

Optimization of Denitrification Bioreactor

Task 2



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Summary

At the time of the Task 1 Report (7/12/2016) we identified changes in the bioreactor design that we implemented converting the reactor from a down-flow system to an up-flow design and that we had recently added the remaining bioreactor media that had been temporarily held back after the design modification to determine the bioreactor response. At that time we were just beginning to measure a decrease in NO_x concentration (Nitrate +Nitrite Nitrogen) at the discharge as a result of the added bioreactor media. We had also proposed to add floating vegetation to the pond surface as a possible means to add additional carbon and microbial substrate to the bioreactor. That report also identified the initial placement of mesocosms on site.

As indicated in the Task1 report, no funding had been allocated by any of the agencies to monitor efficacy of the main bioreactor and therefore weekly sampling and analysis was included in this project. Monitoring results indicated an initial significant decline in bioreactor discharge NO_x suggesting a clear effect of the additional bioreactor media material. However, beginning September of last year NO_x levels in the bioreactor discharge began to rise and since the first of the year concentrations have remained at approximately 20 mg/L NO_x resulting in a bioreactor efficiency of approximately 25%. Two possible reasons for this reduction in efficiency is the possibility of short-circuiting due to excess gas buildup in the reactor and a lack of suitable dissolved organic matter for microbial metabolism. A drawdown event conducted in late February that displaced accumulated denitrification gasses had no significant effect on the denitrification rate when the reactor was brought back online suggesting that short-circuiting due to a build-up of gasses is not likely the cause of lower efficiency. An addition of glucose to the inflow water of the reactor was recently implemented to determine if available carbon was limiting the rate of denitrification, but we are still waiting on results from the laboratory to determine if that action increased the rate of denitrification.

Task 2 of this project was to evaluate various different types of media at the mesocosm scale. Unfortunately, there have been multiple challenges in the design and startup of the mesocosms. Mesocosms had been placed on site last summer but problems with sealing the bottoms of the reactors through multiple attempts was not successfully achieved until the first of the year. Since that time, gravel has been placed in the bottom of the reactor and bottom seals have been holding; however, due to a lack of clarity as to what was limiting the main bioreactor performance we did not initiate any of the alternative media types and therefore the mesocosm study has not yet been initiated although the infrastructure has now been established and is ready to be put online.

Results of Main Bioreactor

Treatment within Bioreactor

During the first four months after the main bioreactor was modified from a down-flow to an upflow design discharge NO_x concentrations remained at a relatively consistent 16-17 mg/L (Figure 1). During this time NO_x concentrations in the downstream monitoring well rose from less than 10mg/L to a relatively steady 15-16 mg/L. This decrease and then increase in NO_x concentration of the downstream monitoring well is attributed to excess DOC being released from the bioreactor and a secondary denitrification zone being established as water infiltrated into the ground below the recharge ditch. As oxygen levels increased in the water column of the bioreactor a greater percentage of the available DOC released from the bioreactor was consumed by aerobic decomposition eventually resulting in no secondary denitrification occurring after water had passed through the main bioreactor. This led us to the conclusion that we needed an additional source of organic matter if we were going to facilitate additional denitrification. As a result we added the remaining bioreactor media resulting in an approximate doubling of the media depth from 22" to 36". There was an immediate decrease in NO_x concentration in the discharge water with levels dropping as low as 5 mg/L; however these low levels only lasted for approximately 4 months before discharge NO_x concentrations began to rise again. Downstream monitoring well NO_x levels showed a similar decline in NO_x levels although the decline and rise was delayed by approximately two months. As for the beginning of this year, NO_x concentrations in the bioreactor and groundwater monitoring well have risen to approximately 20 mg/L and has persisted at this level until the end of March. Throughout this time the NO_x concentrate of inflow water, which represents the NO_x concentrations found in the surface of the Floridan aquifer below the well array field has remained remarkably consistent at 26-27mg/L NO_x-N. By comparing the inlet NO_x concentration with that of the discharge water from the reactor there is a 6-7 mg/L reduction in NO_x or approximately 25% reduction efficiency. Levels as high as 81% reduction efficiency were achieved shortly after media was added to the bioreactor, however those rates did not persist for more than several months.

Dissolved Organic Carbon.

A source of available organic carbon is critical to the denitrification process as it provide the microbes with energy driving the reaction while nitrate provides the microbes with an electron acceptor. The measurement of DOC can include both available and non-readily available forms of organic carbon. For instance, available sources of carbon may occur as sugars or starches, while non-readily available forms would be compounds such as lignin or humic acids. If

available organic carbon is limiting to microbes than this can limit the rate of the denitrification reaction. Figure 2 shows the DOC concentration measured in the incoming water to the bioreactor, the discharge DOC from the bioreactor and DOC concentration in the downstream well. Prior to adding additional media to the reactor in May of 2016 it appeared that available DOC was likely becoming limiting to any additional denitrification since the amount of nitrate reduction in the bioreactor had stabilized. Once additional media was added a rapid increase in DOC occurred, which resulted in an additional increase in denitrification and lowering of NO_x in the discharge water. However, this total DOC and likely available DOC has been declining ever since the media addition and as of the end of January 2017 has actually fallen below the DOC levels found in the discharge water prior to the media addition. This again suggest that DOC is limiting the overall denitrification rate of the reactor and limiting performance.

The low availability of organic carbon in the bioreactor media has been somewhat puzzling during the past year's monitoring since previous results from the denitrification wall bioreactor at the Holly Factory Nursery showed no significant drop off in performance after several years (that denitrification bioreactor used softwood (pine) sawdust as a source of carbon). As a result we have begun to conduct some investigation of the woodchip and sawdust mix that was used in the Watson Dairy bioreactor and it appears that the majority of the species found in the media are from cypress and "heart" wood from pine. These species and "heart" material are known for their inherent resistance to decay and as such may be impacting the availability of carbon to microbes. There were also large pieces of wood often associated with the media occasionally with paint on them suggesting that some of this material was resawn timbers, which again would mean significantly aged wood and therefore a reduced availability of the organic matter in the wood. To test the question of carbon availability as the limiting factor in the rate of decomposition in the reactor we have initiated a glucose dosing experiment to determine if denitrification rates can be stimulated. Results from this treatment have not yet been analyzed, however measurements with a SUNA (optical UV NO_x sensor) suggest that an increase in denitrification did occur as a result of the added carbon.

Mesocosm Experiment

The mesocosm experiment is intended to test and evaluate various substrate treatments and reaction processes in replicate so that a more scientific approach to design of future bioreactors can be implemented. The original design for mesocosms at the Watson site was going to be similar to mesocosms used at the Holly Factory Denitrification Wall project. Those mesocosms were constructed of 6" PVC pipe and were 5 feet in length. These mesocosms performed well, however temperature regulation due to a relatively large surface area to media

volume ratio made it difficult to match groundwater temperature at various times of the year. Additionally, piping along the side wall of the PVC cores likely resulted in some short-circuiting of flow along the edge of the media and therefore an under representation of the actual denitrification potential. The benefits however, were the scale of the system as well as the ready to use components of PVC pipe. To minimize these less than optimal effects of the denitrification wall mesocosm design, this project significantly increased the diameter of the mesocosms from 6" to 36" and decided upon using sections of corrugated HDPE pipe. The final layout would be 24 mesocosms with the potential to evaluate 8 potential treatments simultaneously (Figure 3). As it turned out a major design challenge of this choice was attempting to establish a water tight seal at one end of the pipe under 4.5 feet of hydraulic head. Because the material is made of HDPE, which has a very low surface energy and therefore little cohesion with other materials, a physical connection between the corrugated pipe and end containment device was required. After multiple attempts we finally succeeded in creating a water tight gasket around the bottom of the corrugated pipe using a woven geotextile membrane, a clay based caulking compound a half round plastic clip and 80 stainless screws per mesocosm all torqued to the same level. All of this effort required nearly 6 months of trial and error and in some early attempts the seal would hold for several weeks but then would fail due to degradation of the sealant or slight movement of the soil below the mesocosms due to burrowing organisms. Each time the mesocosms needed to be reworked a significant effort and time had to be committed to correcting the problem. At this time the design has held for over 3 months and we were confident enough to add the 8" gravel base to the mesocosms so that we can replicate the profile of the bioreactor.

Next Steps

Once we receive analytical data back from the glucose dosing experiment we will decide on the next course of action. It is becoming increasingly apparent that the woodchip and sawdust media used at the Watson bioreactor has a limited available carbon supply and that it is most likely limiting the rate of denitrification. The question is whether or not to start with new media or simply add a more available organic carbon source on top of the existing media. By adding new material on top of the existing media we maintain the 25% treatment that the existing media is providing, however we will reduce the available water column in the bioreactor which will likely preclude the addition of *Eichhornia crassipies* (water hyacinth) or *Pistia stratioides* (water lettuce). Removing the existing media will allow a reset of the system which would provide greater flexibility in future operation; however, would also require a considerable amount of additional work. Before making this decision a meeting with pertinent agencies and Del Bottcher (project engineer and co PI) will be conducted.

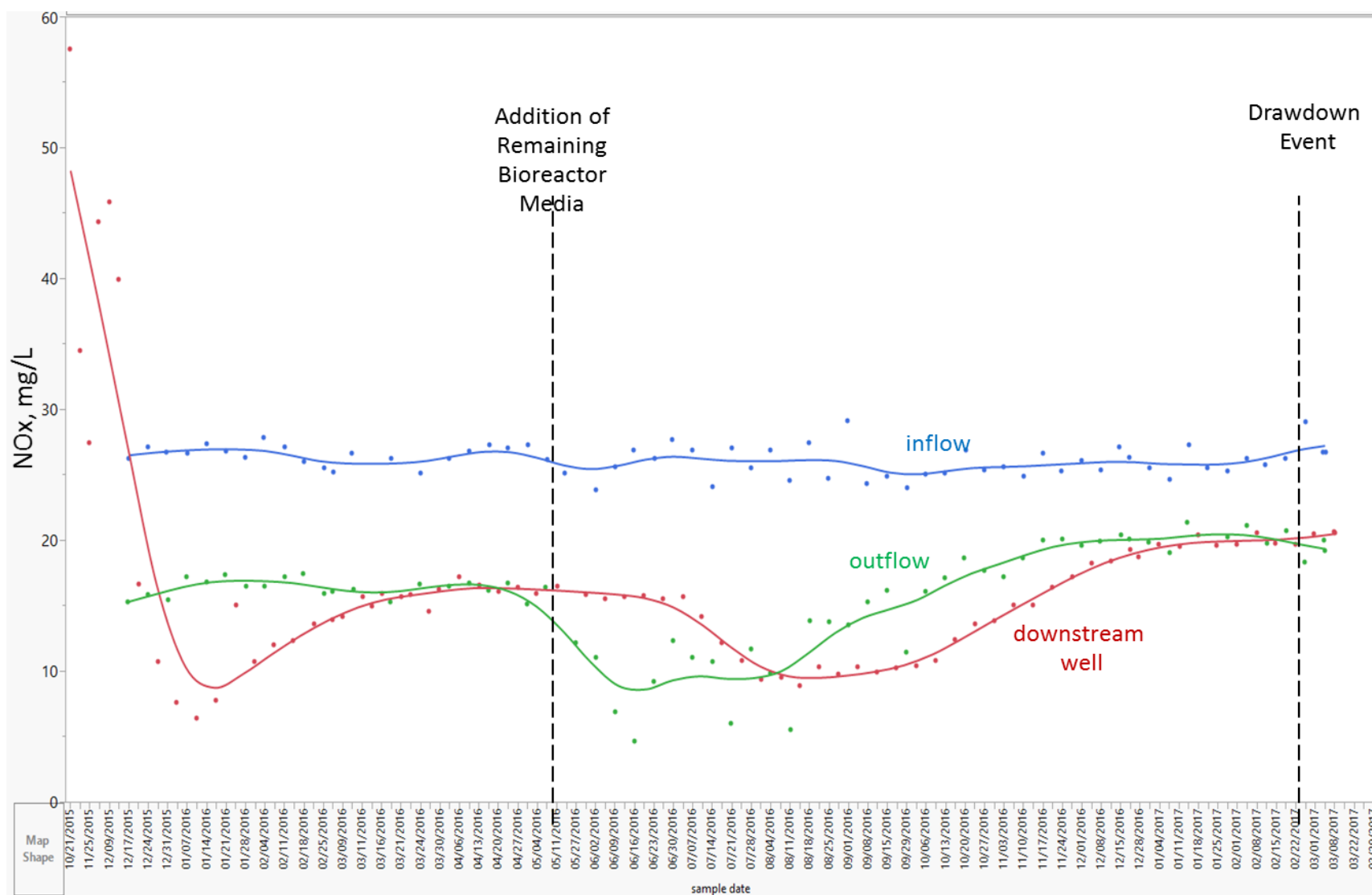


Figure 1. NOx concentration (mg/L) in bioreactor inflow (blue), outflow (green) and downstream monitoring well (red) between October 2015 and March 2017.

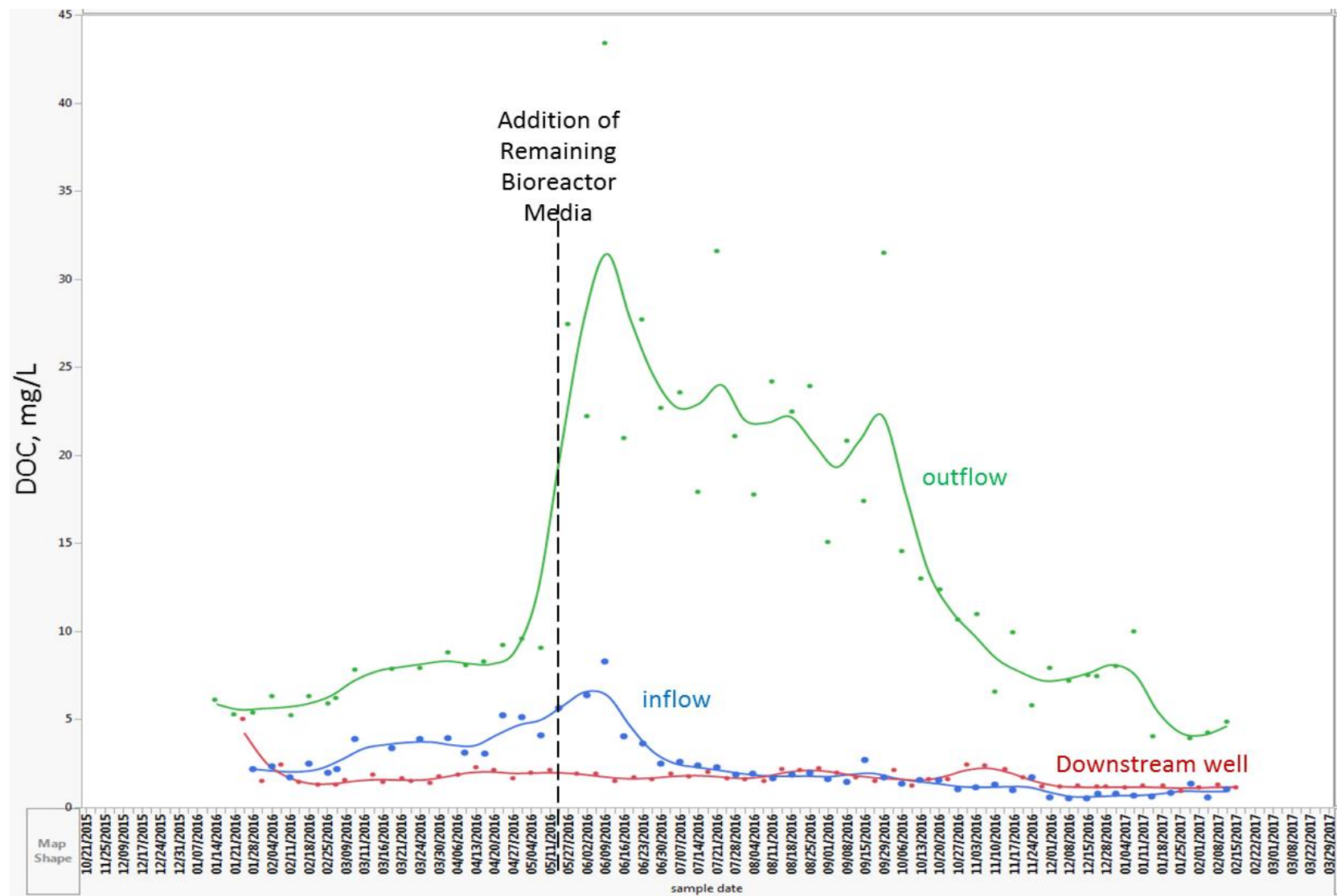


Figure 2. Dissolved Organic Matter (DOC) concentration (mg/L) in bioreactor inflow (blue), outflow (green) and downstream monitoring well (red) between October 2015 and February 2017.

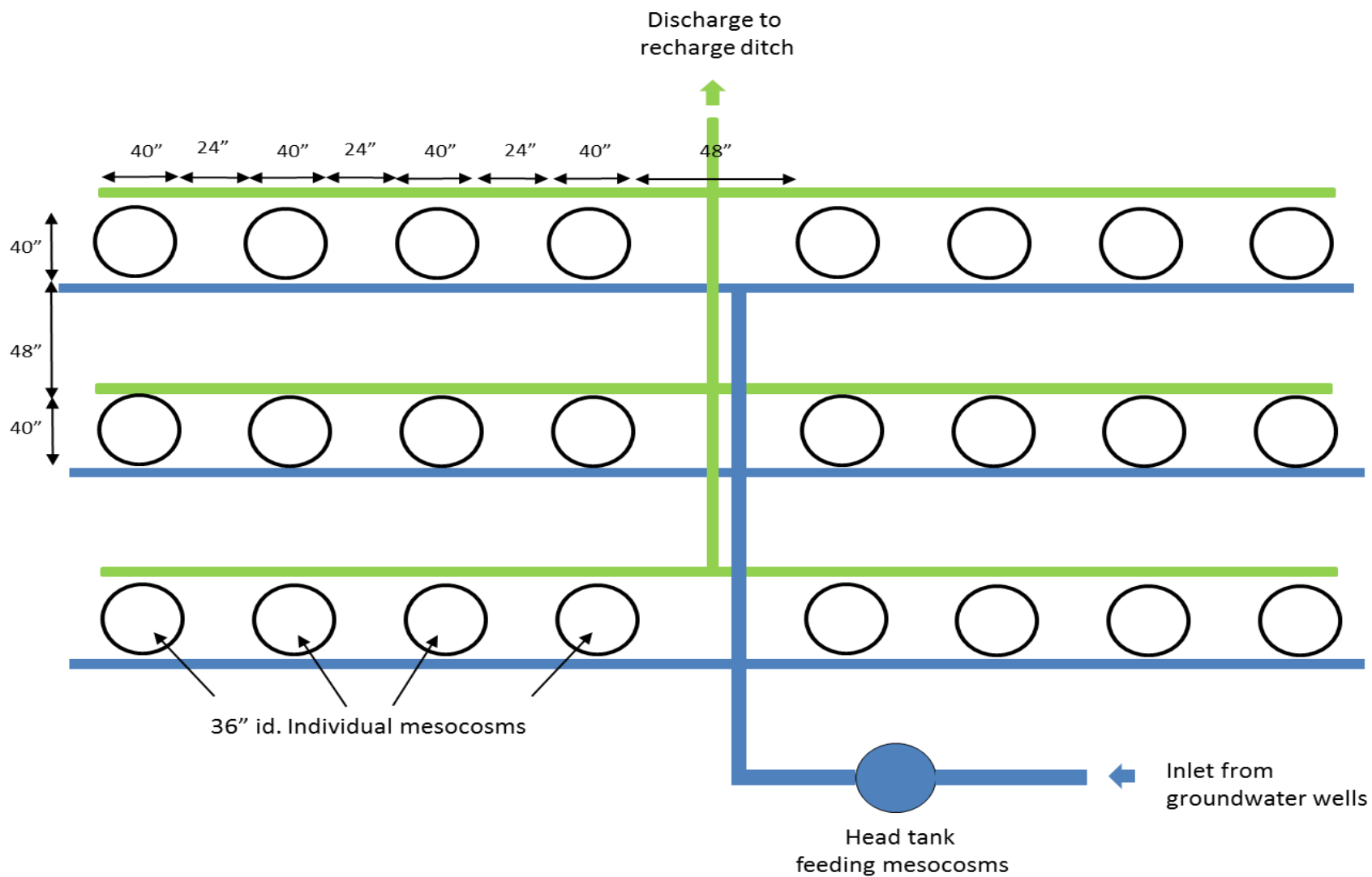


Figure 3. Layout of 24 mesocosms to be used for comparison of various alternative media sources, flow rates and other denitrification media alternatives.