Report of the Jamestown Water Study Committee
APRIL 2003

Executive Summary

Jamestown's water system has been running at capacity for the past twenty years. Increases in population and per capita consumption had been offset by physical improvements to the distribution system. The inevitable shortfall occurred when island precipitation patterns changed dramatically during the summer of 1993. This committee considered various approaches to increase the capacity of the system:

1. Expansion of North Reservoir.
    A. Storage Capacity
    B. Watershed
2. Development of South Reservoir.
3. Bedrock drilling.
    A. Freshwater Wells
    B. Brackish Wells
4. Water Conservation.
5. Inter Basin Transfer
6. Carr Creek Watershed
7. Membrane Filtration

The WSC has spent countless hours of research and investigation into the Towns water supply. At this point in time the committee recommends that an additional 150,00 GPD should be the goal in excess of our current average daily demand of 248,000 gallons. This requires that a safe daily yield of 398,000 GPD be attained with an appropriate treatment capacity. The WSC has explored 7 major avenues of direction in hopes of reaching this goal. The first two approaches were judged to be poor choices for further investigation at this time. Expansion of North Reservoir includes the diversion of Carr Creek and improvements to the impoundment dam. Both of these activities involve extensive permitting obstacles and great reluctance by the DOH. The recent purchase of the Ryng property will allow the Town to construct a pipeline to the mouth of North Pond from Carr Lane and flood @ 100 feet of the property if or when the diversion of Carr Creek becomes feasible. The expansion and raising of the dam may be relevant if the implementation of the transfer of water from South Pond to North Pond is considered as an expansion of the North Pond watershed. Development of South Reservoir is compromised by poor water quality due to high organic content. Extensive evaluation and limnology studies have indicated that a portion of South Pond water may be transfer to North pond. These evaluations included the addition of hypolimnetic aerations systems to improve water quality and reduce the need for additional chemical treatment at the treatment plant. This has resulted in less water for backwashing and filter maintenance. The third approach, bedrock drilling, has produced three wells, which have been permitted and placed on line. Two of these wells are run alternately and the third is a stand-alone. A fourth well is waiting for the completion of a baseline stream benthic study before it can be commissioned. Each well produces @ 50 GPM. The WSC has also drilled exploratory wells in the search for brackish water. The placement of these wells is such that interference with private wells would be eliminated. Currently the Town has advertised for a pilot study to be performed on one of these wells to determine the effectiveness of membrane filter technology for the treatment and supply directly into the distribution system.

Introduction

During the summer of 1993, the North Reservoir was depleted and the public water system of Jamestown was unable to meet local needs. Water had to be imported by National Guard tanker truck to the island for a period of several months, beginning on September 17,1993. In 1994, the reservoir was again at a low level, and a similar trend was apparent in the spring of 1995. In order to develop measures to resolve chronic water shortages, the town council formed the Water Study Committee, and passed the following resolution on 20 December 1993: "The Town Council of the Town of Jamestown hereby resolves the following: That the Jamestown Water Study Committee research and report on the most efficient ways to improve the quality and quantity of the public drinking water supply. In pursuing options toward increasing the public drinking water supply, attention and care should be given to the issue of preserving the supply of water to private well users." The supply of water to Jamestown is an issue which relates to many factors, including population dynamics, precipitation trends, and water use patterns. These topics are reviewed briefly in this report, followed by discussion of possible measures to increase the public water system

Population dynamics

Current and future demand for water in Jamestown is a function of the population growth. Island-wide, the rate of population growth in Jamestown has been very high in the past three decades, reaching a peak of about 39% growth in the decade of the seventies (figure 1). This has resulted in doubling of the island population in the thirty-year period from 1960 to 1990. The R.I. Dept. of Administration predicts only a modest 2.7% per decade population increase for Jamestown to 2010. It is prudent to consider that this value may be underestimated. The large increase seen in population in the past two decades has been, however, largely due to expansion of communities outside the public water system (figure 2). In the period from 1950 to 1981, growth in the village area, served by the water system, was about 400 persons. This is rather slow compared to the 1500-person growth during the same period in the area outside the village, which is not served by the water system. Thus, the population growth on Conanicut Island is non-uniform when one compares the village trend to the total island trend. The proportion, of residents on the town water system, in relation to those who are not, has therefore shifted dramatically in recent years. In 1958 there were 875 water meters in operation on the island, serving almost the entire population. In 1968 about 90% of the island population was still served by the public water system (Metcalf & Eddy 1968). In 1980 there were 1068 water meters in operation representing 2649 persons. By 1992, there were 1293 meters on the water system. This corresponds to about 3065 persons

(2.48 persons/meter), out of a total population of 4999, or 61% of the total island population (US Census Bureau). Thus some 1935 people were using private wells in 1992, principally in the Jamestown Shores community with a water demand of about 104,000 gal/day (38 Martyr). According to build out analysis, the population of the area served by the Jamestown municipal water system could theoretically grow by 1093, to a total of 4149. Build out analysis of the Jamestown Shores indicates a potential total population of 3060, with a water demand of 165,000 gal/day (60 NIG/yr).

Precipitation Trends

The water supply of Jamestown is largely dictated by local precipitation, evapotranspiration, hydrology and geology of the island. There are two sources of information regarding precipitation for Conanicut Island, the Average Precipitation for Rhode Island Map and records maintained by the Town. The Average Precipitation for Rhode Island Map shows that precipitation on the island is generally lower than on the state as a whole (Lang 1961). Precipitation on inland regions is of the order 45 to 50 inches/yr., whereas the precipitation on the islands in Narragansett Bay is of the order 40 to 43 inches/yr. Records maintained by the Town show that the average annual precipitation on Conanicut Island during the last 34 years is 43.4 inches. The lowest precipitation on record is 25.4 inches in 1965, and the recurrence of such low rainfall is estimated as once in 35 years. Other notably dry years were 1974 and 1980, for example. The total rainfall on Jamestown in 1993 was 40.64 inches, a value only slightly below the long-term mean. To understand our water shortages it is important to stress that 1993 *cannot be considered as a particularly dry year.* Therefore, the Jamestown 1993 water crisis cannot be attributed to unusually low annual precipitation (figure 1).

What may be significant in this regard is the abnormal seasonal or monthly variation in rainfall in 1993. Figure 2 shows the variation in mean monthly rainfall on Conanicut Island for the period 1993 to 2003. It is evident that when the long-term average is considered, normally there is remarkably little seasonal or monthly variation in rainfall on the island. During 1993, four months fell outside the normal pattern. March was unusually wet, but May, June, and August were the driest on record, with 1.67, 0.53, and 0.44 inches of precipitation respectively. Although the annual mean rainfall in 1993 was essentially normal, these three consecutive and exceptionally dry summer months led to severe depletion of the limited capacity reservoir system. Variations in Conanicut Island precipitation can be due to both random fluctuations in short-term weather, as well as long-term climate trends. There are significant fluctuations on the scale of decades. For example, the first half of the 20th century was significantly wetter in the northeast than normal. However the second half has seen gradual warming throughout the northern hemisphere. This warming trend could be associated with a general decrease in precipitation for the Rhode Island region, including Conanicut Island. Long-term changes in climate and rainfall due to such causes as the "Greenhouse Effect" should also be considered as a possibility. All water entering the Jamestown water system is entirely from surface run-off of precipitation. , Only a portion of the annual 43.4 inch rainfall that falls on the North Pond watershed can be retrieved into the reservoirs. The fate of rainfall after it reaches the ground is partitioned into the following three components:

	% Total:	Out of 43 .4 inches/yr:
Evapotranspiration	45%	19.5 in./yr.
Surface runoff _	40%	17.4 in./yr.
Groundwater recharge	15%	6.5 in./yr.

Thus only about 40% of the total annual precipitation on the North Pond watershed is recovered as surface runoff into the reservoir. Evapotranspiration rates (evaporation from the ground and uptake of groundwater by plants) are highly variable however, and range from about 6.5 inches per month at the peak of the growing season in July to zero in the winter months (URI Weather Station, Kingston). Evapotranspiration may be significantly greater than precipitation in the summer months. This is of importance when deciding on forestry and land use practice in the watershed.

Water Use Patterns

Water consumption data for the Jamestown municipal water system comes from the pumping record of the water treatment plant. In the 1960's the per capita consumption was of the order 50 to 60 gallons per person per day and this was met by a pumping rate of 110 to 150 thousand gal/day (Metcalf & Eddy 1968). By 1977, water system demand was up to 233 thousand gal/day (Lee Pare 1977). However, this upward trend leveled off and consumption by water system users has been remarkably even for several decades at around 220 thousand gallons per day (figure 3). Given the increase in water users during this period, this constant pumping rate is surprising. In the 1970's and 80's an unknown but significant amount of water was lost from the aging distribution system due to leakage. Actual water consumption during this time was probably significantly lower than the rate of pumping indicates. In the 1990's improvements to the distribution system decreased or eliminated waste through leakage and now the pumping rate more closely reflects consumption. Thus the pumping rate remained level as increased consumption was offset by reduced losses from the water system. It is important to note that with system losses eliminated, no further economies are available to offset future increases in demand and such increases will require increased pumping rates.

The relatively constant consumption, 230 thousand gal/day, is @ 36,000 gallons in excess of the SDY capacity of North Reservoir. The rate of water consumption has been measured directly by changes in the water level of North Reservoir. During the dry period from 9 to 19 June 1994, the water level of the reservoir dropped at a rate of about 0.32 inches/day, equivalent to 240,000 gal/day. The overflow of the reservoir is an infrequent event. For example, in 1977 North Reservoir overflowed the spillway only fifteen days out of the year (Lee Pare 77). If we assume that 40% of the precipitation is recoverable as surface runoff into North Reservoir, then the reservoir receives on the average 246,000 gallons per day. This value is very close to the direct measurements and the observed record of average water consumption and suggests that virtually all of the available water from this catchment basin is being recovered and used and that the amount of water lost over the spillway is negligible.
Water use is strongly seasonal, as shown in figure 4, with a near-doubling of use from about 5 million gallons per month in winter, to over 9 million gal/month in the summer

months. Daily water use per person has grown a steady rise over the period, from around 50 gallons per day per person in the 1950's and 1960's, over 70 gallons per day per person in the 1990's. The comprehensive conservation and education program has reduced the ADC clearly. Unfortunately the peak water demand in June, July and August coincides with the peak evapotranspiration rate, when water loss from the surface of the catchment basin is high, and the recharge rate of the reservoir is at its lowest level. The water system can sustain this demand only if the reservoir is full to capacity at the beginning of the peak-demand summer period. During 1993, the typical high summer water consumption combined with an exceptionally dry summer combined to bring about the worst water crisis known on the island in recent memory.

Catchment Basin and Reservoirs

The principal water catchment on Conanicut Island is the Jamestown Brook Watershed, which provides run off for both North and South Reservoirs. The watershed area of North Reservoir is 0.3 square miles 192 acres. With an average precipitation of 43.4 in/yr, the total precipitation on this watershed is 1x106 gal/yr (614,000 gal/day). This is partitioned between evapotranspiration (45%), surface runoff to the reservoir (40°,) and groundwater recharge (15%). North Reservoir has an area of 25.4 acres and a usable depth of 10 feet. Current usable storage capacity is 60 MG. On the average, North Reservoir normally fills to capacity in March, and then overflows into early spring. The water level then declines from May to November, when the filling cycle begins again. The water quality is generally good, with color averaging 40 standard color units.
The watershed, which feeds South Reservoir, is relatively large compared to that of North Reservoir, or .7 square miles (449 acres), with a theoretical total runoff of 700 to 800 thousand gal/day (Hazen 981). The quality of this watershed for water catchment appears to be high with 73% of the area covered by forest and 26% is pasture and meadow. However, the municipal system rarely draws from this source. The watershed south of Eldred Avenue is marshy and characterized by many shallow vernal pools and intermittently flowing water. The vegetation consists of low brush with mixed hardwood trees, notably Red, or Swamp, Maples. The ground is covered by several inches of forest detritus, primarily deciduous leaves. This combination of standing water and deciduous leaves infuses the watershed with very high levels of soluble and colloidal organic material. Water color, an indicator of organic material in water, is frequently greater than 100 standard color units, with spikes as great as 280 color units during rain events (Wingate 1995).

The storage capacity of South Reservoir is relatively limited, only 8 million gallons, due to the small area of the pond (4.7 acres). Dependable yield from South Reservoir has been estimated as about 89,000 thousand gal/day (FST 2000).

Development of North Reservoir

With a usable reservoir capacity of 60MG, it takes 245 days of mean runoff to fill an empty North Reservoir. With the current capacity and the mean current consumption of 248,000 gal/d, the reservoir has a water supply for only 242 days. Increasing the spillway height could increase this storage capacity. Raising the dam height by one foot would increase the reservoir storage capacity by 9 million gallons. The committee seriously considered this alternative until it was discovered that the structural integrity of the North Pond dam is marginal. It became clear that raising the dam height would be both unsafe and costly. Furthermore, raising the water level in the reservoir would inundate surrounding land creating a situation requiring permits that are hard to obtain. At the recommendation of this committee, the Town Council had a gravel bed constructed along the base of the dam to provide an improved margin of safety against dam failure. However, in light of the permitting process and the condition of the dam, the committee concluded that raising the dam would be impractical at this time.

Development of South Reservoir

To utilize South Reservoir water in the municipal system, its high organic content must be reduced. The reduction of this organic content in any water is well known to be difficult. The initial decomposition of leaf material proceeds fairly quickly. However, a midpoint is soon reached when carbon ring structures are formed which are very stable. These ring structures, which include tannins and lignans, are collectively called humic acids. Humic acids must be reduced in municipal water supplies because they interact with chlorination to produce hazardous Trihalomethanes, are the source of poor taste, smell, and color, and act as carriers of enrichment nutrients, which can cause algal blooms in finished water.

The standard approach for the removal of humic acids from municipal water is by flocculation, coagulation, and filtration. Unfortunately in this case, this approach is hardly practical. The cost of treatment chemicals is high because of the large quantities required. The resulting floc quickly clogs sand filters requiring frequent backwashing. The result is a costly "two steps forwards, one step backward" production of marginal water at a slow rate. The slow rate of production requires equipment and personnel to operate longer hours and represents an additional cost of production.

The Committee considered three approaches to reducing humic acids: 1) could high quality water be intercepted ahead of heavy humic acid addition higher up in the South Reservoir watershed? 2) Could high quality water be impounded by flow management during rain events? 3) Could we use South Reservoir itself as a pretreatment vessel by accelerating the decomposition of humic acids? 4) Blending South Pond Water with North Pond water.

Expansion of South Reservoir

The WSC has completed the preliminary design for the expansion of the reservoir to the west of the existing pond. The area available for expansion would result in @ 5 acre-feet of water or 1.6 MG. Although no detailed cost analysis has been completed, the cost would be high and the permitting most likely would also extensive.

Water from Bedrock Drilling

One potential source of water is from bedrock drilling, and this must be considered as one of several possible solutions to Jamestown's municipal water problem. Because of the common and rich aquifers sited at shallow level in sand and gravel deposits of glacial age throughout the state, this approach has generally not been developed on the mainland in Rhode Island. However in nearby south-eastern Massachusetts, where bedrock geology is similar to that of Conanicut Island, a large number of wells have been successfully drilled into bedrock, with individual wells yielding from 20 to 100 gal/min (28,800 to 144,000 gal/day; Kastrinos and Wilkinson 1994). Such wells tap groundwater flow that is trapped in secondary openings or. Fractures in the bedrock, typically in regions where the earth's crust is fractured or faulted. It is therefore important to evaluate this groundwater source and the underlying geology.

Conanicut Island has a relatively complex geologic structure consisting of four distinct rock formations. The oldest known rocks are found south of the Jamestown village and along the coastline to the east of Fort Wetherill. They are at least 600 million years old, and possibly much older. These rocks belong to the Price's Neck Formation, an ancient deposit of volcanic rocks. The southern end of Conanicut Island including Fort Wetherill, Horse's Head, and the Dumplings area, is composed of granitic rocks, which belong to the 595 million year old Newport granite formation. The entire region of Beavertail and much of the central part of Conanicut Island (south of Great Creek) is built up of Cambrian, greenish-grey shale and sandstone known as the Jamestown Formation, about 530 million years in age. Rocks from the Pennsylvanian period form the bedrock of the entire northern half of Conanicut Island, north of Great Creek. These 300 million year old sedimentary rocks are known as the Rhode Island Formation, and also make up Dutch Island and Beaverhead (Fort Getty). The southern boundary of the Rhode Island Formation is a major fault system known as the Beaverhead Fault Zone, which trends northeast, from West Passage, through the marsh between Beaverhead and Beavertail, and runs through Great Creek, into the East Passage.

Two geologic factors are likely to influence the yield of wells drilled in bedrock: the orientation of the layers or beds of rock strata, and the distribution of faults and fractures. The layers of Pennsylvanian rocks, which make up the north half of the island, form a broad basin, with a long axis trending approximately north-south. This is a favorable situation, as water trapped in these rocks is likely to flow towards the center of the island. These rocks contain a large number of fractures of varying sizes and directions. Studies of the rock outcrops along the coast of Conanicut Island show that the principal direction of fractures is north-north-east, as shown in figure 7. In addition to fractures, there are large faults in the rocks of Conanicut Island. One of these is the Jamestown Brook Fault, which trends between the South Pond and North Pond reservoirs and has given rise to the valley along which the Brook flows. This fault line is of great importance for the hydrology of the island, as it has formed a line of weakness in the rocks, and led to the erosion and sculpturing of the Jamestown Brook valley and the catchment basins of the two reservoirs. Secondly, the fault zone has provided abundant fractures in the adjacent rocks, and thus created a bedrock aquifer that can be successfully exploited by drilling.

In an attempt to limit the potential effects on private wells, the WSC developed a plan of drilling for brackish or dirty water wells. The use of these wells would limit any impact on private potable water wells since the wells would not be located in proximity to each other. The treatment of these wells would be accomplished thru membrane filtration or conventional treatment as may be required. Membrane filtration is discussed under a separate heading.

Wel1 JR-1

At the recommendation of this committee the Town of Jamestown funded the drilling of a bedrock test well in the Jamestown Brook fault zone just to the south-east of the North Pond dam. This well, JR-1, was located on the basis of a geophysical survey carried out by Hydrosource Associates Inc., including a gravimetric, magnetic and electromagnetic survey of the site. An 8-inch diameter hole was drilled into Pennsylvanian slate bedrock, to a final depth of 345 feet on December 28th 1994. Initial results indicated a high water yield of the order 100 to 200 gals/min from the well, with good water quality, and main inflow of water at a level of approximately 187 feet depth.
Well JR-1 was subject to a 12-hour-pumping test on 7 February 1995. The water temperature was monitored during the test. As shown in figure 9, the temperature of water pumped from the well was approximately 10°C and remained rather constant throughout the test. In contrast, water in the near-by North Pond reservoir at the time of pumping was 3.6°C. The large difference in these temperatures is important in considering a possible link between the reservoir and the well. This difference is so large, that it is highly unlikely, that any significant water intrusion or leakage from the reservoir into the well occurred during the 12-hour test. Such a leakage would have showed up as a decreasing temperature trend. These results are very important in that they show that the large yield of water from the well is not depleting the reservoir.
The variations in flow rate (gallons per minute) and draw-down in the well (feet) during the 12-hour pumping test are shown in figure 10. The pumping rate was varied in steps from 100 to 200 gal/min. The test was carried out until the draw down in the well was approximately at sea level; any greater draw down could result in sea-water intrusion into the well. As shown in figure 11, the recovery of the water level was very rapid when the test was stopped after a period of twelve hours. Chemical analysis of the well water shows that it is of high quality, and significantly better than the North Pond reservoir water. It requires only minor treatment, and thus its regular use results in savings for the water treatment plant and less backwashing. The current yield of the well is 50 GPM for an average of 16 hours a day or 48,000 gallons. This well alternates with well JR-3.

Well JR-2

This well proved to be a dry hole. It was placed at the mouth of South Pond. Fracture trace analysis performed by the USGS showed that the rock fractures were to confined to support the transfer of water thru them.

Well JR-3

This well is located @ 400 feet south of JR-1 and produces @ 50 GPM. This well is permitted and alternates with well JR-1. This well has special DEM monitoring requirements for long term vegetative monitoring to assess any changes in the wetland communities. To date there have been no vegetative changes relative to the pumping of this well. This well has a rather complex pump rate as determined by DEM, but if an average is taken of 40 GPM for an average 16 hour day results in 38,400 GPD.

Well JR-4

This well has moderately high iron concentrations and also produces @ 40 to 50 GPM. The Town is required to perform benthic studies of the streambed of the Jamestown Brook before we can apply for a permit to put this well on line. To date the water level of Jamestown Brook has not been deep enough top to perform this evaluation. We anticipate applying for a waiver of this requirement if the study cannot be performed during the 2003 season.

Well JR-5

This well has moderately high levels of iron and also contains sodium levels of @ 40 ppm. This well is slated to be pilot tested for an alternative membrane filtration study. It also produces @ 40 to 50 GPM.

Well JR-6

This well has good water quality and produces @ 40 to 50 GPM. It has been permitted by CRMC and needs wellhead protection radius protection for final DOH approval. If 100% wellhead protection coverage is not attainable, a variance is available. This well must go thru the treatment plant process. 40 GPM for a 20-hour pump day results in 48,000 GPD.

Well JR-7, 8 Dry Holes

Both of these wells are located adjacent to treatment plant at North Rd.
They are currently used as monitoring wells to measure the static water level of the area.

Interception of High Quality Water

Our first task was to determine the distribution of humic acids in the watershed. Casual observation suggested that the highest density of shallow pools and darkly colored water is located immediately upstream from the reservoir inlet. If this proved to be the case, we thought that some quantity of high quality water might be intercepted and piped to South Reservoir. The remaining flow would be directed into the diversion channels on either side of the reservoir and bypassed. Had this idea been feasible, we would have been faced with an additional problem. Wetlands regulations prohibit the reduction of wetland acreage. We anticipated that the Department of Environmental Management would view the reduction of natural flow through the watershed as a reduction in acreage and would probably prohibit this plan. The watershed from South Reservoir to the Watson Farm access road was surveyed with a hand colorimeter, in the spring of 1994. Preliminary tests had shown good correlation between watercolor and tannin and lignan concentration. Rainfall in the preceding month had been normal and no rain had fallen in the preceding 72 hours. At the head of South Reservoir, entering water measured greater than 100 Alpha Platinum Color Units (Standard Methods). A defined channel, Jamestown Brook, meanders through most of the watershed from Eldred Avenue. Color measurements taken along this channel and in adjacent pools and small drainages indicated that the concentration of humic acids gradually decreases as the spillway of North Reservoir is approached. The exception to this trend was a branch of very low color water that we traced to an improved well site located on the high ground just south of Watson Farm. Although the stonework at this site was in disrepair, it had clearly been used as a farm water source. We concluded from these measurements that contrary to our expectation, sources of humic acids are essentially evenly distributed throughout the watershed. The interception point would have to be located high up in the watershed to capture even minimally acceptable water. Such a location so greatly reduces the effective watershed size that the potential increase in water is insignificant.

South Reservoir as a Pretreatment Vessel

The Committee considered that it might be possible to accelerate the natural decomposition of organic material in South Reservoir water. Three processes were considered: Enhancement of bacterial action by aeration, enhancement of bacterial action by mixing, and precipitation of colloidal material by agglutination. The results are as follows: 1. None of the three processes, aeration, mixing, and precipitation, significantly increased the rate of decomposition of humic acids compared to the rate of decomposition of stagnant (control) water. However, the study shows that under any conditions, organics are reduced by 50% in one to two months. 2. After a trial period of 31 days, color measured 60-65 standard units, a level which is still very high for treatment. At capacity, South Reservoir represents a water system of approximately 10 days duration for the town. Any change in the rate of organic decomposition as measured by these trials is too small to be useful within this volume/time relationship. 3. The rate of humic acid reduction in South Reservoir is too low to supply the municipal treatment facility directly under any of the management methods considered here. However, the rate of reduction is adequate to allow partially improved South Reservoir water to be pumped to the northern end of North Reservoir for additional treatment. The Town has installed a siphon and stilling well to allow the water from the bottom of the reservoir to overflow and discharge, leaving the surface water with a higher detention time for the sun to act as an oxidant. This oxidation decreases the amount of tannin color in the water. The surface water is then pumped back to North Pond when it meets minimum water quality standards. The improvements to the water quality extend the time and volume of the water we can pump back to North Pond. The installation of the permanent transfer pipe line to North Pond will allow the Town to also use selected depth withdrawal and capture the water with the highest quality at any given depth.

Impoundment of High Quality Water

We considered the possibility that an extended rain event might flush accumulated humic acids from the watershed and that for some period of time after flushing, water of acceptable quality might be impounded in South Reservoir. South Reservoir would be maintained as a catchment and would remain empty except during rain events. An automated flow diverter would be installed in the weir at the head of the reservoir so that water high in humic acids would pass into the diversion channels and pass around South Reservoir. This mechanism would redirect the flow of acceptable water into the reservoir. Impounded water would then be pumped to North Reservoir and South Reservoir would return to its dry standby status. Once drained and dry, bulldozers could be used to increase the holding capacity of South Pond by lowering the northern end of the basin. The spoil could be used to strengthen the earthwork dam. The Study Committee was fortunate to have the assistance of Mr. John Wingate, Masters Candidate of URI's the Department of Civil Engineering, in evaluating this theory. Mr. Wingate measured humic acid concentration during four extended rain events. His measurements show that the concentration of humic acids actually increases as rain events progress! Furthermore, at no time during these rain events did water quality approach practical treatable levels. "The lowest measured color for any significant period of time was recorded prior to peak flow during Rain Event #3. The water maintained 90 standard color units for approximately ten hours." -John Wingate.

Inter Basin Transfer

During the winter of 1992, The Town installed a transfer pump system and 8” HDPE pipe to the north end of North Pond for the basin-to-basin transfer of water from South Pond to North Pond. The transfer of water between basins could result in the increase of the safe daily yield of North Pond to 321,000 GPD and South Pond to 83,000 GPD. The treatment of South Pond water by the current treatment plant is not practical during the summer months of high-required production. The basin to basin transfer will also need a number of years of experimental use to best determine the maximum amount of gallon age that can be transferred without reducing the water Quality in North Pond to an untreatable level. (Figure 5.) The Town has received a grant for $250,000 to permanently install the pipeline and construct a permanent pump station to be located at South Pond. The intake for this permanent pump station will allow for withdrawal of water various depths to capture of highest quality water for transfer. The plans have been completed for this project and the anticipated start date is late summer/early fall of 2003.

Conservation

The Town has established a water conservation and retrofit program to mandate new water conservation technologies and has developed a protocol for various uses relative to time and reservoir height. The retrofit and new construction appliance program requires the change out of toilets, faucets and showerheads within 5 years of the adopted ordinance for existing buildings. Within 10 years all cloths washers must be changed out.

New construction and upon sale of property all appliances and fixtures must be energy star listed.
The reservoir level and time of year determine which water uses are allowable. Restrictions range from none to a ban on all outside uses. Restricted uses include the use of in ground sprinklers, car, boat, house washing, vegetable and flower gardens, and commercial car washes. A variance procedure is available for relief of the ordinance.

Carr Creek Diversion

Carr Creek on the north part of Conanicut Island has a relatively large watershed that is currently unutilized. The diversion of water from the Carr Creek watershed to North Pond is in principle a relatively simple project, which could increase the water flow to the reservoir by at least 60%. This watershed consists of two distinct regions, but only the northern part of this drainage contains high quality water that is easily recoverable. The Carr Creek north watershed has an area of 0.2 sq.mi. and currently drains into the East Passage. The north Carr Creek watershed could yield 200 thousand gal/day, recoverable by pumping from a sump near East Shore Road, through a pipe to North Pond. Direct measurements of Carr Creek in January 1994 indicated water flow of the order 230 to 300 thousand, but as high as one million gal/day. Chemical analysis of water collected from Carr Creek on 23 December 1993 shows that it is of good quality. The Carr Creek south watershed has an area of 0.11 sq. mi. and could yield over 100 thousand gal/day. The water quality is unknown, and utilization of this part of the drainage is problematic, as it is discharged to the coast along a broad reach on East Shore Road. The diversion of the Carr Creek watershed to North Pond would have some impact on surrounding land uses. Members of this committee and Town Officials met on March 28, 1994 with representatives of the Rhode Island Department of Environmental Management (RIDEM) and the Rhode Island Department of Health (RIDOH) to discuss how the Departments would regulate the diversion of Carr Creek to North Pond. It was determined that if Carr Creek were diverted to the North Pond, it would become a tributary to a drinking water system and be regulated as such by RIDEM and RIDOH, even though it may only be contributing to the drinking water system at limited times during the year. Mr. Russell J. Chateauneuf, P.E., Chief of the RIDEM Individual Sewage Disposal System and Groundwater Section, met with this committee on April 26, 1994. The impact of diverting Carr Creek on surrounding land uses as it relates to the design and installation of individual sewage disposal systems (ISDS) was discussed. The Carr Creek watershed is outside of the Town's sewer district and thus is served only by ISDSs. If Carr Creek were used as a tributary to a drinking water system, stricter regulations regarding the design and installation of ISDS's would be imposed by RIDEM. These stricter regulations require that ISDS's be located at least 200 feet from any drinking water system or any tributary watercourse or drain. These regulations regarding drinking water supplies may render some already platted lots within the Carr Creek watershed unbuildable. For these reasons, the committee felt it was not appropriate at this time to have an extensive study of land use conducted to determine the impact of changing the status of Carr Creek to a tributary to a drinking water system. In addition, the DOH has indicated that they would not be amenable to allowing use of Carr Creek because of contamination risks posed by surrounding land uses. Attached as appendix 1 and 2 are memos of RIDEM addressing the Jamestown water system.

Membrane Filtration

Membranes are another form of filtration used to remove solids from water. The membrane system consists of forcing water through a fibrous material using high pressure. Cleansed water exits through the walls of the containment vessel. Membrane filtration produces extremely clean effluent free of most or all contaminants depending on pore size selected.

The USEPA considers the membrane filtering process to be best available technology (BAT) due to the physical barrier that is imposed on microorganisms, solids and contaminants. Membrane technology consists of forcing raw water through a semi-permeable membrane using high pressure. By varying the pressure and the size of the pores in the membrane, the process can selectively retain particles of different sizes.

Spiral wound and hollow fiber membranes are two types of membranes commonly used in water purification. Hollow fiber membranes have some advantages over spiral wound membranes. Hollow fiber membranes have a larger surface area than spiral would membranes generating more area for particles to become trapped. Hollow fiber membranes can be flushed in reverse removing solids that have become lodged in the membrane and restoring some of the process efficiency. For these reasons, hollow fiber membranes provide a better overall product for the treatment of potable water.

The majority of ultra-filtration membranes manufactured are made from synthetic organic polymers. The hollow fibers are constructed into bundles and installed in a fiberglass pressure vessel. An epoxy is applied to both ends of the bundle. When the epoxy has dried the ends of the receptacles are cut off, revealing the open ends of the hollow fibers.

Raw water is exposed to ozone, chlorine dioxide (or another strong oxidant) and possibly a coagulant to assist in the removal of particulates from the water. Effluent is sent to a settling tank to allow for the dissipation of the oxidant residual and to allow time for solids to settle out. In some systems water is pre-filtered with a bag filter to remove any large particulates that still exist. The water then enters one end of the hollow fiber membrane system where permeate (cleansed water) passes through the membrane walls and out through ports in the side of the vessel. Wastewater, or concentrate, flows out the opposite end of the column and is either recycled to the head of the plant or wasted. In other systems the membrane system is housed within the settling tank and water is pulled from the tank through the membranes by vacuum pumps.

Membrane systems produce an excellent effluent quality but must be periodically backwashed or cleaned with a solvent (acid or detergent) to ensure that continuous reduction in flux (flow rate through the membrane) doesn’t occur. The application of membrane technology to North Pond surface supply may require the addition of a coagulant, which may cause high operation and maintenance costs as a result of significant levels of solids fouling and interfering with the effectiveness of the membrane system.

The Town of Seekonk, MA has decided to move forward with a chlorine/ permanganate/ membrane system to remove manganese levels as high as 6 mg/l from a 2,500 gpm well supply. The Town of Littleton, MA has installed an ozone/membrane system to remove about 0.25 mg/l of iron and about 0.6 mg/l of manganese from a 1,100 gpm well supply. This process was selected to meet Giardia and Cryptosporidium removal goals as well as to reduce radon and natural organic matter. The membrane systems are estimated to cost about 25 percent more than the more conventional pressure filtration system.