AECOM has developed the enclosed approach plan for the Milford Water Company to utilize for the installation of the proposed granular activated carbon (GAC) layer (GAC "sandwich") for assisting with the removal of organic compounds. This plan has been developed based on consultation with other utilities that are presently utilizing GAC sandwich technology, consultation with academic researchers experienced in measuring the efficacy of this technology, and with the carbon supplier (Calgon Carbon). Milford Water Company has also been consulted to assess logistics. This plan is divided into three sections, namely:

Phase 1: Preparation
Phase 2: Installation
Phase 3: Operation & Monitoring

Following a brief description of the project background, each of these proposed phases is described in detail.

Background

Because the use of slow sand filtration is a fairly outdated technology, the practice of installing GAC layers in slow sand filters is not well documented in the literature. Normally a pilot program would establish design parameters for this technology, however, the MWC is committed to implementing this technology as soon as possible, precluding the luxury of a pilot study. Without the benefit of a pilot program, it is necessary to base the performance expectations on the findings of others. Fortunately, there are existing utilities in New England that have full scale and pilot scale experience with this application, and academic researchers at the University of New Hampshire that have insight into the efficacy of this technology.

The purpose of the GAC sandwich layer is to assist with the removal of organic compounds through the slow sand filter (SSF) process. This in turn should help the MWC to reduce disinfection by-products which are formed when organic matter reacts with chlorine. Normally, SSF's are unable to remove appreciable amounts of organic matter because they cannot generally remove dissolved compounds. However, placing GAC within the filter, between layers of sand (hence the term "GAC sandwich") has shown to be an effective means of enhancing a SSF for organics removal. There are many types of carbon available. Based on discussions with the GAC media supplier, Calgon Carbon, all other slow sand GAC sandwich filters have utilized approximately 6-inches of F400 carbon, a 12 x 40 mesh of bituminous carbon. Attachment B contains a product specification for this carbon (note that this is a generalized product bulletin and not to be considered as a product submittal specific to this project). This particular carbon has a high iodine number, is resistant to abrasion, and is a sanitary grade product with NSF approval for use in water treatment applications.

Through discussions with the MWC and the Massachusetts Department of Environmental Protection (MADEP), it has been agreed that SSF No. 4 will be equipped with the GAC layer and SSF No. 3 will serve as the control filter for the purposes of assessing performance of the GAC layer. SSF No. 4 is roughly 250 x 65 in plan area, although the earthen side walls slope so that the bottom area is less than the top surface area. The average surface area of SSF No. 4 is as calculated below:

Area taken from bottom of slope (bottom of beds)	= 13,276 sq. ft.
Area taken at top contour of filters	= <u>16,620 sq. ft.</u>
Average	= 14,950 sq.ft

The volume of GAC required for a 6-inch layer is 7,474 ft3 (277 CY) which will be placed mid-depth into the SSF. Figure 1 shows a schematic cross section of the existing and modified filter, using "d" as the initial depth of sand media (the actual depth is unknown at this time although believed to be 36-inches).

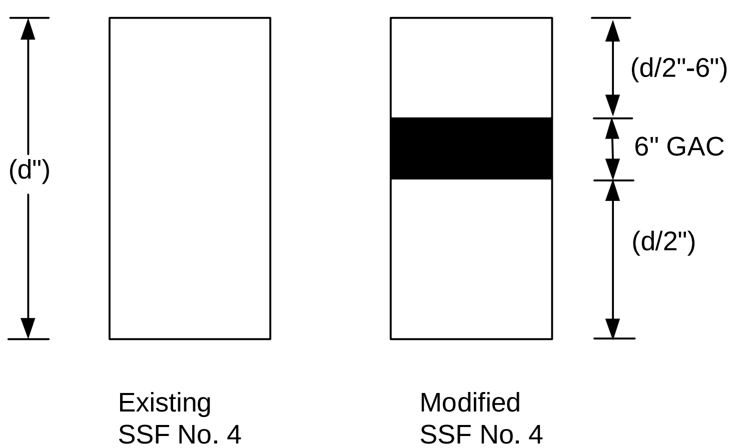

Figure 1: Proposed Depth of Media for SSF No. 4

Assuming 36-inches of sand depth, the volume of sand to be removed from the filter and set aside is estimated at 877 CY.

Figures 2 and 3 show the site plan and flow diagram respectively. As shown, SSF No.'s No. 3 and 4 are adjacent, uncovered and share a common wetwell labeled as Clearwell No. 3 on the Figure 3 schematic diagram. A report prepared in 2002 indicated that a dedicated pipe connects SSF No. 4 with this clearwell, and that there is no flow control, no filter-to-waste capability, and no sampling ports for either SSF 3 or 4. These issues will need to be addressed, as described in the Phase I description below.

PHASE 1: PREPARATION

The MWC must ensure that SSF No. 4 is ready for the carbon when the carbon is delivered. There are several steps that must be undertaken to reach this point. These steps are itemized below. Many of these can be conducted in parallel with other tasks.

1-A) Selection of Media. Working with Calgon Carbon, the MWC should send a source water sample to Calgon so that bench scale adsorption tests can be conducted to select the optimal media and media depth for this application. As previously noted it is expected that 6-inches of F400 will be recommended, however, Calgon should be consulted to make this determination, based on the testing results. AECOM has previously transmitted TOC and TTHM data to Calgon for their review.

Following selection of the media, MWC must receive a written quotation and delivery date and logistics from Calgon so that the planning of the installation can commence. AECOM will work with MWC to coordinate these items with Calgon. At a minimum the following information must be provided by Calgon following selection of the media.

- Contractual terms including cost and guaranteed delivery date
- Breakdown of scope of supply and installation services
- Number of delivery trucks anticipated

1-B) Piping Modification at SSF. No 4. A major concern is the inability to drain or filter to waste during the installation of the carbon and after the SSF is placed back on line. It is understood that traditionally the MWC will ripen a newly scraped & re-sanded filter by operating at a very low loading rate and will blend this filtered water with the other supplies. The higher turbidity from the newly sanded filter is offset by the very low flow from it, and the blending with other sources. For the subject project, the following points must be taken into consideration:

- Virgin GAC will release a very dark “carbon dust” into the water upon initial installation, which in turn imparts a dark hue to the water. This is normally purged by the practice of initial backwashing and the skimming of carbon fines (i.e., very small carbon grains) during start-up. However, neither of these practices is possible with a slow sand filter. The presence of fines is less of a concern due to the very low loading rate on the SSF, but the passage of the carbon dust and subsequent dark water into the finished water supply is a concern. Furthermore, installing the GAC will be accomplished by slurrying the GAC onto the top of the sand. A significant amount of water will drain through the carbon, into the lower sand layer, and eventually into the underdrain during installation. If the SSF is not able to drain-to-waste, this slurry water will enter in Clearwell No. 3 and into the finished water, which must be avoided. If the SSF No. 4 is isolated from the clearwell, but unable to drain, this slurry water may accumulate and rise to an elevation within the filter itself to the point where it could impede the carbon installation. A drain/ waste line would eliminate all of these concerns.

- To install the filter-to-waste and drain line, the MWC should investigate the possibility of utilizing the pipe that discharges to the effluent chamber located in the northeast corner of SSF No. 4 adjacent to the river. A submersible pump can be used to dewater this chamber during the drain/wasting operations. The water could discharge either to the lagoons or to the river, pending DEP approval

- Sample taps for SSF No. 3 and 4 will be needed. Intercepting the effluent pipe between SSF No. 4 and Clearwell No. 3 as described above would provide the MWC with an opportunity to not only install a wasting system but would also be the means of installing a sample tap. Because the installation of carbon into SSF No. 3 may also be required in the future, and because a sample line for SSF No. 3 will also be needed (SSF No. 3 will be the “control” filter for assessing performance of the GAC sandwich), it may be prudent for the MWC to take advantage of the make preparations for the potential of wasting from SSF No. 3 as well.

- Flow cannot be allowed to travel backwards from Clearwell No. 3 into the underdrain and then upwards through the media of SSF No. 4 as has reportedly occurred in the past. Cross-connections with other finished water sources will hinder the sampling efforts and could also inhibit the ability of the GAC media to adsorb organics. The MWC should strive to provide forward flow only through the filters by installation of a check valve on the discharge into the clearwell. A bypass loop and isolation valve should be installed around the check valve so that the filter can be refilled from Clearwell No. 3, thorough the bottom underdrain when the filter is ready to go back on line.

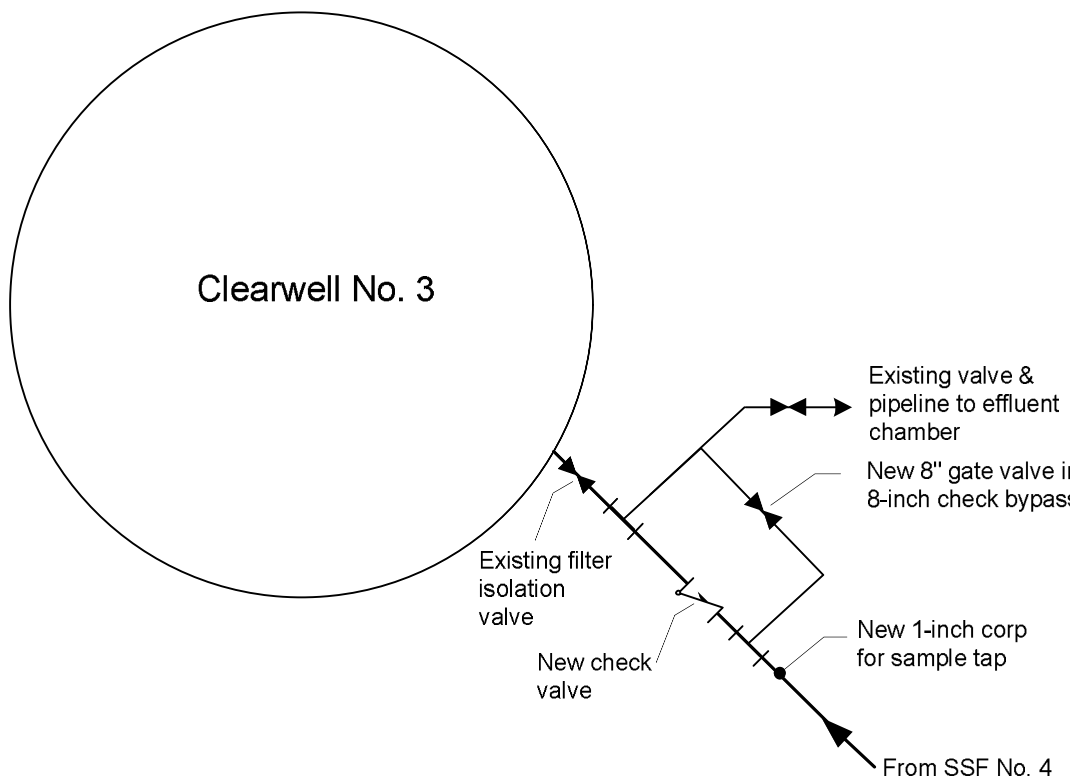

Figure 4. Proposed Piping Modifications to SSF No. 4 Effluent

1-C) Sand Specifications &SSF As-builts. Provide AECOM with the SSF No. 4 sand specifications as provided by the media supplier and also the as-built drawings or record drawings of the SSF's if available.

1-D) Prep for Carbon Bulk Delivery. Prepare for the delivery of carbon by ensuring that the bulk tanker which will deliver carbon can gain access to the area between SSF No. 1 and SSF No. 4. AECOM will send Calgon an image of the site plan showing the available area for unloading the carbon and will obtain the weight of a full truckload . The carbon will be delivered in bulk containers as shown in Figure 5.

It is recommended that MWC investigate the gravel drive between SSF No. 1 and SSF No. 4. If there are pipes in this area that are close to grade and vulnerable to heavy loads, or if the area is not considered stable enough to support a tanker truck, then the tanker will be required to park in the existing main gravel drive parallel to SSF No. 3 and the DE lagoons. In either case, transfer of carbon from the bulk truck to the loading site is accomplished with a high pressure water supply and a 4-inch camlock style hose.

Figure 5. Bulk Carbon Delivery Truck (courtesy Dan wells, Winthrop ME Water District).

1-E) Potable Water Supply. MWC must ensure that an adequate supply of potable water at a minimum of ___psi is available for slurry water to deliver the carbon to the application point.

1-F) Sand Storage. A clean, flat space must be identified to store the top half of the sand which will be removed from SSF No. 4. This will amount to approximately 900 CY. For perspective, this is equivalent to a pile with dimensions of 200 ft x 50 ft x 3 feet deep. The sand must be kept free of debris during the storage period and then must be able to be reinstalled without inadvertent mixing with stones and other debris during transfer back into the filter bed. Ideally, a concrete or paved surface would be recommended. If this is not possible, tarps placed on flat ground may be used instead.

1-G) Maximize System Reliability. Removing SSF No. 4 from service, which is capable of 1.4 mgd of filtered water, will result in a fairly significant loss of system redundancy. Therefore, prior to the works, it will be crucial that the other unit processes at the facility be in reliable condition. The MWC should perform any scheduled repairs in advance and make as many provisions as possible to ensure that the other unit processes, particular the DE filters, be in the best working order possible. To minimize the demand on the system during the works, and thus maximize system redundancy, the MWC may want to consider issuing a water conservation notice to users.

PHASE 2. INSTALLATION

Because of the unique nature of this proposed operation, it is difficult to predict the time required to remove the sand, install the GAC, and then re-install the sand. For reference, the time required for the operators in Winthrop ME to install a GAC sandwich in one filter was 30 days, and the MWC's filters are approximately 4-times the area. Granted, the Winthrop filters are covered, making access and working conditions more cumbersome. Nonetheless, this underscores the importance of preparing everything in advance to minimize the duration of filter downtime. The following steps are proposed for converting the filter. Note that it will be important to prevent water from Clearwell No. 3 from entering the filter during this operation.

2-A) Measure Depth of Sand. Upon initial draining of SSF No. 4, measure the depth of sand. Be sure to check the depth in several locations as localized mounds may exist. It is important to know the depth of sand so as to be able to measure the appropriate amount to remove. The sand can be measured either by making careful excavations, or using a core sampler.

2-B) Remove top half layer of Sand. It is anticipated that the removal of the top half layer of the sand can be performed using similar means as during a filter re-sanding event, the difference being that in this case the sand removed must be stored for re-installation. To ensure that the correct depth of sand is removed across the extent of the filter bed, a transit or laser level should be used as described below:

- Referring to Figure 6, first find or establish a fixed benchmark in an undisturbed location. This can be the top of an existing structure or a nail in a tree – as long as the elevation is permanent and sight lines to it are unobstructed. Assume an arbitrary elevation for the benchmark (for the purposes of this example, assume elevation 100 ft).
- Set up a transit in a secure location, level the instrument, and using a surveyors rod take a back-sight on the benchmark to get the height of the instrument (HI). For example, if the back-sight on the benchmark reads 6-feet on the rod, the HI equals 106 ft.
- Next, use the rod to establish the elevation of the top of the existing sand (TOS). It is likely that the sand will not be perfectly level, so several readings in multiple locations are recommended and an average value should be established. The elevation of the top of sand is simply the HI minus the rod reading. For example, if the average rod readings is 11 ft, the average TOS elevation = (106-11) = 95 ft.
- The elevation to which sand removal should occur is the top of the excavation (TOE) as shown in Figure 6 and is found by subtracting half of the depth of filter sand (d/2) from the previously established TOS elevation. For example, if the depth of sand is found to be 3 ft, the TOE = 95 – (3/2) = 93.5 ft. The rod reading should equal HI-(TOE), or in this example, 106-93.5 = 12.5 ft.
- During removal of the sand, the level and rod should be used periodically to check that the TOE is correct, and reference stakes placed to show where the TOE elevation is located within the filter bed.

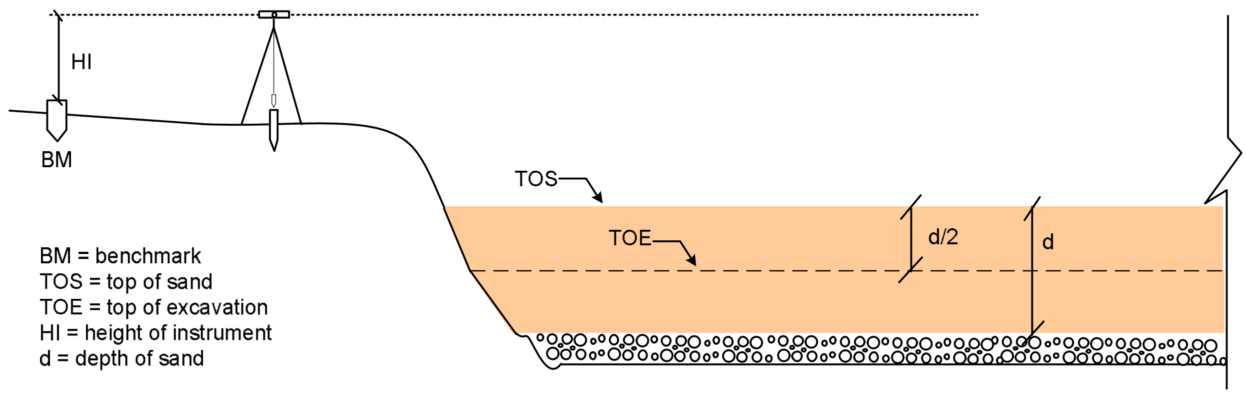

Figure 6. Illustration of Critical Elevations for Sand Removal

Excavating the sand to a common, level installation is important because a uniform depth of GAC is desired, and the depth and uniformity of the GAC layer is dependent on the underlying surface. If the GAC is not level or is installed in uneven depths, short-circuiting of the raw water will occur resulting in loss of adsorption performance. Installation of the GAC will be easier with a more consistent subgrade as well.

2-C) Storage of Removed Sand. As previously noted, care should be taken to properly store the removed sand for ease of re-installation. The MWC may also consider storing the schmutzdecke (dirty later) in a separate location so that this can be re-installed which could assist with the ripening of the filter when it is put back into service (this was done in the Winthrop ME GAC sandwich operations).

2-D) Place GAC onto Sand. The next step will be to install the GAC. The GAC will be slurried onto the top of the sand from the bulk tanker truck. MWC must ensure that the slurry water be potable, since the water will drain through the GAC and into the lower sand layer and ultimately the filter bottom. As noted in Step 1B, this water should be removed from the filter bed by draining to waste.

Placing the GAC slurry can be expected to go relatively quickly. According to the chief operator at the Winthrop ME facility, the placing of the GAC was finished in one day. Although the Winthrop filters are smaller than SSF No. 4, it should still be expected that the GAC transfer from the bulk tanker to the leveled filter bed should be a fairly smooth operation. Because the water will drain from the GAC slurry and into the sand, it could be difficult to judge how much GAC slurry to apply to a given area. For this reason, the operators in Winthrop ME constructed a wooden form out of 2 x 6 lumber. This was a 3-

sided form approximately 8 ft x 10 ft which the operators moved from section to section in a grid like fashion. Operators filled the form with the slurry and then used a screed across the top of the form to level the GAC (a screed is simply a straight-edge board used to level off the GAC slurry, similar to placing concrete). The form was then retracted and placed alongside the previously deposited GAC section. Because the water from the slurry will drain into the sand, the GAC will be dry enough then to retain its shape (much like a sand castle) allowing the operators to place the next section without too much disturbance of the previously placed GAC section.

Figures 6 through 9 show illustrations of the form technique. Note that workers had placed plywood on the sand surface for better distribution of weight and to not disturb the leveled sand bed. There may be other techniques that the MWC may choose to utilize. Regardless of the method of installing the GAC, installers should strive for as level a carbon layer as reasonably possible.

Figure 6 – GAC Bulk Hauler & Transfer Hose.

Figure 7- Placing GAC with Slurry Water.

Figure 8 – GAC Form.

Figure 9- GAC Form & Plywood Walkboards.

Because the perimeter of SSF No. 4 is earthen and irregular, a modification of the form technique will be called for. When working along the periphery, installers can use a grade stake to mark off the desired depth which should be.

2-E) Replacing Sand. After the GAC is installed, the sand that had been removed in Step 2-B can be brought back onto the GAC. It may be possible to follow behind the GAC installation with the sand installation, staying far enough back so that the sand installation does not impact the placement of GAC. The top of sand should be placed level using the technique described in Step 2-B. Note that there will be a surplus of sand, equivalent to volume of GAC.

In placing the sand, it will be very important to not disturb the GAC layer. The sand can be loaded from the entry ramp at the north end of the filter and gently pushed forward so that bring equipment on top of the GAC will not be required. However, if necessary to walk overtop of the GAC, plywood sheet are recommended. Ideally, however, it would be better to limit walking to the top of the sand layer

PHASE 3 IMPLEMENTATION.

Before placing the SSF No. 4 into service (i.e., into Clearwell No. 3), the following steps are recommended. These steps are intended to protect the quality of the finished water leaving the plant.

3-A. Wet the Filter. It is assumed that the filter and underdrain will be dry upon completion of media installation. To prevent air binding when initially placing into service, the filter should be allowed to fill from the bottom and flow upwards until water appears above the top sand layer. This can be accomplished by closing the waste valve to the effluent chamber and opening the existing filter isolation valve and check valve bypass valve as shown in Figure 4.

3-B. Filter to Waste. When the filter is wetted, raw water can be placed onto the filter. The filter effluent pipe should be placed back into the wasting mode and diverted away from Clearwell No. 3 and to the effluent chamber. Wasting should occur for several bed volumes. A bed volume is equivalent to approximately 350,000 gallons and until the filtered water is free of color as imparted by the carbon. Wasting is not a substitute for ripening, but is intended to purge the system of inert particles including carbon dust that may result from the placement of the media. During wasting, monitoring should include the following:

Table 1. Monitoring Parameters During Wasting

Parameter	Filter No. 3	Filter No. 4
Turbidity	4 times daily	Hourly
pH	1 daily	4 times daily
Color	1 daily	4 times daily
appearance	1 daily	4 times daily

The appearance of the filer ted water may show evidence of inert particles and/or carbon fines, which would not necessarily be identified in turbidity or color samples as these generally colloidal particles. It is recommended that operators collect samples in clear glass containers for close inspection of the filtrate. The purpose of sampling both SSF No. 3 and 4 is to make use of SSF No. 3 as the control filter, to make comparisons between the new filter and a stable filter and to establish reference conditions.

3-C. Filter to Clearwell No. 3. Once the filtrate from SSF No. 4 is stable, ripening can commence as is normally practiced. It is recommended that the filter be operated at a low loading rate as is usually practiced during ripening. The following parameters are recommended for analysis once the filter is in service (including during ripening):

Parameter	Raw Water	SSF No. 3	SSF No. 4	Finished Water
pH	1 daily	weekly	1 daily	1 daily
Color	1 daily	weekly	1 daily	1 daily
UV-254	1 daily	1 daily	1 daily	1 daily
TOC*	1 weekly	1 weekly	1 weekly	1 weekly
Temperature	1 daily			
TTHM	-	-	-	Bi-weekly
Flow	1 daily			

Virgin GAC will raise the pH of the filtered water. This is because the carbon will adsorb chlorides, sulfates, nitrates, and other anions from the water. Filtered water pH will remain elevated until the carbon's pores become filled with these anions. Typically, it may take several days for the pH to drop to normal.

ATTACHMENT A -

Correspondence with Mike Donaway at Calgon carbon.

- I asked about what would be the best carbon to use for this application & how to determine, and Mike said that all of the sandwich applications have used F400 (a 12 x 40 mesh).
- F400 is a sanitary grade carbon with a high iodine number. Since it's used often, the carbon is readily available and would have probably a 2-week delivery time after order. Mike will confirm.
- A service technician would accompany the delivery, which comes in pressurized bulk containers and is slurried onto the top of the filter.
- In Winthrop ME, there was no attempt to remove fines. Fines are very small media particles that are normally skimmed off the top layer of a newly backwashed filter and disposed of. The presence of fines creates rapid headloss development particularly on a high rate filter such as will be built in the new plant. Given that the slow sand filters will operate at a very low loading rate, it is likely that the presence of fines is not a major problem.
- Most of Calgon's experience with this practice has come from Europe, and he offered to provide a brochure/information packet so that we can see case study examples.
- Stephanie at Calgon is looking into applicable bench scale testing options, which may come out of the background references from the European installations as referenced above.
- The carbon apparently undergoes bioactivity with extends the carbon adsorption duration. Rutland VT is conducting a pilot study to test this bioactivity. Mike suggested I call the Rutland city engineer, Evan Polachowski, at 802-773-1813 to get more details.

<u>Conversation with Evan at Rutland VT.</u> I spoke to Evan Polachowski in Rutland to get an update on their pilot study. They have a 7-mgd SSF's facility.

- They have raw TOC's in the 1.5 – 3.0 mg/L range and have problems with HAA's more than TTHM's.
- They have been conducting a 1-year pilot study to look at UV removal through 3 pilot filters: a sandwich filter of 6-inches of F400 with virgin carbon; an exhausted carbon filter built same as the virgin carbon filter; and a sand control filter. The purpose of the exhausted GAC pilot filter is to see how much removal of organics can be achieved by bioregenerated GAC media.
- Robin Collins at UNH has estimated that a bioregenerated filter can still get 10-35 % removal of organics after exhaustion. (The term bioregeneration is used to describe the process whereby microbial activity in a granular activated carbon filter has the potential to extend the service life of GAC beds through in situ biological regeneration of sorption sites.)
- In Rutland, the control filter with just sand has shown an 11% removal of organics as measured by UV, and the exhausted filter has shown a 22 % removal of organics. But the sandwich filter has shown a 72 % removal of UV, even after 9 months of use.
- They are not sure if they will ultimately install the sandwich GAC layer. They will be looking at MIEX next.
- Evan suggested calling Tim Gormley in Milo ME to hear about their full-scale experience.

Conversation with Tim Gormley of Milo Water District. I called Tim Gormley at 207-943-2501.

- Milo has an SSF plant (not sure of what size) that takes highly colored water from the Sebec River.
- About 10 years ago, they put in a GAC sandwich that "worked well for 2 or 3 years", but is now not helping with DBP's anymore as would be expected after 10 years of service.
- Milo will be converting to chloramines and will be replacing the GAC soon.
- Tim said that the sandwich concept is good because it's so simple, but does not last more than a few years and is costly.

Conversation with Dr Robin Collins UNH. I spoke to Dr Collins to see if I could obtain more information on the bioregeneration process. He said that one of his students prepared a thesis on it back in 1996 and presented at ACE around that time.

- In summary, the bioregen can occur in a role reversal with sorption, where sorption takes place at certain temps and bioregen at others.
- After providing him with the project background, he felt that the sandwich is a good concept for Milford in general.
- He said that Thames Water has been using the GAC sandwich for a long time and has patented an installation process. This is because the GAC must be very level and placed in the correct manor.
- Dr Collins asked if the problem is TTHM's or HAA's. I explained that TTHM's were more problematic. He strongly recommended that AECOM/MWC look instead at air stripping and not GAC, because TTHM's are easily strippable. This is a better way to remove TTHM's in the long run and can be a permanent installation. He will send a design manuscript for my review.