DESIGN REPORT

Pine Water Association
Slow Sand/Nanofiltration Demonstration Plant

Submitted To:

Arizona Department of Environmental Quality
Office of Waste and Water Quality Management
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Phoenix, AZ 85004

From:

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Date

INTRODUCTION

The Pine Water Association presently serves approximately 130 people domestic water and irrigation water in separate systems. Their water comes from a spring but flows in a creekbed before being diverted for domestic and irrigation use. As a result during storm runoff and snowmelt the water contains some sediment. Presently there is no filtration on the system. A sedimentation chamber plus chlorination is the only water treatment.

The Environmental Protection Agency (EPA) has recently instituted a new requirement that all surface treated water has to be filtered. Lois Krebs of the Pine Water Association visited the 20,000 gallons per day (GPD) Consolidated Water Utilities Pilot Nanofiltration Plant on Sept. 8, 1989. This facility is approximately the same size that is needed by the Pine Water Association. However the nanofiltration capacity will need to be doubled due to a reduction in production during colder weather. Following this visit the Pine Water Association requested the University of Arizona help with the plant and a contract was signed.

JUSTIFICATION

Nanofiltration is a relatively new treatment process commercially available since 1986. It is a low pressure form of reverse osmosis that also has a higher flux rate. Thus the treatment is less expensive then reverse osmosis, the total cost is not much different than conventional treatment. Nanofiltration has the ability to reject macromolecules, with molecular weights as low as 200 to 300, at relatively low operating pressures (70-110 psi). As a result nanofiltration removes most of the hardness and salinity as well as dissolved organics. The combination of lower pressure and higher flux rates than reverse osmosis have significantly reduced costs to the point where the process is competitive with conventional treatment. Conventional treatment does not remove any hardness or salinity and relatively small amounts of dissolved organics.

Fort Myers, Florida is constructing a 20 MGD nanofiltration plant with a projected cost of approximately 50 cents/1000 gallons. Fort Myers is planning to use nanofiltration because it reduces trihalomethane (THM) and organic halogens (TOX) precursors, softens the water and also reduces the total dissolved solids (TDS). The bids they have received for the nanofiltration equipment were 20-% lower than expected. Fort Myers has a 5 year bonded production guarantee from Hydranautics/Nitto Denko that should allow them to meet or stay under their predicted costs of 50 cents/1000 gallons (Edwards et al., 1988).

From 1987-89 a team of researchers from the University of Arizona have been studying the use of nanofiltration with both recharged municipal effluent and Colorado River water (Cluff et al., 1989 A&B) (Amy et al., 1989). These tests were sponsored by the John F. Long Foundation Inc. in Phoenix, Arizona. The test using recharged municipal effluent has shown that nanofiltration removes 2/3 of the salinity, 4/5 of the hardness and over 90% of the dissolved carbon and THM formation potential. In addition the product water meets all of the present and projects future standards under the 1986 Safe Drinking Water Act.

The nanofiltration was subjected to seeded virus studies by Dr. Charles Gerba from the Department of Microbiology. No virus permeated the membrane. Dr. Gary Amy from the Department of Civil Engineering studied the dissolved organics and Dr. Gordon Dutt from Soil and Water Science studied the inorganic content (salinity). The other team member was Carl Hickman a reverse osmosis specialist from Cave Creek, Az. These tests indicated that nanofiltration could have a major impact in future water supplies. Nanofiltration will provide water utilities with an economic solution in providing their customers with good quality water at a reasonable rate.

The above studies led to the construction of a 20,000 gallon per day (GPD) pilot nanofiltration plant at Apache Junction, AZ using Colorado River water. This plant has been operating since April 1989. This pilot plant study is being financed by Consolidated Water Utilities who are planning to build a 1 MGD plant in the near future. This plant has successfully demonstrated the use of a slow sand filter as a pretreatment of surface water for nanofiltration. Furthermore it has demonstrated that a recovery rate as high as 95% is feasible for Colorado River water that has a salinity of 600-800 ppm. Higher recoveries are accomplished by using brackish water reverse osmosis (RO) elements as the last stage on the reject stream. The low pressure RO can be operated at the same pressure as the nanofilter with reduced flow. Thus up to 95% recovery from a nanofiltration/RO plant is economically feasible.

This proposed project will not only provide a very good quality water for the people served by the Pine Water Association but will also serve as a pilot for thousands of other small water systems that have increased difficulty in meeting the ever increasing requirements from the Environmental Protection Agency (EPA). It is appropriate that the University of Arizona install this system for the Pine Water Association since this will be the first of its type in the nation in full time production for consumers. This unique combination of a slow sand filter coupled with nanofiltration has been proven both in bench tests in Phoenix and an ongoing pilot test at Apache Junction.

As far as can be determined although slow sand filtration has been used for many decades in Europe and nanofiltration is being used on groundwater in Florida, the slow sand/nanofiltration combination has not been used for the commercial treatment of water for potable use. Because of this uniqueness slow sand/nanofiltration is the subject of a patent disclosure now being processed by the University of Arizona. The uniqueness of this treatment developed by the University of Arizona makes it even more appropriate that the Pine Water Association request to implement this method of treatment for their water system is accepted. The construction of the slow sand filter will utilize modern plastics (HDPE) with a reinforced mortar coating on sloping banks. This is not widely used, particularly in water treatment systems. It is very durable and inexpensive. In addition to providing additional information in construction costs the facility at Pine will provide operational data that will help other similar installations throughout the world.

OBJECTIVES

1. To construct a slow sand/nanofiltration unit to provide an excellent quality water for the Pine Water Association.

2. To evaluate the feasibility and suitability of slow sand/nanofiltration technology for meeting the water quality requirements of small water systems which rely on surface water sources.

METHODS

To install a 48,000 GPD (77 degrees F, 100 psi) slow sand/nanofiltration plant to treat all of the potable water delivered by the Pine Water Association. The Pine installation will be very typical of any small water systems using surface water that is not presently filtered. The results of this experiment can easily be generalized for use in other facilities since characteristically the water quality coming from both the slow sand and/or nanofilter are more independent of variations in source than conventional treatment. When those two treatments are combined an excellent potable water should be achieved in spite of changing quality of the feed water.

WATER SOURCE INFORMATION

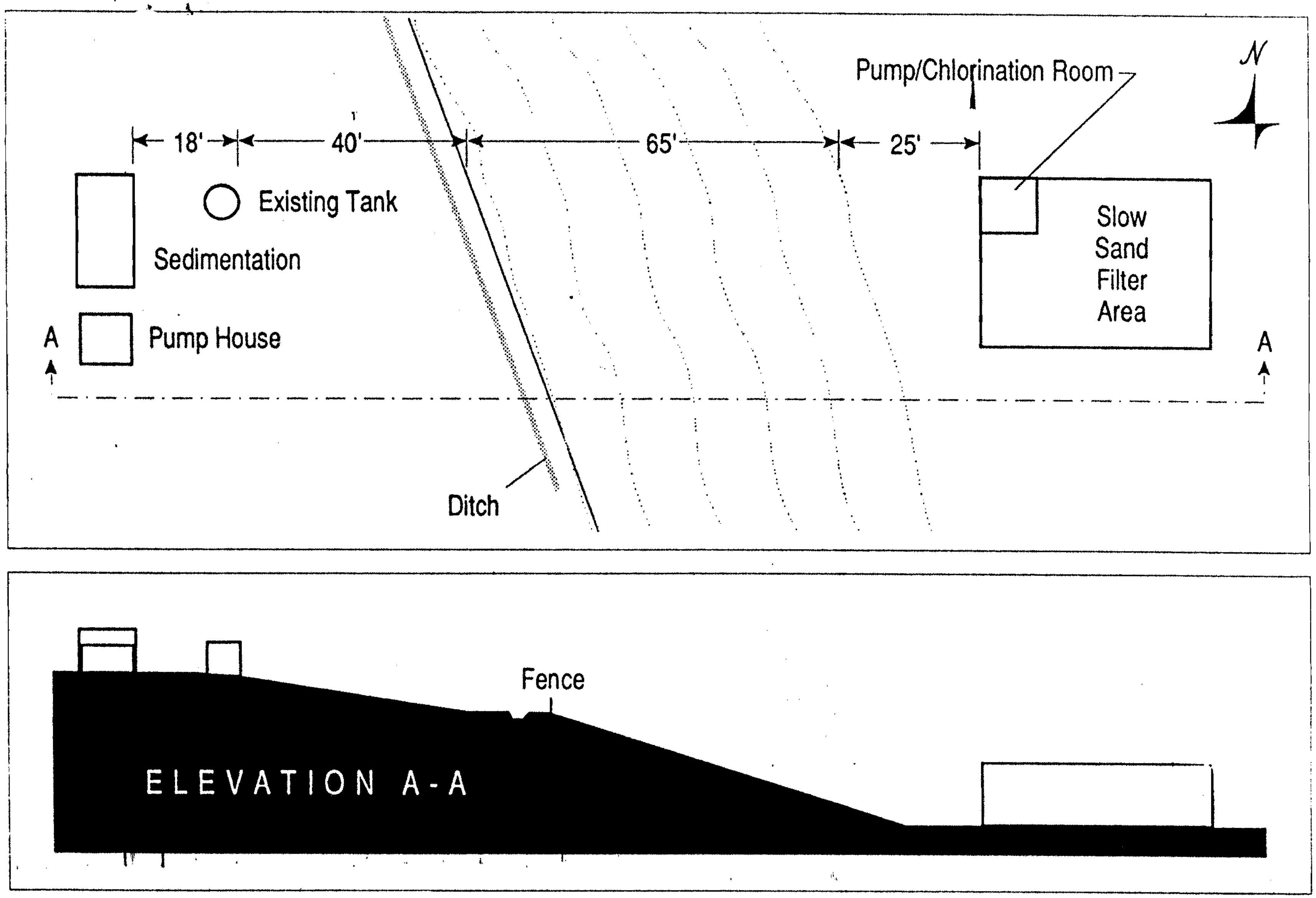
Water at Pine is available from springs 2 1/2 miles above the construction site. The salinity and hardness of the water is much lower than Colorado River water. A water analysis is given in Table 1 below. The main reason for using nanofiltration at Pine would be to greatly reduce dissolved organics and eliminate pathogens without chlorination. Even if some chlorination is required by the Department of Environmental Quality (DEQ) to prevent possible regrowth, the dissolved organic content would be so low that there would be relatively few THM or TOX carcinogenic substances formed. Due to the reduced dissolved organics in the water less chlorine will be needed to reach the desired detectable residual at the end of the system. Furthermore the water should be excellent tasting with a clarity similar to bottled water even in periods of turbid flow.

Pumping System

The nanofilter system will be pressurized with two submersible pumps. The low-pressure will be used in the summer when production is high. If necessary some of the nanofilter elements will be turned off since that nanofilters will be so effective in the summer time that it may exceed the capacity of the pump so that there would be no reject produced. In the winter when the temperature drops below 40 degrees and production is low the higher pressure pump with all of the nanofilter elements will be used.

Site Preparation

The site has been surveyed. The approximate location of these two 10 x 22 x 9 foot filters is shown in Figure 1. This is subject to change if conditions warrant.



Pump/Chlorination Room
N
18'
40'
65'
25'
Existing Tank
Sedimentation
Pump House
Slow
Sand
Filter
Area
A
A
Ditch
Fence
ELEVATION A-A

Figure 1

Plans have been drawn up and reviewed by a registered engineer. Since the nanofilter has already been approved for potable use with groundwater in Florida and slow sand filters have been used for over a hundred years, particularly in Europe, the approval is anticipated.

Slow Sand Filters

The slow sand filters will have sloping walls with slopes 9:1 (vertical to horizontal). The filters will be lined with 30 mil high density polyethylene plastic (HDPE) and the side slopes covered with plastic netting reinforcement and a one inch layer of gunite. This will protect the otherwise exposed plastic with a layer of reinforced cement. The filters are shown in Figure 2.

The filter will be excavated below the ground surface a distance of 4.5 feet with the additional 4.5 feet above the existing ground surface. The plastic liner and plastic reinforcement will be secured in a 8 x 12 inch trench that will be filled with mortar. At this time some mortar will also be placed on the bottom of the filters to hold the plastic reinforcement in place. The gunite will be applied later.

The 30 mil HDPE gunite coated liner will be installed prior to filling with a 10-inch gravel layer containing 3-inch perforated drainage pipe system. A layer of plastic window screen will then be placed on the rock followed by a 3 ft layer of mortar sand. The excavation of the slow sand filter, installation of the plastic, and gravel and sand will be accomplished with men and equipment furnished by the Pine Water Association under the working supervision of the principal investigator. The application of the gunite coating will be contracted out.

Water would flow into the slow sand filter from the sedimentation tank by gravity using a 2 inch PVC line. This flow would be controlled with a solonoid valve operated by a float switch located in the slow sand filter.

Water will flow from the slow sand filter in the 3-inch collector drains to a stilling basin constructed of 18 inch PIP plastic pipe. This stilling basin will contain the two submersible pumps used in pressurizing the nanofilter.

The pumping of water from the stilling well of the slow sand filter would be controlled with a float switch so that the nanofilter system would not operate when there was not sufficient water. The pumping of the water would be determined by a float switch in the existing gravity feed tank. The pumping would be activated whenever there was sufficient storage to sustain a meaningful run of the nanofilter. The water from the slow sand filter would first be pumped through five micron cartridge filters. This type of filter cartridge is readily available. By having two filters the filter elements should last for 30 days or more between replacement. These filter elements are available for approximately $16.00 each.

Nanofiltration Systems

The nanofiltration system will consist of four 8-inch elements placed in two 80-inch long vessels. An additional four 4-inch elements in two 80-inch vessels will also be used. The location of the nanofilters between the two sand filters is shown in Figure 2.

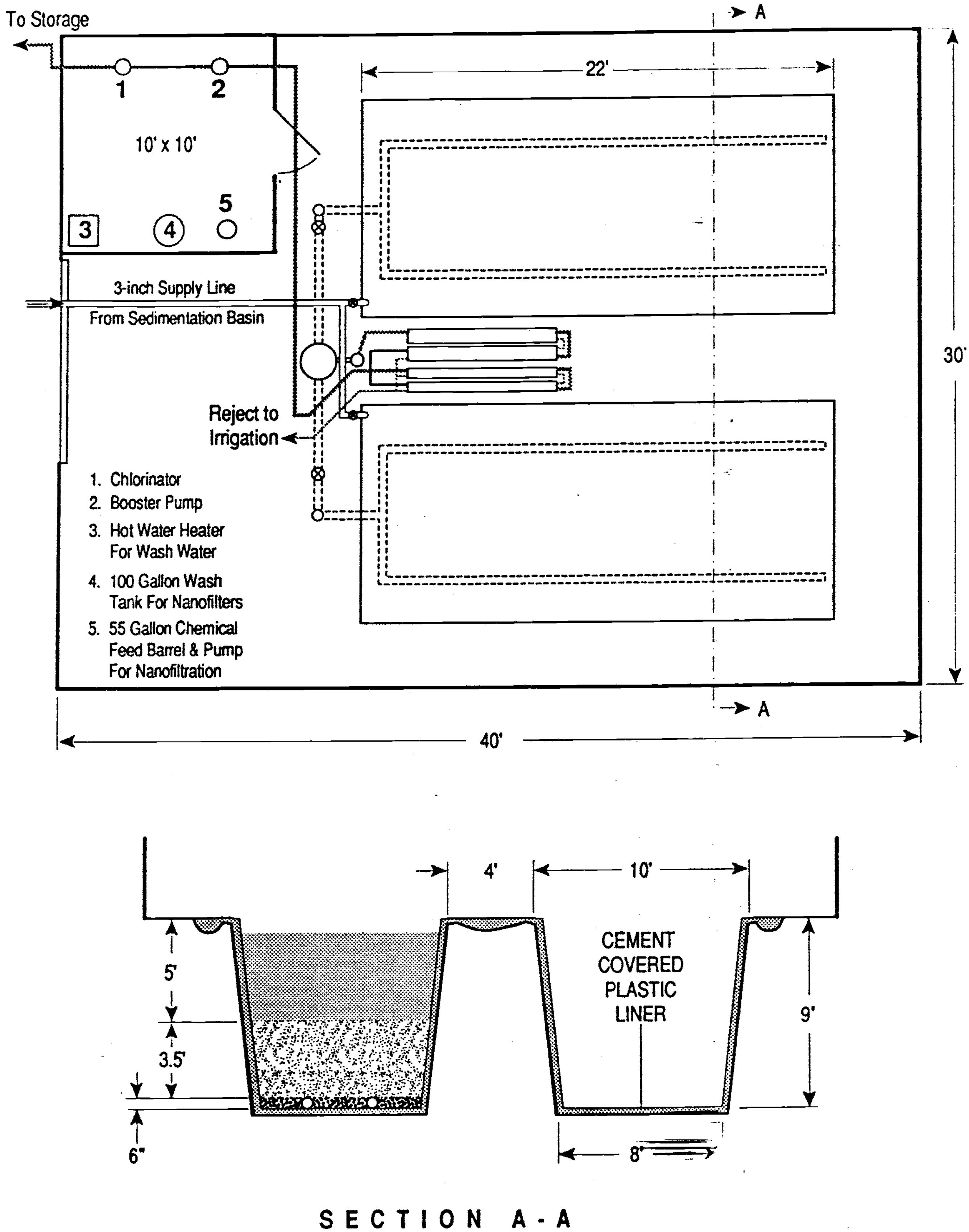

To Storage
A
22'
1
2
10' x 10'
5
3
4
3-inch Supply Line
From Sedimentation Basin
30'
Reject to Irrigation
1. Chlorinator
2. Booster Pump
3. Hot Water Heater For Wash Water
4. 100 Gallon Wash Tank For Nanofilters
5. 55 Gallon Chemical Feed Barrel & Pump For Nanofiltration
A
40'
4'
10'
CEMENT COVERED PLASTIC LINER
5'
3.5'
9'
6"
8'
SECTION A-A

Figure 2