CHAPTER 5. SUMMARY & CONCLUSIONS

The Upper Occoquan Sewage Authority (UOSA) operates an advanced water reclamation facility (WRF) that discharges high quality reclaimed wastewater to Bull Run, a tributary to the Occoquan Reservoir in Northern Virginia. The Occoquan Reservoir is an eutrophic impoundment which was originally constructed in 1957, and which today serves as a raw water source for over 750,000 customers. The UOSA WRF discharge enters Bull Run near the City of Manassas, Virginia, and the combined flow reaches the tailwaters of the Occoquan Reservoir less than 10 miles from the point of discharge, and approximately 17.5 miles from the Occoquan Dam.

For nearly 25 years, the UOSA WRF has operated its biological treatment process to maximize the conversion of ammonium and organic nitrogen to nitrate. This mode of operation was originally adopted because of some early operating difficulties with an ion exchange nitrogen removal system. During the initial years of WRF operation, it was found that, while high nitrate concentrations were often observed in the upper reaches of the reservoir, they were rapidly reduced to values near 1 – 2 mg/L as N by the time flows reached the Occoquan Dam. This phenomenon has continued to be observed even as UOSA flows have approximately tripled from 7.5 MGD to 21 MGD.

Coupled with observations of water quality in the impoundment, static microcosm studies have shown that, in the absence of molecular oxygen, nitrate from the UOSA WRF discharge may serve as an alternate terminal electron acceptor for heterotrophic organisms in the hypolimnetic waters. Studies have also shown that the presence of nitrate in the water column during periods of anoxia may delay the onset of reducing conditions that promote the release of phosphorus immobilized in the deposited sediments. Observed data in the reservoir during periods of anoxia have also been found to be consistent with such a poising effect on oxidation-reduction (REDOX) potentials.

Recent efforts to develop a more robust hydrodynamic and water quality model of the Occoquan Reservoir have resulted in a need for more quantitative information on the kinetics of nitrate removal under anoxic conditions. The model selected, CE-QUAL-W2, is being developed to support water quality management decisions in the Occoquan Reservoir in several important ways:

1. To provide a predictive capability of the capacity of the system to remove nitrate under conditions of anoxia, and in so doing, to poise the redox potential at values that will retard the release of sediment-bound phosphorus.

2. To provide predictions of nitrate transport to the lower reservoir under conditions where molecular oxygen persists in the water column in order to assess the potential for the UOSA WRF discharge to cause the drinking water maximum contaminant level (MCL) for nitrate-nitrogen to be exceeded in the source water withdrawn by FCWA for treatment.

3. To provide predictions of the nitrogen load to the Potomac Estuary, and thence to the Chesapeake Bay from the Occoquan Watershed as part of the nutrient reduction plan in the 1987 Chesapeake Bay Agreement.

In order to support these uses of the model, it was determined that kinetic studies conducted in microcosms would be more useful if the reservoir were more realistically simulated with a continuous flow system. The experimental protocol developed was a biphasic CSTRs-in-series microcosm system comprised of reservoir water and deposited sediment. Each reactor was configured with a detention time and effective depth to simulate a selected reach of the reservoir. The system was filled and fed with water composed of representative mixtures of natural stream water and UOSA WRF effluent. Nitrate concentrations in the system were monitored over time, and denitrification rate constants calculated from the data. Additional chemical constituents were also monitored in order to observe other effects of nitrate on reservoir water quality.

From the microcosm study observations reported in this thesis, the following observations and conclusions seem warranted:

1. A continuous flow microcosm system was developed that could be used, through manipulation of feed water characteristics, oxygen supply, hydraulic detention time,

and effective depth, to satisfactorily simulate selected reaches of the Occoquan Reservoir in studies of physical, chemical, and biological processes.

2. An experimental protocol was developed that would allow observations of physical, chemical, and biological phenomena of interest occurring during periods of anoxia in the Occoquan Reservoir, including rate of oxygen depletion, rate of ORP change, rate of dissimilatory denitrification, and rate of release of dissolved iron and manganese from deposited sediments.

3. The microcosm design and experimental protocols developed appear to be sufficiently robust to support future research into the behavior of other sediment-water interactions of interest.

4. For conditions in the upper reaches of the Occoquan Reservoir, an observed first-order denitrification rate constant of 0.22 day^{-1} was determined to be more representative of the *in situ* condition than the default values commonly set in CE-QUAL-W2.

5. The chemistry of manganese may be more important in sediment-water interactions in the Occoquan Reservoir than has been previously thought. In addition to serving as another terminal electron acceptor during anoxic conditions, the data seem to suggest that oxidized manganese may also catalyze the oxidation of organic matter under aerobic conditions, and may directly served as electron acceptor under both aerobic and anoxic conditions. Subsequently, the resulting reduced forms of manganese may chemically reduce oxidized nitrogen forms in the water column or at the sediment surface.

6. Sediment phosphorus release was not detected in the current experiments, but nevertheless, was believed to occur. The failure to detect release was attributed to phosphorus adsorption onto the Plexiglas walls of the microcosm reactors.

Finally, several recommendations may be made from the work described herein:

1. The results continue to support the view that nitrate has a beneficial role in the maintenance of acceptable source water quality in the Occoquan reservoir. As a result, it is recommended that, under most conditions, the UOSA WRF should continue to discharge a nitrified effluent to the reservoir in order to ensure a sufficient nitrate supply to suppress the release of sediment phosphorus as well as releases of reduced manganese and iron.

2. Additional studies with continuous flow systems should be carried out to confirm the rates of sediment phosphorus release observed in the field after the depletion of water column nitrate.

3. Future experiments should be conducted to investigate the effect, if any, of varying ambient nitrate concentrations on denitrification rate constants.

4. Future experiments should be conducted to further understand the interactions of manganese and nitrate in the Occoquan Reservoir, with a particular emphasis on determining if chemical reduction of nitrate by newly precipitated manganese occurs, and if so, to further refine the overall effects on nitrogen removal in the Occoquan Reservoir.