

## Effect of Increased Flow Rate on the Microbial Population in the Waterloo Biofilter®

Craig Jowett, Heather Millar, Kris Pataky  
Waterloo Biofilter Systems Inc.  
June 17, 2003

### Background

All organisms require a source of carbon and energy to continue to grow properly. The two sources of carbon for the biosynthesis of cell tissue are carbon dioxide and carbon found in organic matter. If an organism derives its cell carbon from CO<sub>2</sub>, it is called autotrophic; if it uses organic carbon, it is called heterotrophic (Tchobanoglous & Schroeder, 1985, pg.126). The BOD removers in fixed film Biological Nutrient Removal systems, such as the Waterloo Biofilter®, are heterotrophic (Farmingdale, 1997, pg.8). The heterotrophic aerobic bacteria in the Biofilter utilize oxygen, organic material, ammonium-N and ortho-P to produce CO<sub>2</sub>, H<sub>2</sub>O and more bacterial cells (Farmingdale, 1997, pg.2).

Most bacteria reproduce by binary fission, which means during active bacterial growth the size of the microbial population is continuously doubling. The time required for the population size to double is called the doubling time. Based on the growth rates (under optimal conditions) for a sample of representative bacteria the median doubling time was found to be 60 minutes (Atlas, 1988, pg. 107).

Figure 1 shows the typical bacterial growth pattern showing an initial period of little or no growth called the *lag phase*, a period of rapid growth called the *exponential or log phase*, a period of stabilization called the stationary phase, and a period where the number of cells dying outnumber those being reproduced (when wastes accumulate and nutrients are exhausted) called the *death phase* (Burks & Minnis, 1994, pg. 44). This pattern represents a single bacterial colony or an entire population such as in a Waterloo Biofilter.

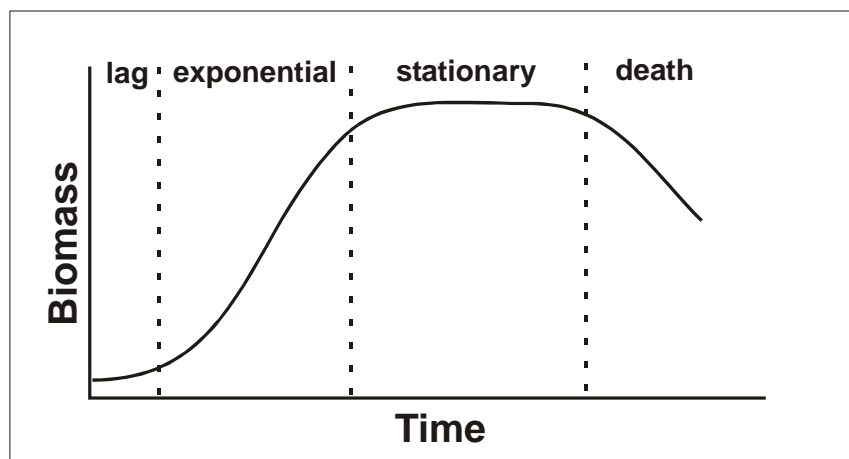


Figure 1. Typical Bacterial Growth Pattern

## Effect of Increased Flow

When a flow rate of  $50 \text{ m}^3/\text{day}$  is applied to the Biofilter there is an initial start-up period where treatment is delayed (Figure 2 - **lag I**). This corresponds to the lag period in which the bacteria are adjusting to their new environment, preparing for reproduction by synthesizing the needed macromolecules for cell division (Burks & Minnis, 1994, pg.45). Once the bacteria have adjusted they will enter the exponential phase (**exponential I**) and begin to multiply rapidly. If the flow rate of  $50 \text{ m}^3/\text{day}$  is sustained the bacterial population will reach a stationary phase (**stationary I**). This steady state will be maintained as long as the Biofilter is continually fed. If the organic loading is stopped the bacterial population will enter the death phase because the nutrients will be exhausted. In this phase the bacteria will use cannibalism to obtain their food source thus the Biomass will decrease. When the flow rate is increased from  $50 \text{ m}^3/\text{day}$  to  $400 \text{ m}^3/\text{day}$  the loading rate of BOD increases as well. This increase in BOD provides the bacteria with the needed nutrients to rapidly enter a new exponential phase of growth (**exponential II**). The initial lag period or delay in treatment will not occur because the **stationary I** period represents the **lag II** period for the new  $400 \text{ m}^3/\text{day}$  flow. The population will then reach a higher stationary phase (**stationary II**).

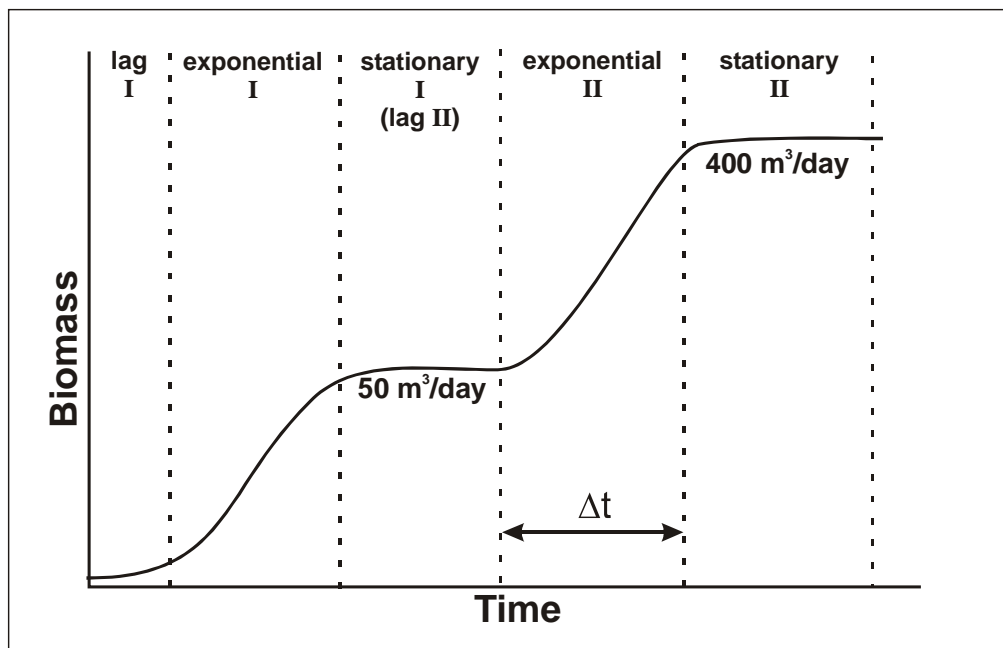


Figure 2. Bacterial growth curve showing the change in Biomass level with an increase in flow rate.

The time  $\Delta t$  for the population to reach **stationary II** is of interest when 'step-function' flow increases are met. Assuming that the population level is a direct function of the BOD loading rate, which is dependent on the flow rate, with an 8-fold increase in flow rate from  $50 \text{ m}^3/\text{day}$  to  $400 \text{ m}^3/\text{day}$  we can expect that the bacteria will duplicate in relation to the increase of food or substrate source. Therefore, using the median doubling time of 1 hour, the bacteria can theoretically adjust to the increased flow rate in about 3 hours (i.e., doubling from 50 to 100 to 200 to 400 in 3 growth phases of one hour each). This rapid growth is possible in an ideal environment, but it indicates that the catch-up can be attained in very quick time, possibly as little as one day.

This rapid adjustment to step-function type increased flow is demonstrated in the Rattlesnake data. Referring to the *Year 2 Graph – Rattlesnake Site: 2000 Theoretical Organic Mass Loading and Effluent Concentration*, for instance, a dramatic and sustained jump in the organic loading rate does not have an adverse effect on the BOD effluent concentration. This supports the theoretical calculation in the ideal environment above, and also shows that the Waterloo Biofilter can be designed to withstand periodic jumps in mass loading from 50 m<sup>3</sup>/day to 400 m<sup>3</sup>/day with little to no effect on the effluent quality.

## References

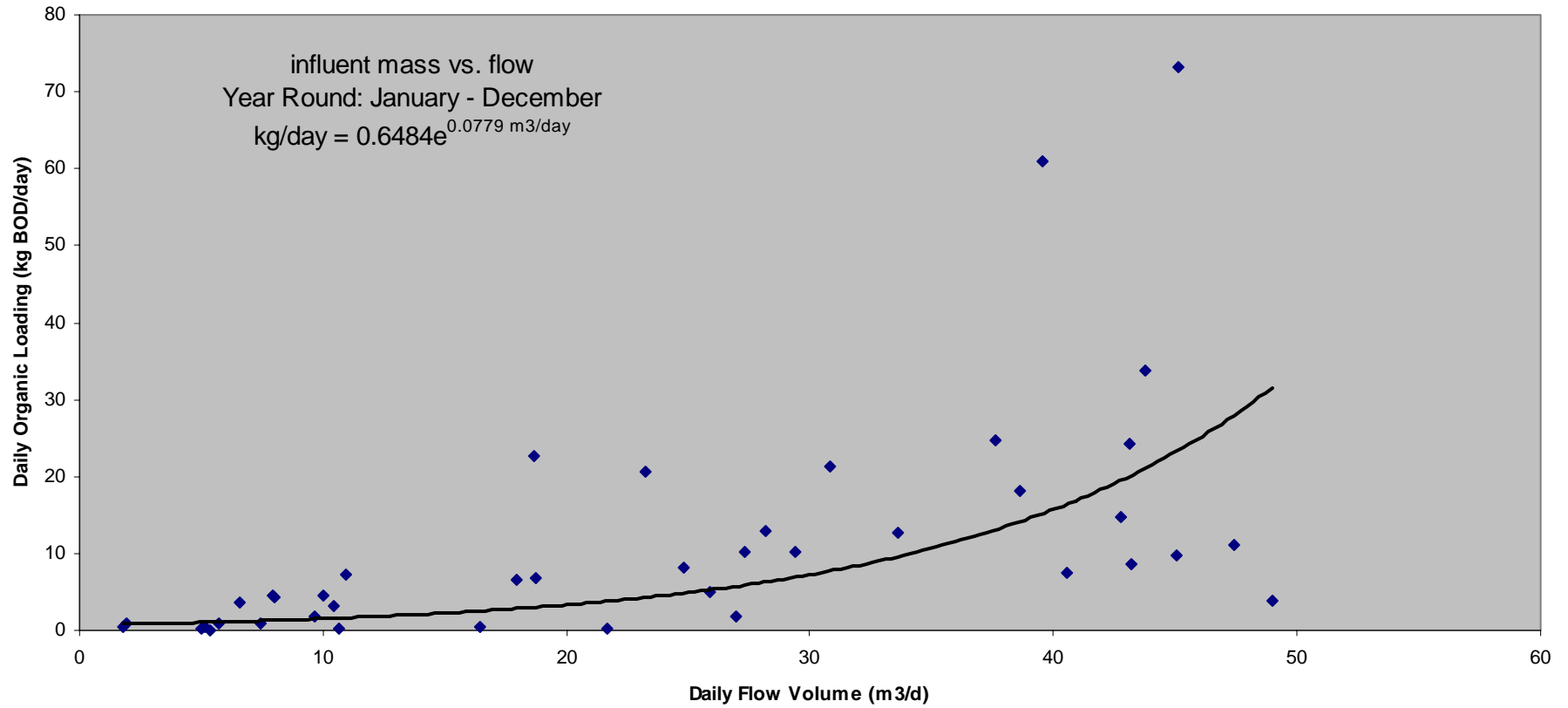
TCHOBANOGLIOUS, G., and E. D. SCHROEDER. 1985. *Water Quality*. Addison-Wesley Publishing Co., University of California at Davis

FARMINGDALE, S. 1997. *Fixed Film Operational Strategies*. Paper Presented at the Long Island Sound Nitrogen Removal Training Program  
[www.dec.state.ny.us/website/dow/bwcp/module4.pdf](http://www.dec.state.ny.us/website/dow/bwcp/module4.pdf)

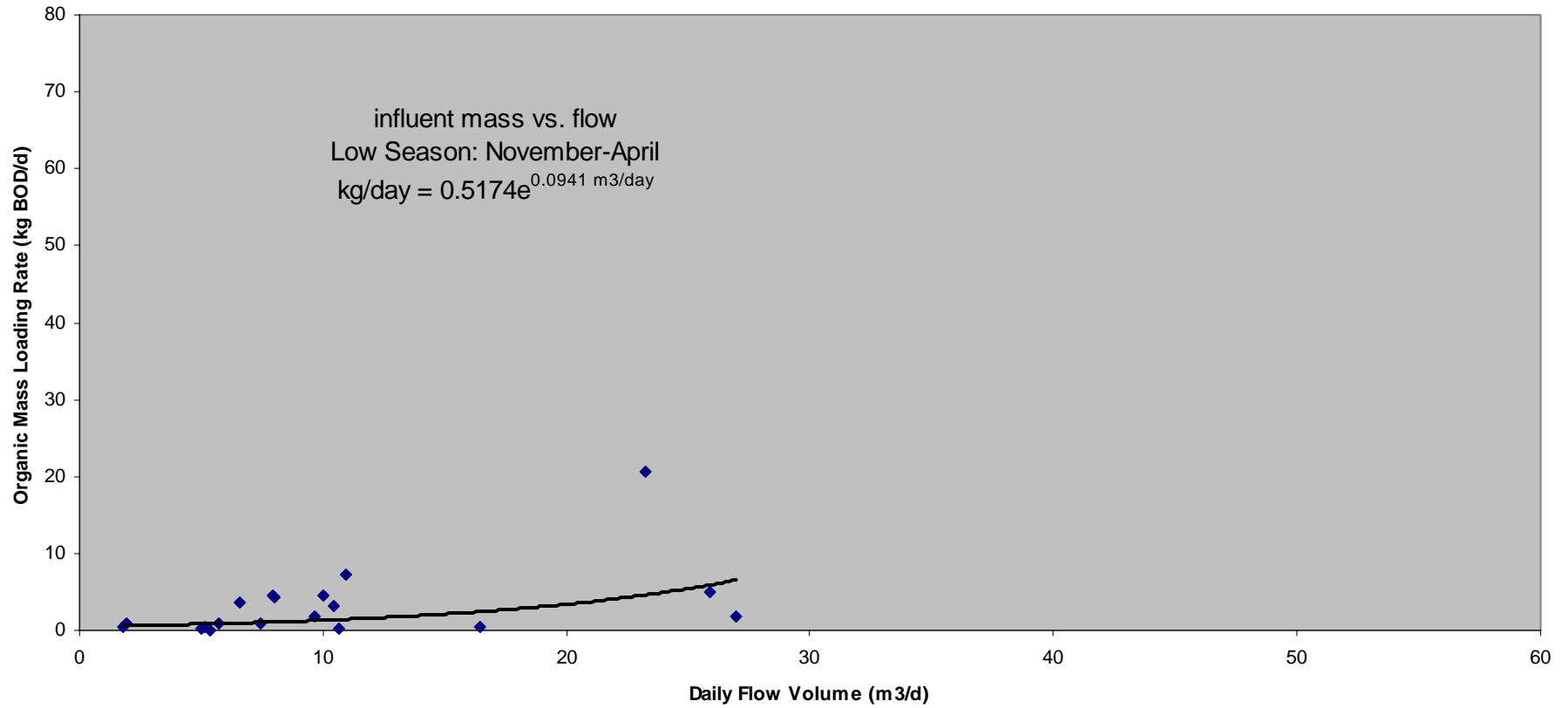
ATLAS, R. M. 1988. *Microbiology: Fundamentals and Applications*. Macmillan Publishing Co., New York, NY

BURKS, D. B., and M. M. Minnis. 1994. *Onsite Wastewater Treatment Systems*. Hogarth House Ltd., Madison, WI

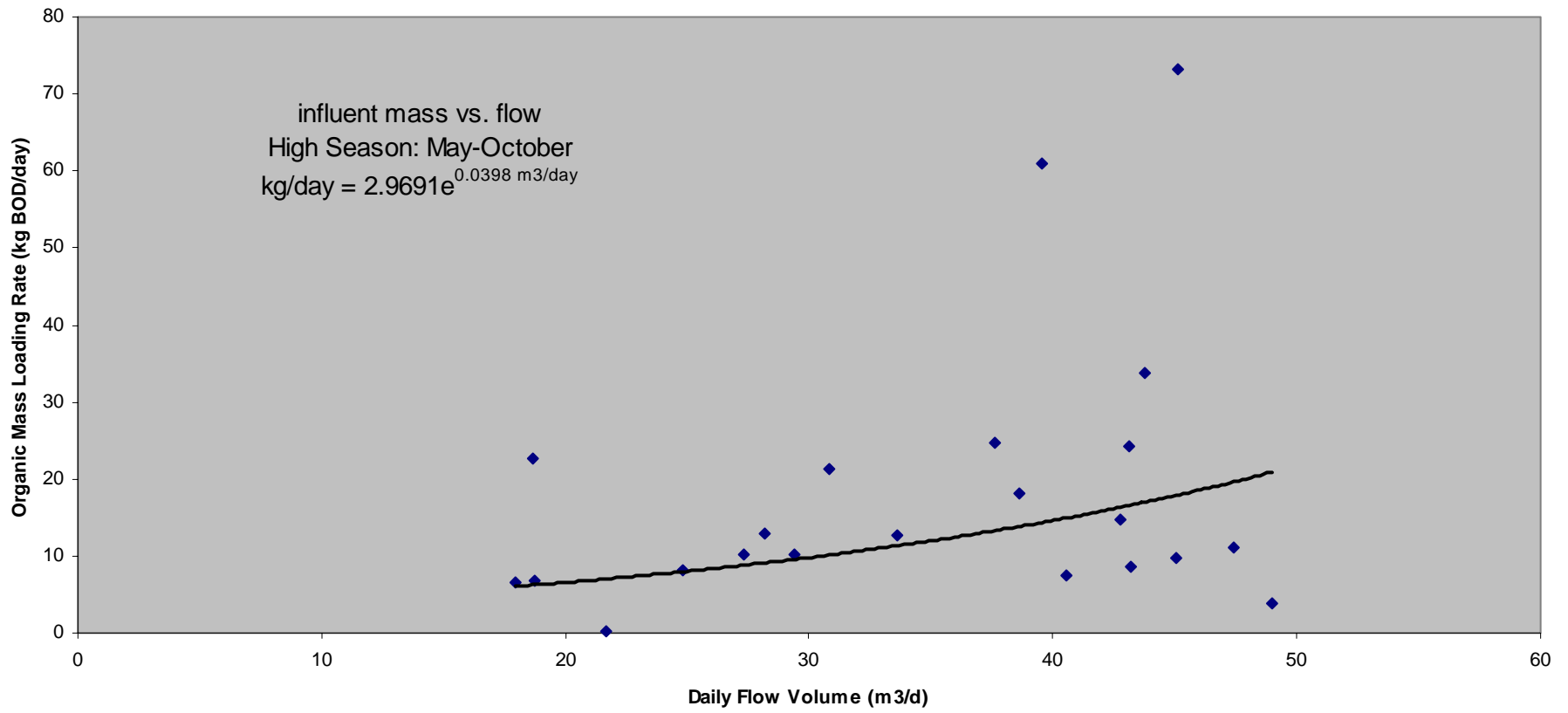
**Full Year: Organic Mass Loading vs. Daily Flow Volume**  
**Rattlesnake Site 1999-2002**



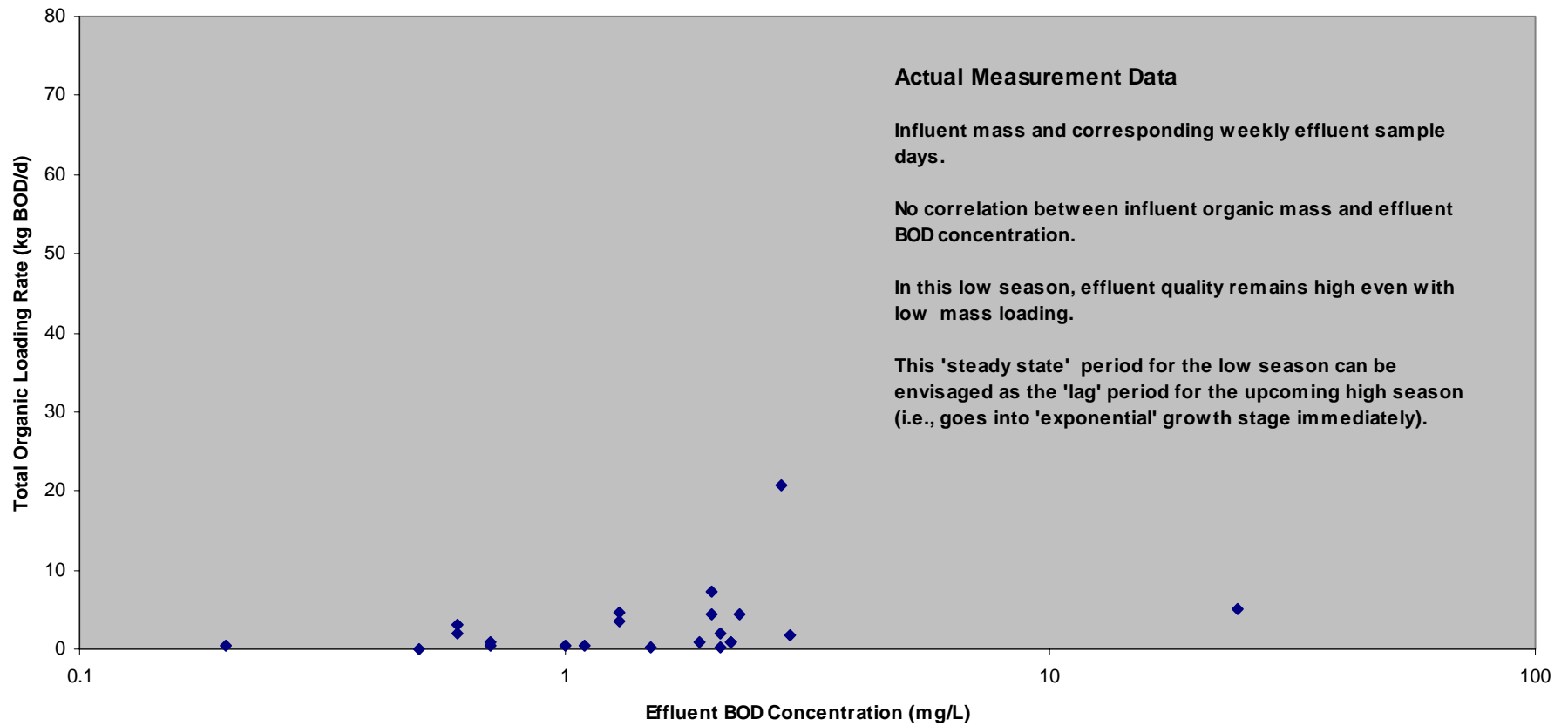
### Low Season: Flow Rate vs. Organic Mass Loading Rate Rattlesnake Site 1999-2002



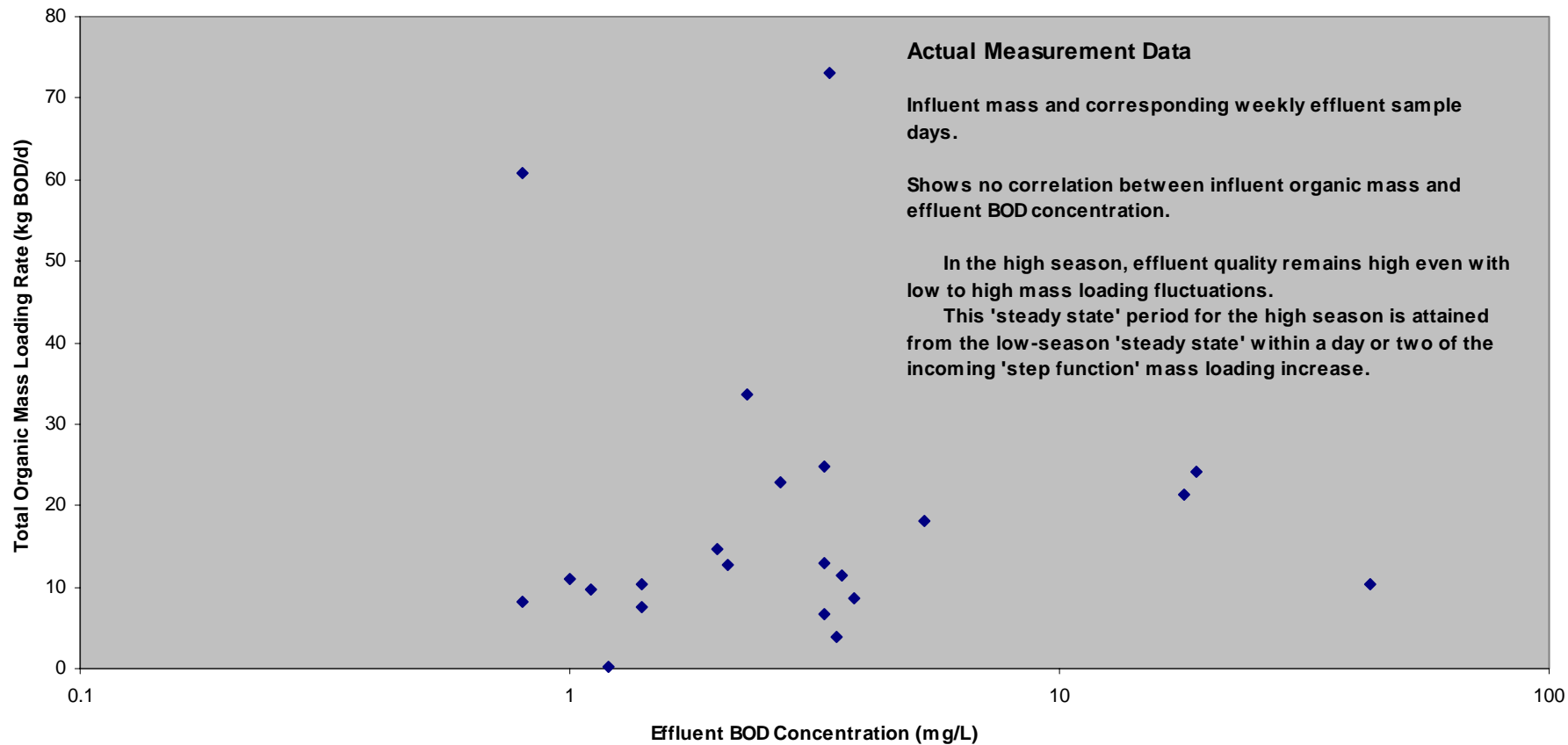
High Season: Flow Rate vs. Organic Mass Loading Rate  
Rattlesnake Site 1999-2002



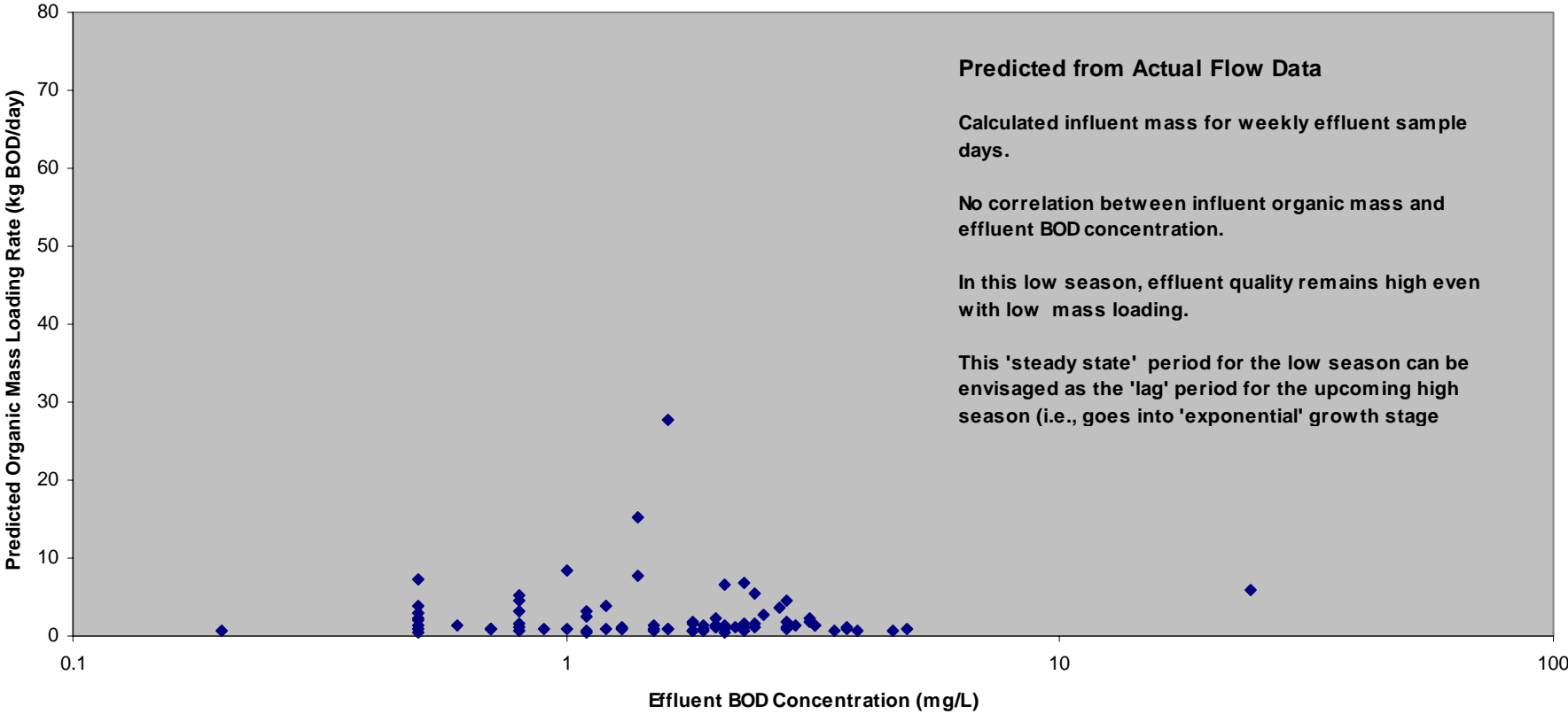
**Low Season: November-April**  
**Organic Loading Rate vs. Effluent BOD Concentration**  
*Rattlesnake Site*



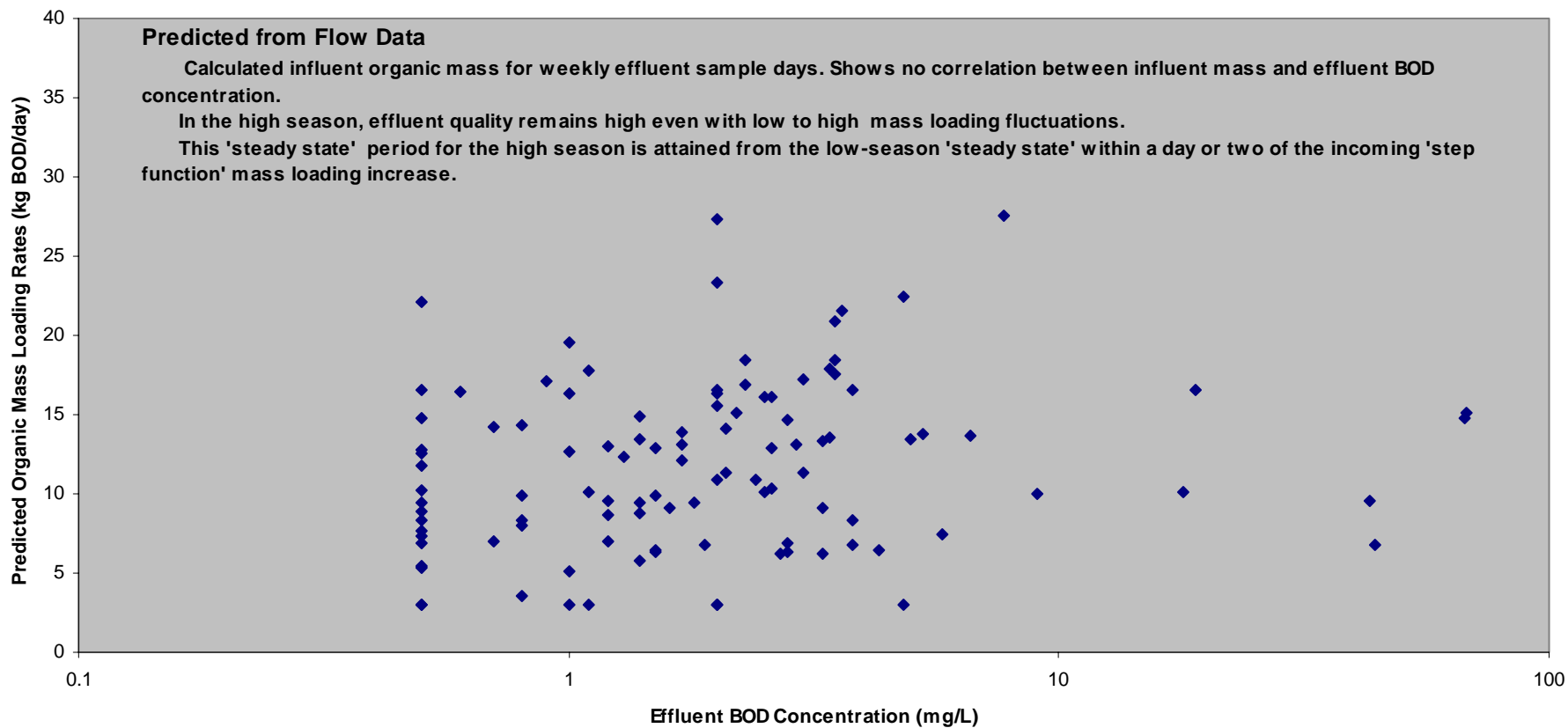
**High Season: May-October**  
**Organic Loading Rate vs. Effluent BOD Concentration**  
*Rattlesnake Site*



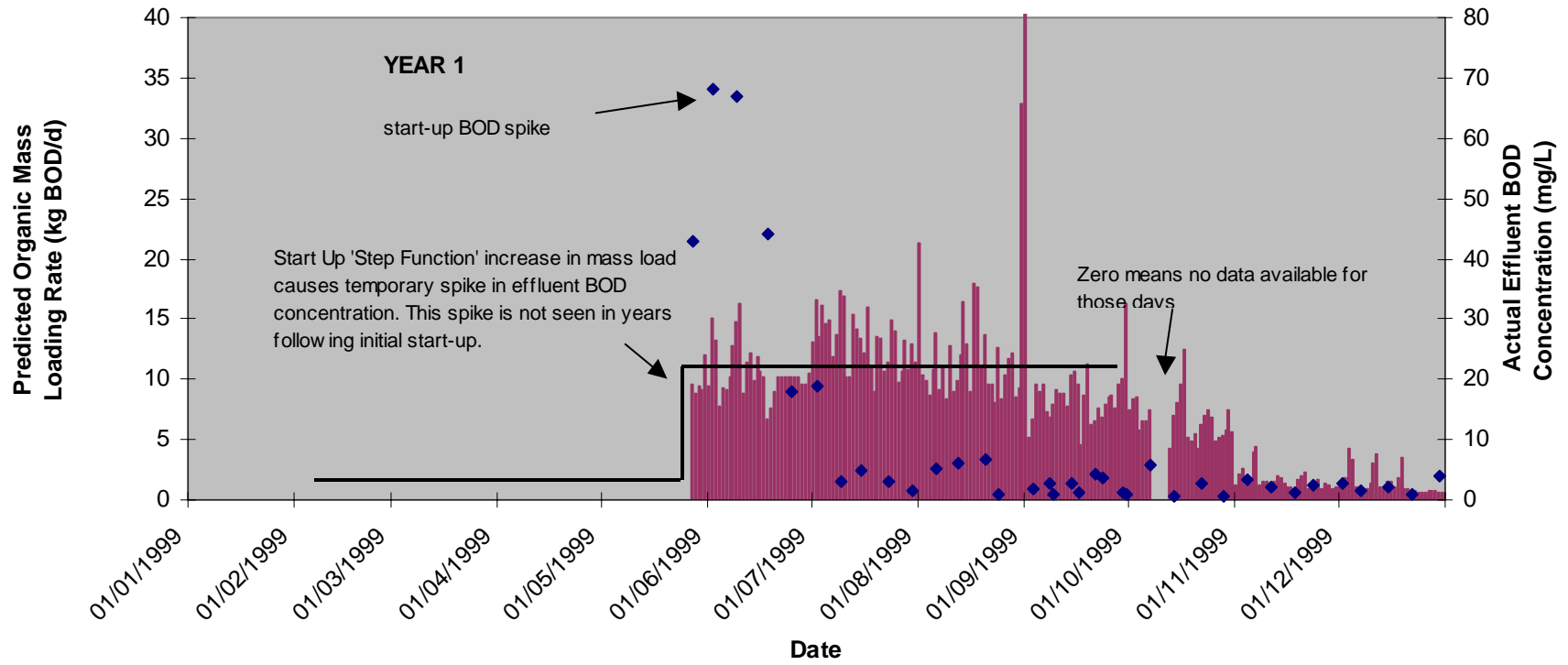
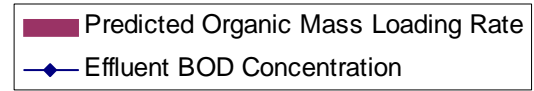
**Low Season: November - April Predicted Organic Mass  
Loading Rates vs. Effluent BOD Concentration  
*Rattlesnake Site 1999-2002***



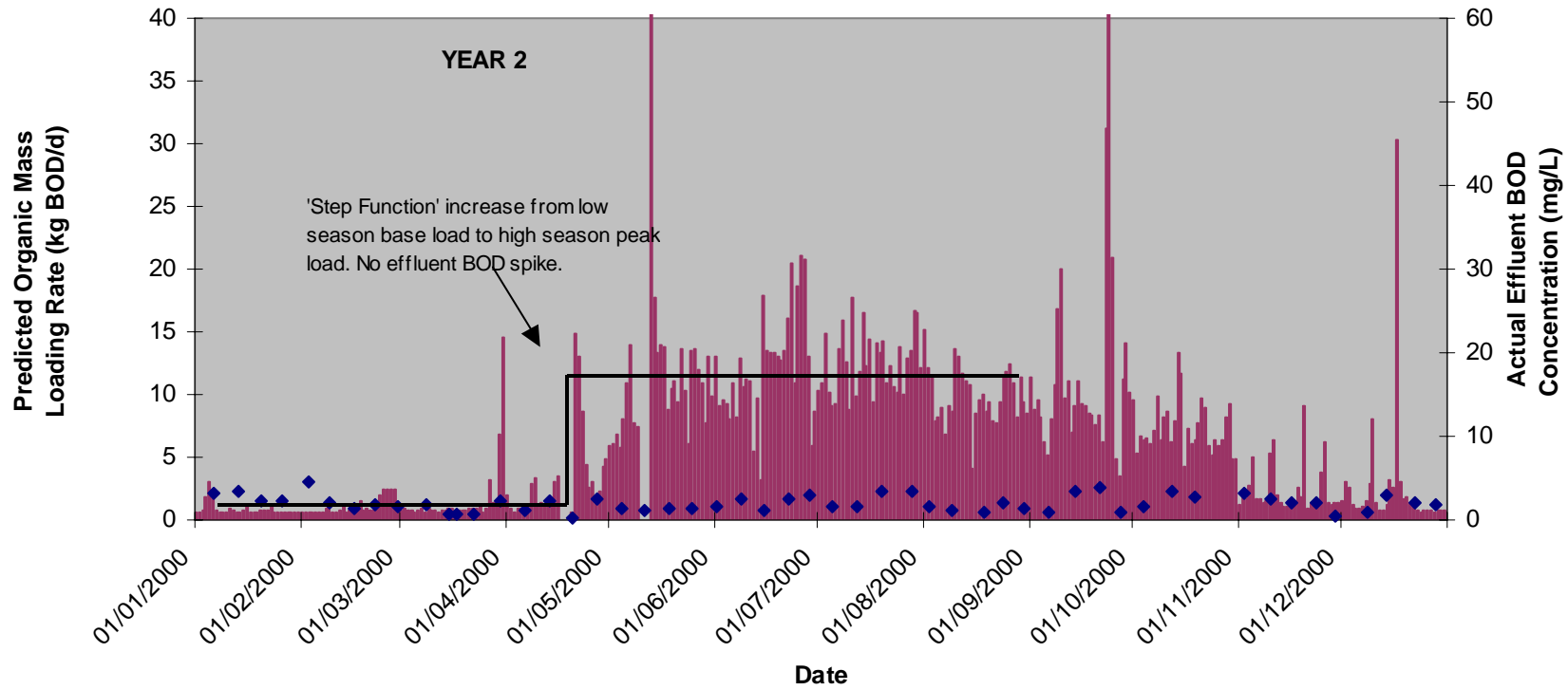
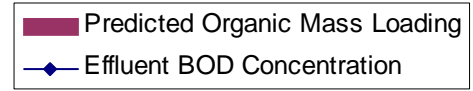
**High Season: May-October Predicted Organic Mass  
Loading Rates vs. Effluent BOD Concentration**  
*Rattlesnake Site 1999-2002*



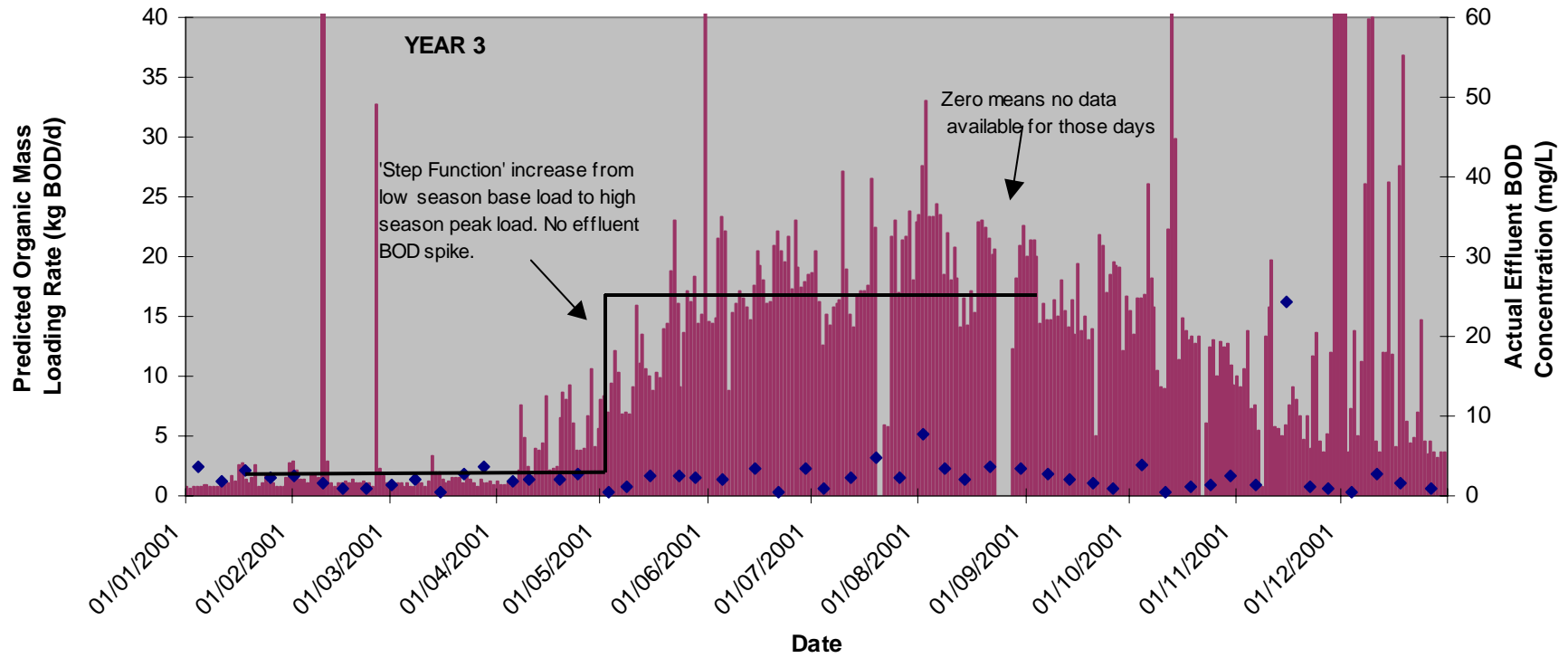
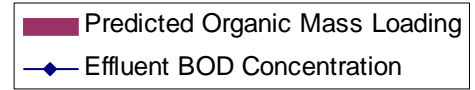
### Rattlesnake Site: 1999 Predicted Organic Mass Loading and Actual Effluent Concentration



### Rattlesnake Site: 2000 Predicted Organic Mass Loading and Actual Effluent Concentration



### Rattlesnake Site: 2001 Predicted Organic Mass Loading and Actual Effluent Concentration



# Rattlesnake Site: 2002 Predicted Organic Mass Loading and Actual Effluent Concentration

