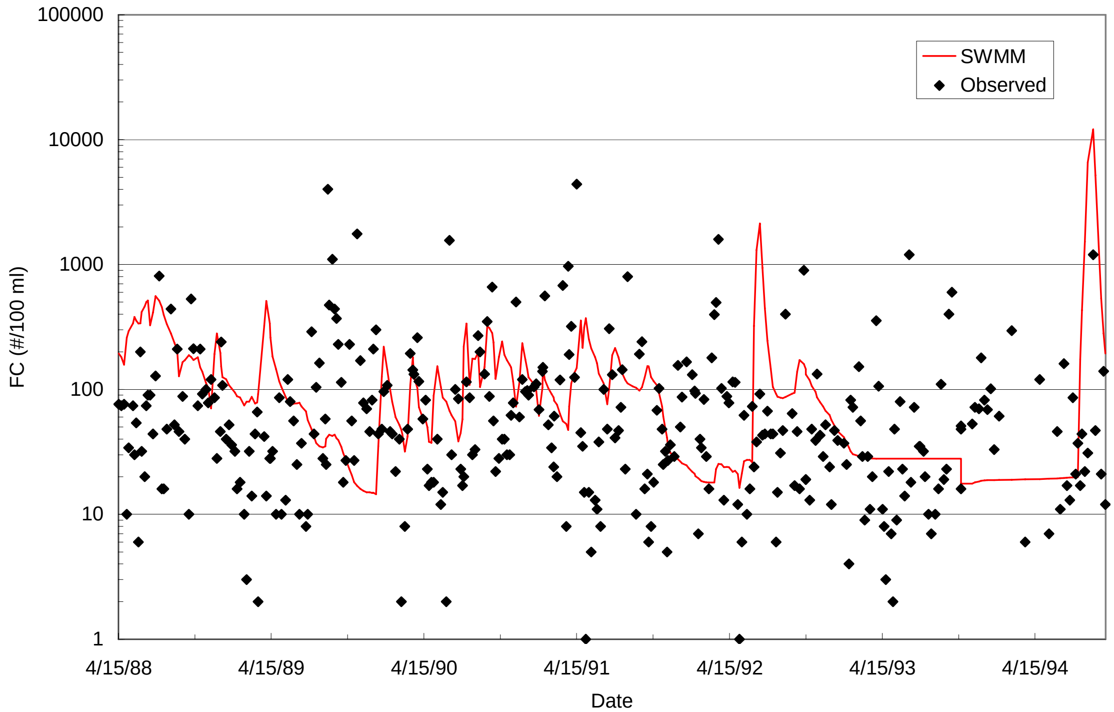


**Figure A-9. Observed versus simulated fecal coliform at monitoring station CH6.**

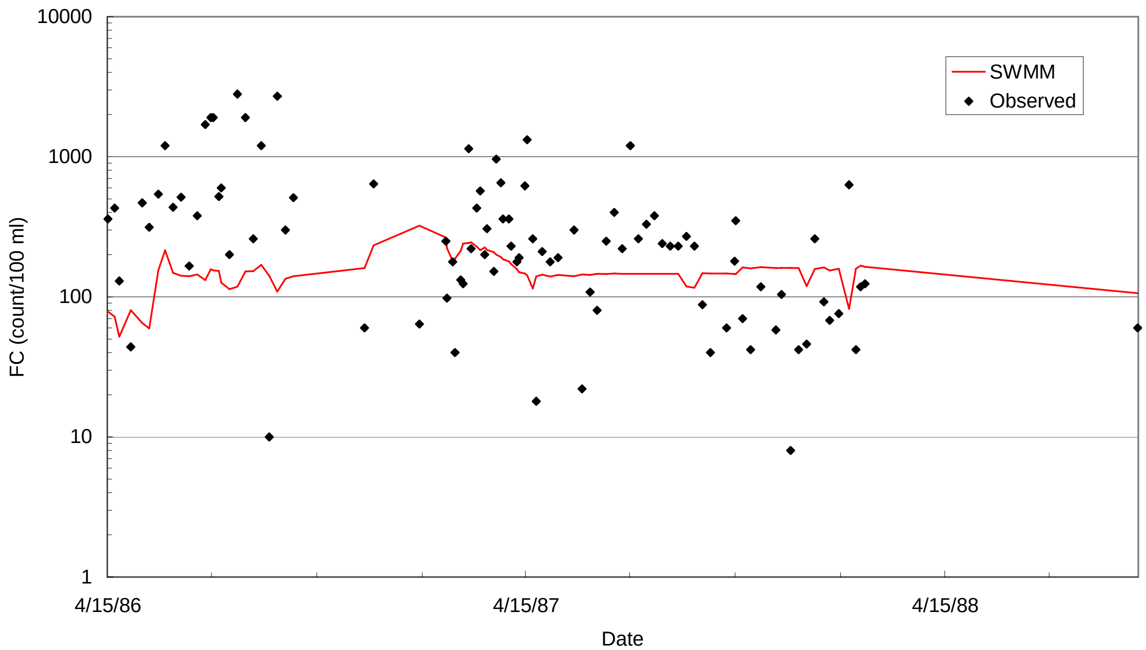


**Figure A-10. Observed versus simulated fecal coliform at monitoring station CH2.**

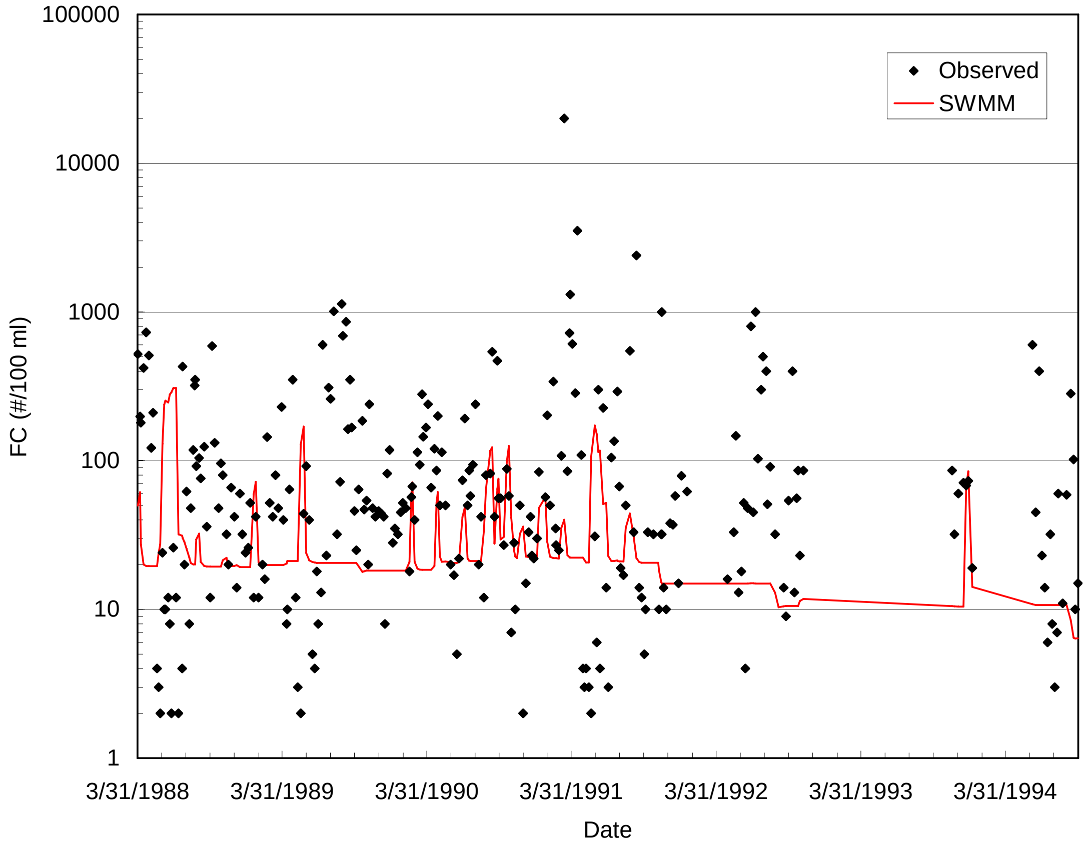


**Figure A-11. Observed versus simulated fecal coliform at monitoring station CL3.**

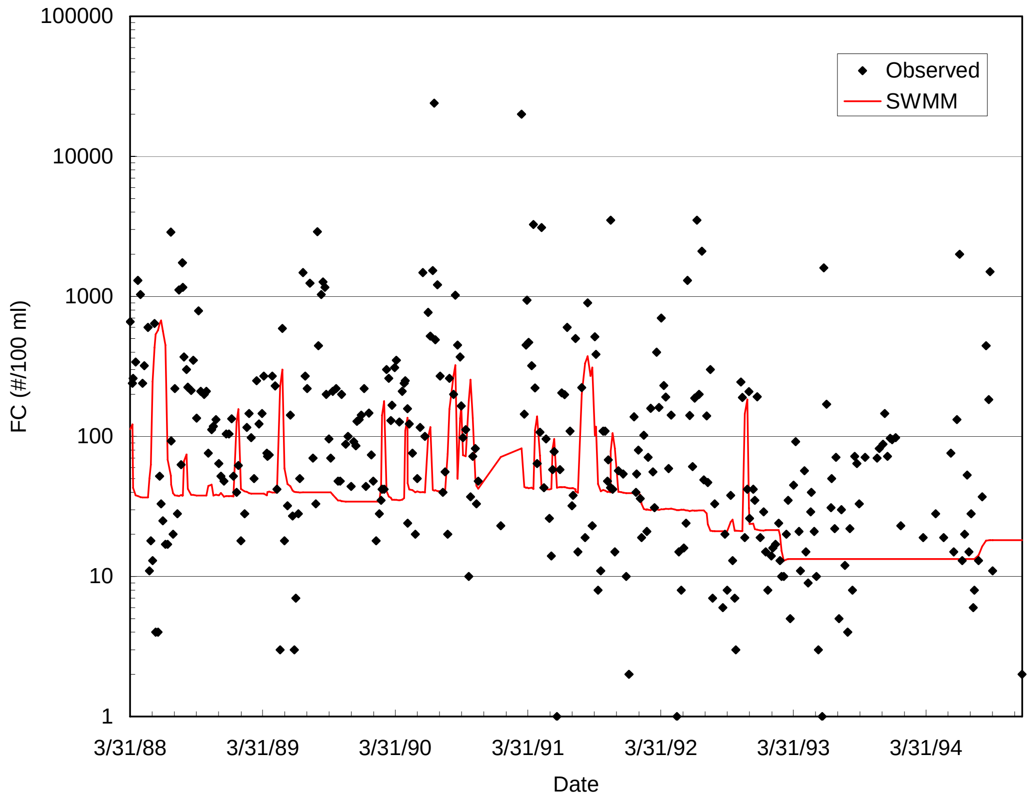


**Figure A-12. Observed versus simulated fecal coliform at monitoring station CL2.**

# APPENDIX B: ANNUAL AVERAGE SUBBASIN FECAL COLIFORM LOADS

**Table B-1. Annual Average Subbasin Fecal Coliform Loads.**

| SUBBASIN | ACRES | AVERAGE LOAD (#FC/YEAR) | AVG #FC/AC | RANK |
|---|---|---|---|---|
| **77** | 42.0 | 1.425E+16 | 3.393E+14 | 1 |
| **133** | 23.0 | 6.950E+15 | 3.022E+14 | 2 |
| **81** | 56.8 | 1.461E+16 | 2.572E+14 | 3 |
| **144** | 9.2 | 2.000E+15 | 2.179E+14 | 4 |
| **118** | 8.8 | 1.892E+15 | 2.140E+14 | 5 |
| **126** | 188.2 | 3.842E+16 | 2.041E+14 | 6 |
| **119** | 19.6 | 3.902E+15 | 1.993E+14 | 7 |
| **154** | 31.8 | 6.289E+15 | 1.978E+14 | 8 |
| **180** | 37.0 | 7.070E+15 | 1.913E+14 | 9 |
| **51** | 0.0 | 1.077E+16 | 1.889E+14 | 10 |
| **45** | 18.5 | 3.414E+15 | 1.849E+14 | 11 |
| **152** | 71.4 | 1.293E+16 | 1.811E+14 | 12 |
| **135** | 26.2 | 4.707E+15 | 1.799E+14 | 13 |
| **149** | 18.7 | 3.323E+15 | 1.776E+14 | 14 |
| **91** | 0.0 | 7.300E+15 | 1.768E+14 | 15 |
| **2** | 1055.9 | 1.805E+17 | 1.710E+14 | 16 |
| **27** | 0.0 | 1.066E+16 | 1.686E+14 | 17 |
| **48** | 0.0 | 3.065E+15 | 1.655E+14 | 18 |
| **12** | 192.4 | 3.158E+16 | 1.641E+14 | 19 |
| **171** | 87.9 | 1.415E+16 | 1.611E+14 | 20 |
| **18** | 251.6 | 3.962E+16 | 1.575E+14 | 21 |
| **3** | 252.3 | 3.955E+16 | 1.568E+14 | 22 |
| **109** | 0.0 | 1.175E+16 | 1.546E+14 | 23 |
| **57** | 22.1 | 3.378E+15 | 1.528E+14 | 24 |
| **31** | 8.3 | 1.260E+15 | 1.518E+14 | 25 |
| **52** | 17.0 | 2.450E+15 | 1.442E+14 | 26 |
| **16** | 151.3 | 2.084E+16 | 1.377E+14 | 27 |
| **172** | 146.1 | 1.975E+16 | 1.352E+14 | 28 |
| **70** | 8.0 | 1.080E+15 | 1.343E+14 | 29 |
| **26** | 263.2 | 3.533E+16 | 1.343E+14 | 30 |
| **104** | 117.3 | 1.503E+16 | 1.281E+14 | 31 |
| **32** | 5.8 | 7.360E+14 | 1.278E+14 | 32 |
| **174** | 15.7 | 2.006E+15 | 1.275E+14 | 33 |
| **13** | 62.1 | 7.830E+15 | 1.260E+14 | 34 |
| **75** | 6.0 | 7.530E+14 | 1.259E+14 | 35 |
| **1** | 826.8 | 1.025E+17 | 1.240E+14 | 36 |
| **166** | 8.3 | 9.950E+14 | 1.199E+14 | 37 |
| **69** | 26.2 | 3.116E+15 | 1.188E+14 | 38 |
| **108** | 3.0 | 3.229E+14 | 1.095E+14 | 39 |
| **5** | 767.5 | 8.180E+16 | 1.066E+14 | 40 |
| **89** | 31.9 | 3.377E+15 | 1.058E+14 | 41 |
| **22** | 49.4 | 5.183E+15 | 1.049E+14 | 42 |
| **72** | 13.2 | 1.343E+15 | 1.021E+14 | 43 |
| **36** | 10.8 | 1.102E+15 | 1.018E+14 | 44 |

| SUBBASIN | ACRES | AVERAGE LOAD (#FC/YEAR) | AVG #FC/AC | RANK |
|---|---|---|---|---|
| **150** | 0.0 | 1.086E+15 | 9.936E+13 | 45 |
| **177** | 6.6 | 6.560E+14 | 9.880E+13 | 46 |
| **106** | 25.8 | 2.536E+15 | 9.822E+13 | 47 |
| **17** | 35.0 | 3.418E+15 | 9.760E+13 | 48 |
| **176** | 25.8 | 2.514E+15 | 9.752E+13 | 49 |
| **90** | 5.4 | 5.263E+14 | 9.746E+13 | 50 |
| **34** | 9.3 | 9.000E+14 | 9.709E+13 | 51 |
| **96** | 2.7 | 2.611E+14 | 9.670E+13 | 52 |
| **6** | 270.8 | 2.586E+16 | 9.549E+13 | 53 |
| **99** | 47.2 | 4.445E+15 | 9.417E+13 | 54 |
| **84** | 38.0 | 3.472E+15 | 9.130E+13 | 55 |
| **15** | 19.0 | 1.728E+15 | 9.090E+13 | 56 |
| **148** | 27.3 | 2.453E+15 | 8.982E+13 | 57 |
| **54** | 20.0 | 1.791E+15 | 8.942E+13 | 58 |
| **100** | 354.5 | 3.166E+16 | 8.932E+13 | 59 |
| **30** | 447.3 | 3.877E+16 | 8.667E+13 | 60 |
| **68** | 107.5 | 9.270E+15 | 8.620E+13 | 61 |
| **127** | 13.5 | 1.164E+15 | 8.597E+13 | 62 |
| **103** | 7.4 | 6.320E+14 | 8.541E+13 | 63 |
| **178** | 18.4 | 1.570E+15 | 8.523E+13 | 64 |
| **175** | 14.8 | 1.237E+15 | 8.352E+13 | 65 |
| **73** | 16.2 | 1.345E+15 | 8.302E+13 | 66 |
| **170** | 103.0 | 8.390E+15 | 8.142E+13 | 67 |
| **7** | 296.8 | 2.329E+16 | 7.848E+13 | 68 |
| **300** | 166.7 | 1.284E+16 | 7.705E+13 | 69 |
| **114** | 0.0 | 2.551E+16 | 7.637E+13 | 70 |
| **132** | 20.0 | 1.505E+15 | 7.540E+13 | 71 |
| **162** | 23.3 | 1.701E+15 | 7.297E+13 | 72 |
| **35** | 21.9 | 1.540E+15 | 7.038E+13 | 73 |
| **20** | 80.0 | 5.527E+15 | 6.907E+13 | 74 |
| **146** | 17.5 | 1.194E+15 | 6.819E+13 | 75 |
| **10** | 14.9 | 1.008E+15 | 6.770E+13 | 76 |
| **110** | 31.4 | 2.115E+15 | 6.731E+13 | 77 |
| **74** | 31.5 | 2.116E+15 | 6.722E+13 | 78 |
| **50** | 111.2 | 7.440E+15 | 6.694E+13 | 79 |
| **169** | 2.7 | 1.748E+14 | 6.596E+13 | 80 |
| **88** | 134.8 | 8.800E+15 | 6.528E+13 | 81 |
| **161** | 10.8 | 6.720E+14 | 6.228E+13 | 82 |
| **113** | 16.1 | 9.830E+14 | 6.090E+13 | 83 |
| **11** | 13.8 | 7.795E+14 | 5.649E+13 | 84 |
| **145** | 6.4 | 3.555E+14 | 5.546E+13 | 85 |
| **94** | 129.8 | 7.136E+15 | 5.498E+13 | 86 |
| **123** | 0.0 | 8.120E+14 | 5.486E+13 | 87 |
| **8** | 26.3 | 1.404E+15 | 5.332E+13 | 88 |
| **82** | 98.6 | 5.224E+15 | 5.297E+13 | 89 |
| **42** | 7.6 | 3.877E+14 | 5.115E+13 | 90 |
| **157** | 48.5 | 2.424E+15 | 4.997E+13 | 91 |

| SUBBASIN | ACRES | AVERAGE LOAD (#FC/YEAR) | AVG #FC/AC | RANK |
|---|---|---|---|---|
| **46** | 24.6 | 1.178E+15 | 4.781E+13 | 92 |
| **165** | 4.3 | 2.061E+14 | 4.771E+13 | 93 |
| **147** | 7.2 | 3.227E+14 | 4.470E+13 | 94 |
| **173** | 3.3 | 1.466E+14 | 4.470E+13 | 95 |
| **95** | 12.8 | 5.631E+14 | 4.399E+13 | 96 |
| **128** | 27.3 | 1.174E+15 | 4.308E+13 | 97 |
| **19** | 41.4 | 1.770E+15 | 4.277E+13 | 98 |
| **156** | 8.9 | 3.230E+14 | 3.621E+13 | 99 |
| **163** | 6.8 | 2.275E+14 | 3.336E+13 | 100 |
| **160** | 33.4 | 1.051E+15 | 3.150E+13 | 101 |
| **117** | 26.4 | 8.075E+14 | 3.065E+13 | 102 |
| **168** | 9.4 | 2.215E+14 | 2.364E+13 | 103 |
| **179** | 63.7 | 1.404E+15 | 2.205E+13 | 104 |
| **159** | 27.9 | 5.771E+14 | 2.068E+13 | 105 |
| **83** | 6.6 | 1.365E+14 | 2.068E+13 | 106 |
| **142** | 26.6 | 5.288E+14 | 1.992E+13 | 107 |
| **66** | 6.7 | 1.258E+14 | 1.878E+13 | 108 |
| **105** | 5.2 | 4.418E+13 | 8.496E+12 | 109 |
| **85** | 30.5 | 2.276E+14 | 7.453E+12 | 110 |
| **41** | 7.4 | 5.086E+13 | 6.854E+12 | 111 |
| **21** | 20.4 | 1.139E+14 | 5.578E+12 | 112 |
| **124** | 16.9 | 6.260E+13 | 3.704E+12 | 113 |
| **102** | 321.0 | 1.166E+15 | 3.632E+12 | 114 |
| **53** | 22.6 | 7.440E+13 | 3.296E+12 | 115 |
| **24** | 61.6 | 1.659E+14 | 2.693E+12 | 116 |
| **181** | 137.8 | 3.276E+14 | 2.378E+12 | 117 |
| **61** | 0.0 | 7.700E+13 | 8.499E+11 | 118 |
| **80** | 3.8 | 3.181E+12 | 8.371E+11 | 119 |
| **138** | 73.1 | 5.697E+13 | 7.797E+11 | 120 |
| **71** | 9.9 | 6.349E+12 | 6.420E+11 | 121 |
| **40** | 88.5 | 2.297E+13 | 2.595E+11 | 122 |
| **140** | 13.3 | 1.007E+12 | 7.571E+10 | 123 |
| **63** | 18.5 | 7.700E+11 | 4.162E+10 | 124 |
| **111** | 2.7 | 5.285E+10 | 1.957E+10 | 125 |
| **101** | 10.3 | 1.276E+11 | 1.235E+10 | 126 |
| **97** | 30.6 | 1.156E+11 | 3.778E+09 | 127 |
| **92** | 13.2 | 1.840E+10 | 1.394E+09 | 128 |
| **93** | 7.5 | 4.827E+09 | 6.462E+08 | 129 |
| **25** | 46.3 | 5.646E+09 | 1.219E+08 | 130 |
| **64** | 6.9 | 0.000E+00 | 0.000E+00 | 131 |
| **98** | 55.7 | 0.000E+00 | 0.000E+00 | 132 |
| **112** | 15.2 | 0.000E+00 | 0.000E+00 | 133 |
| **115** | 0.0 | 0.000E+00 | 0.000E+00 | 134 |