# Evaluation of Full Scale GAC Treatment at Manchester Water Works for Compliance with the Information Collection Rule

**Conducted during the period of January 1 through April 1, 1999**

**Manchester Water Works**

**June 1999**

**Acknowledgements:**

Manchester Water Works appreciates the support and assistance of Environmental Engineering and Technology, especially lab director Alan Kersnick for his help in completing the project. Also it is important to recognize Manchester's laboratory staff as well, particularly Cheryl Wood and Diane Bogacki for their consistent attention to detail during the sampling and analysis portion of this effort.

Additionally, it is important to recognize Steven Allgeier and James Westrick of the USEPA for their willingness to allow Manchester to perform a full scale study. For Manchester this was an opportunity to save the expense of a pilot or bench study, while gathering information on an operational GAC system. Delays in startup of this study associated with difficulties in operation of a newly renovated furnace for carbon reactivation created a situation where USEPA's patience was appreciated.

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## Section I – Conclusions and Recommendations

In compliance with the ICR, Manchester Water Works performed an analysis of the breakthrough characteristics of one of its full scale granular activated carbon (GAC) filters. Based on a review of the analytical results, a clear picture of the breakthrough characteristics for Trihalomethanes (THM), Haloacetic acids (HAA), and their precursors was observed.

Typical of past studies examining breakthrough in Manchester, initial results for each of the analytes studied was extraordinary. As an example, removals of Total Organic Carbon (TOC) and UV254, were in the 80 – 90 % range for the first few days. Both parameters reached what would be considered a relative plateau after about 50 days of operation. At this plateau, the filter was removing approximately 30 – 40 % of the TOC and UV254 applied. These removal rates dropped off only slightly (perhaps 10 %) over the next 45 days.

Somewhat different trends were observed in the precursor testing as revealed by the Simulated Distribution System (SDS) analyses. Here, testing for simulated THM and HAA development revealed an initial ability to remove nearly all the reactive potential, or precursor. Breakthrough of these analytes was observed over the next 40 or so days into the cycle, when again the performance of the filters reached a plateau. This plateau appeared to be in the 50 – 60 % removal range however as opposed to the lower range for TOC and UV254 removals indicated above. Interestingly, the THM removal continued to drop off to a rate of about 30% removal at the end of the project while the HAA precursor seemed to do somewhat better. Other factors such as reaction pH and reaction kinetics may also be a factor in this observation.

The cyclic nature of GAC performance presents some challenge from the system operator's view. The knowledge that the performance will initially be very high, but will quickly decline, should be reflected in the operational control of the GAC system. Additionally, seasonal variants in the demand for either THM or HAA precursor removals needs to be coupled with practical concerns over taste and odor control as well as the availability of the GAC to remove VOC, SOC, or other water contaminants where they exist, or potentially could occur on a sporadic basis. These considerations, coupled with the demand to control THM and or HAA levels present an interesting matrix for water system operators to deal with. In our case, we find it prudent to taper our GAC system so as to control THM and HAA levels while maintaining a single carbon filter in a state of high adsorbancy to deal with any aberrant water quality episodes.

## Section II: Background Information

The Manchester NH Water Treatment Plant was completed in 1974. The plant has a 40 MGD maximum hydraulic capacity and treats an average of 16.1 MGD. Maximum recorded consumption for the Manchester system is about 31.4 MGD. In an effort to provide control over raw water quality, the department maintains simple fee ownership of over 8000 acres of the watershed's most sensitive areas. We feel this combination of watershed protection and full treatment capability affords the community the best possible combination of technological and ecological controls over water quality and is highly consistent with recent understanding of the "multiple barrier" approach to water supply. For more information regarding Manchester's watershed protection program, see figure I below as well as appendix I.

WTP

Treatment is performed in a conventional fashion with mechanical flash mix, followed by tappered flocculation, gravity sedimentation and series sand and GAC filtration. This design was installed to achieve aesthetic control of taste, odor and color attributes of the Lake Massabesic supply. Figures II and IV present this configuration graphically, as well as figure III which presents some additional plant design data. The Manchester Water Treatment Plant as seen in the eyes of the ICR is shown in appendix II

Typical of most Southern New England supplies, Lake Massabesic is a soft, mildly acidic surface water with mesotropic characteristics. TOC originates primarily from upland peat and shallow pond areas which

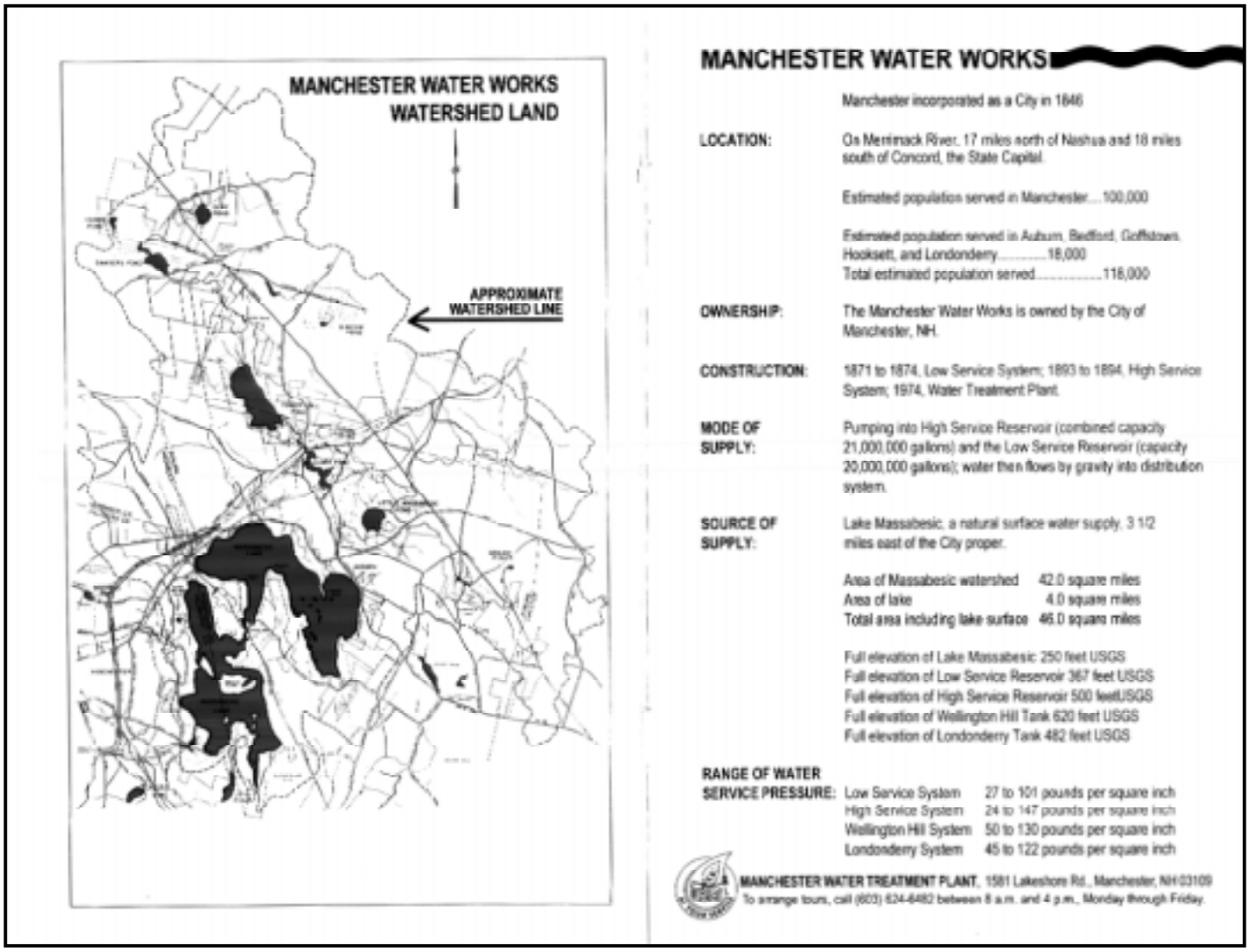



**Figure I – Manchester Water Treatment Plant Supply Information**

develop extraordinarily high levels of color. Typical water quality data compiled from the ICR are shown below in table I.

The Water Treatment Plant design as mentioned above was developed to address any questions which may develop with regards to aesthetic quality. I have enclosed ICR reports A2 and A3 which provide specific design and engineering data in appendix II of this report. Additionally, appendix III of this report contains the ICR block diagram which looks at the plant as a series of unit processes with all sampling and chemical application points highlighted. Figure II below presents the WTP as presented in our WTP brochure. A notable aspect of our operation is the carbon regeneration furnace activity. Manchester Water Works was fortunate in 1978 to be granted funding through USEPA Municipal Environmental Research Laboratory to pursue a cooperative agreement to investigate the practical application of on site carbon reactivation. This 5 year long study demonstrated that reactivated carbon is of significant quality and compares quite favorably to virgin media in its adsorptive characteristics.

Another notable aspect of Manchester's design involves the use of series filtration. As a facility of early 1970's vintage, the use of series filters was somewhat novel. This design was adopted to maximize the potential life of the activated carbon by helping to assure that its adsorptive sites remain unencumbered by blinding aluminum hydroxide particulate matter. In this light the units function as adsorbers solely, and not as filter-adsorbers. Additionally the filtration process utilized the Automatic Backwash filter design which is still in service in Manchester. The advantage to this type of filter is that it remains in service while being

backwashed incrementally over approximately 100 minutes. The disadvantage of this process is the potential for incremental particle release immediately following backwash of each cell. In this filter one cell relates to a maximum discharge of about 263 liters/minute (70 gpm) Another way to look at this is that one cell is about 0.25% of flow under normal operating conditions. Manchester is currently evaluating options for filter modification or replacement in order to upgrade performance and plant capacity.

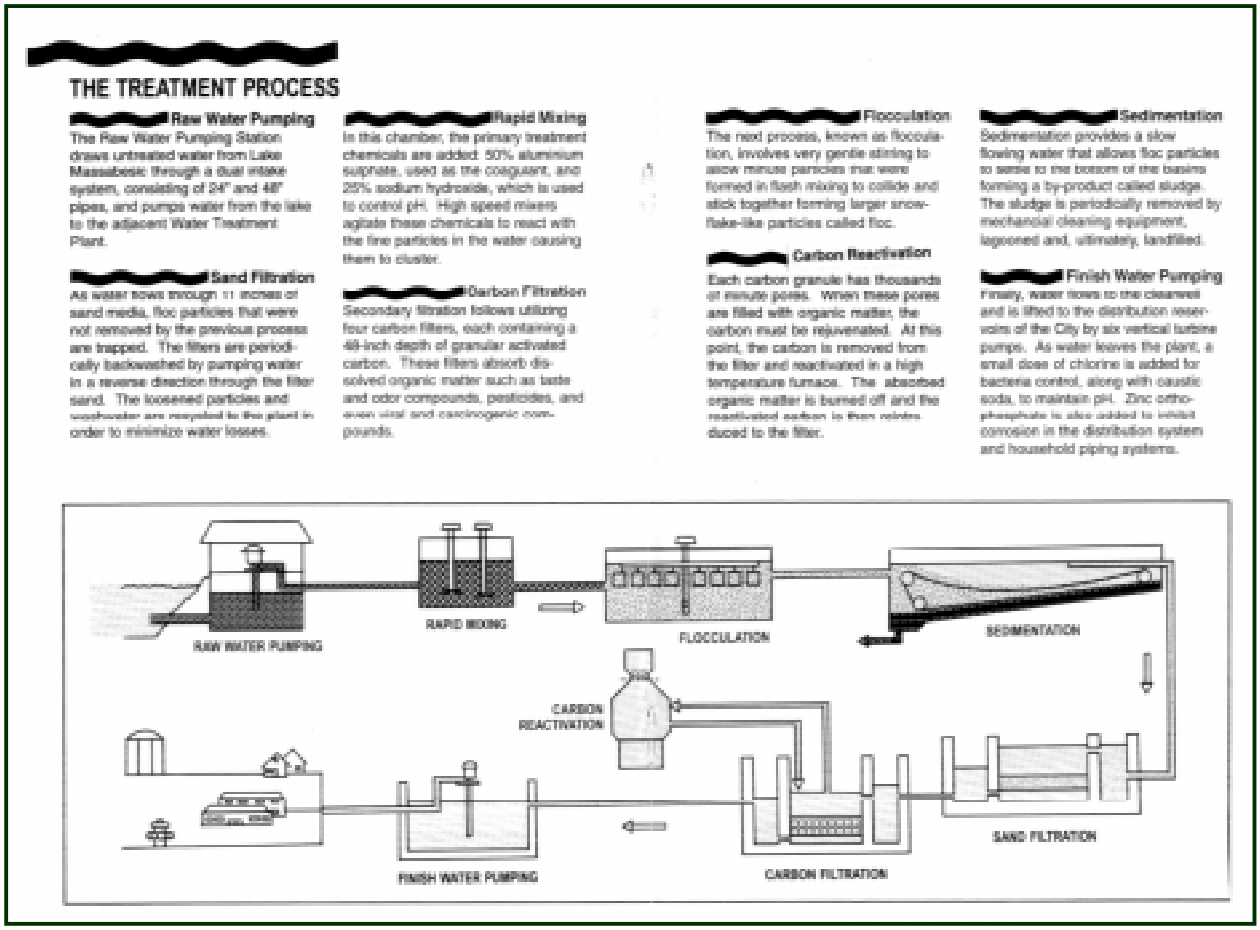



**Figure 2 – WTP Unit Process Description**

## TECHNICAL DATA AND PLANT SPECIFICATIONS

### GENERAL

| | |
|---|---|
| Avg. Daily Flow | 15.5MGD |
| Max. Hydraulic Flow | 40.0MGD |

### RAPID MIXING

| | |
|---|---|
| Number of Basins | 2 |
| Dimensions/each | 12' x 12' x 7' W.D. |
| Liquid Volume | 15,680 gals |
| Number of Mixers | 2 |
| Detention Time at Avg. Flow | 100 seconds |
| Detention Time at Max. Flow | 32 seconds |

### FLOCCULATION

| | |
|---|---|
| Number of Basins | 4 |
| Dimensions of Each | 50' x50' x 11' W.D. |
| Liquid Volume | 205,700 gals. |
| Number of Flocculators per Tank | 4 |
| Detention Time at Avg. Flow | 80 Minutes |
| Detention Time at Max. Flow | 30 Minutes |

### SEDIMENTATION

| | |
|---|---|
| Number of Basins | 4 |
| Dimensions of Each | 50' x 168' x 11' W.D. |
| Liquid Volume | 692,000 gals. |
| Detention Time at Avg. Flow | 5.00 Hours |
| Detention Time at Max Flow | 1.65 Hours |

### SAND FILTRATION

| | |
|---|---|
| Number of Filters | 4 |
| Dimensions of Each | 16' x110' |
| Surface Loading at Max. Flow | 4.0 GPM/FT² |
| Media | Silica Sand 11" |
| Backwash | Automatic-Backwashing on Headloss Criteria |

### CARBON FILTRATION

| | |
|---|---|
| Number of Filters | 4 |
| Dimensions of Each | 16' x 110' |
| Surface Loading at Max. Flow | 4.0 GPM/FT² |
| Media | Granular Activated Carbon 48" |
| Media Size | 8 x 30 Mesh |
| Backwash | Automatic Backwashing on Headloss Criteria |

### CARBON REACTIVATION

| | |
|---|---|
| Capacity | 500 Lbs./Hour |
| Fuel | #2 Fuel Oil |

### CLEARWELL & PUMPING EQUIPMENT

| | |
|---|---|
| Number & Capacity of High Service Distribution Pumps | 1-5MGD;2-10MGD |
| Number & Capacity of Low Service Distribution Pumps | 1-5MGD; 2-10MGD |
| Low Lift Pumps | 1-19MGD; 1-30MGD |

**Figure III – WTP Design Specifications**

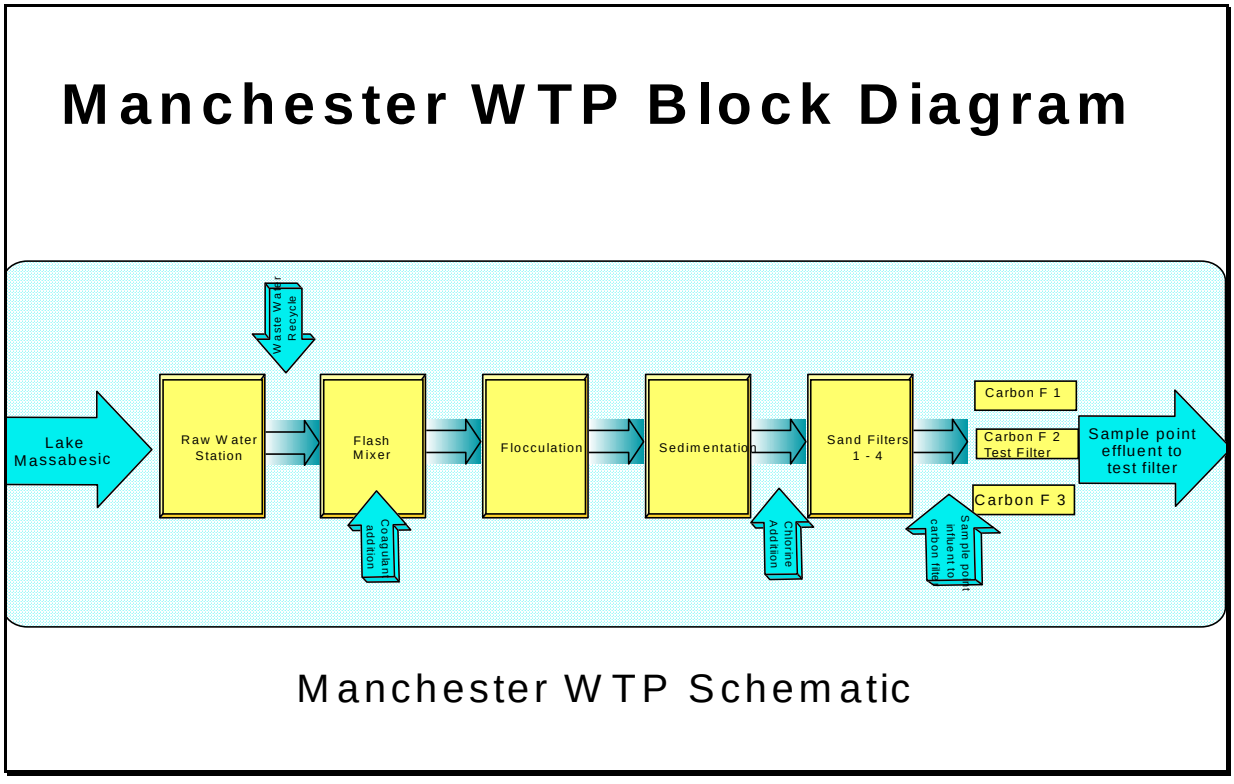



**Figure IV – Manchester WTP Schematic**

**Full-Scale Water Quality Data**

***Full-Scale Influent Water Quality Data***

| Item | Units | Average | Std Dev | Min | Max | Count |
|---|---|---|---|---|---|---|
| Temperature | C | 14.1 | 8.1 | 2.7 | 26 | 17 |
| PH | Unit | 6.67 | 0.15 | 6.3 | 6.9 | 18 |
| Turbidity | ntu | 0.76 | 0.8 | 0.34 | 3.92 | 18 |
| Alkalinity | mg/L as CaCO3 | 10.7 | 4.4 | 6 | 24 | 18 |
| Total Hardness | mg/L as CaCO3 | 22.1 | 7.95 | 14 | 40 | 16 |
| Calcium Hardness | mg/L as CaCO3 | 15.8 | 5.9 | 11 | 35 | 16 |
| TOC | mg/L | 4.12 | 0.41 | 3.6 | 4.85 | 17 |
| UV254 | 1/cm | 0.11 | 0.02 | 0.07 | 0.17 | 18 |
| Bromide | µg/L | 40 | 30 | 20 | 60 | 2 |
| TSUVA* | L/(mg*m) | 2.6 | 5.4 | 2.1 | 3.4 | 17 |

*TSUVA = [UV254 (1/m)] / [TOC (mg/L)]. Summary information for TSUVA should only be calculated from TSUVA values with paired TOC and UV254 measurements

***Full-Scale Finished Water Quality Data***

| Item | Units | Average | Std Dev | Min | Max | Count |
|---|---|---|---|---|---|---|
| Temperature | C | 15.5 | 6.31 | 5 | 25.9 | 18 |
| PH | unit | 7.52 | 0.234 | 7.14 | 8.1 | 18 |
| Turbidity | ntu | 0.08 | 0.04 | 0.04 | 0.21 | 18 |
| TOC | mg/L | 2.38 | 0.33 | 1.9 | 3 | 17 |
| UV254 | 1/cm | 0.029 | 0.011 | 0.013 | 0.06 | 18 |
| DS-THM4 | µg/L | 49.6 | 29.3 | 15.9 | 104.7 | 16 |
| DS-HAA5 | µg/L | NA | NA | NA | NA | NA |
| DS-HAA6 | µg/L | 45.1 | 36.5 | 7 | 115.8 | 15 |

**Table I – WTP Influent and Effluent Data (18 months of ICR)**

## Section III - Materials and Methods

As this evaluation involved a full scale analysis of GAC performance, the pretreatment of water entering the test filter was also performed full scale. As Manchester is a conventional design with coagulation being supplied by alum and polyaluminum chloride, the water entering the test filter was very consistent in quality. (see results) When sand prefiltration is also factored in, it is clear that the water quality and carbon adsorption rates are not impeded by particulate matter blinding off sites as might be the case in a full scale evaluation where the GAC filter is removing flocc as well as dissolved adsorbates.

WTP Operational Information

Plant operational criteria during the trial was closely monitored. As this evaluation took place during the period of January 5 to March 31, 1999, the plant flows were generally low (< 30% max), and water temperatures were fairly constant at about 3 - 4 degrees C. Initially coagulation was based on a polyaluminum chloride application ranging from 18 – 24 mg/l with pH ranging from 6.3 to 6.5. On February 9th a switch was made to an alum based coagulation scheme with dosages in the 22 – 26 mg/l range with coagulation taking place at 5.8. This change produced a 17% reduction in sand filter effluent TOC (from mean values of 2.91 mg/l to 2.41 mg/l) , while also creating an unfortunate increase in settled turbidity. To account for these issues, Manchester evaluated a combination of polyaluminum chloride and alum. Enough alum was applied to reduce coagulation pH to the desired 5.8 region, while polyaluminum chloride was added to enhance flocc formation. The resulting dosages of approximately 5 mg/l alum in combination with 20 – 24 ppm polyaluminum chloride produced excellent settled water turbidities while maintaining the lowered TOC typical of alum treatment alone. This change was made on March 16 and had no measurable impact on TOC levels. Manchester currently is convinced that this combination of coagulants produces the best combination of settled turbidities and TOC removal currently achievable without advanced treatment in this type of water supply. Table II below summarizes typical sand filter effluent quality over the full 18 months of the ICR.

Carbon Filter Information

Specific data concerning the operation of the full scale filter is pertinent to this analysis. The filter selected for this analysis was carbon filter II. This filter consists of approximately 113,600 kg of granular activated carbon. The unit measures 39 m long by 5.8 m wide by 1.4 m deep. The unit is designed to operate at up to 163 l/min/m2. (4 gpm/ft2) The nature of the media used in this evaluation consisted of a combination of virgin and reactivated carbon. Reactivation at Manchester is accomplished in a fluidized bed system. The quality of the media was initially characterized for iodine adsorption and apparent density. This sample was a composite taken from 6 sites in the filter and averaged 741 mg/gm and 42 gm/100cm3, respectively. Further information concerning Manchester's carbon reactivator and reactivation program is contained in Appendix III.

***Full Scale Sand Filter Effluent data***

| Item | Units | Average | Std Dev | Min | Max | Count |
|---|---|---|---|---|---|---|
| pH | Unit | 6.1 | 0.32 | 5.32 | 6.7 | 18 |
| Turbidity | Ntu | 0.13 | 0.06 | 0.05 | 0.26 | 17 |
| TOC | Mg/L | 2.6 | 0.31 | 2.15 | 3.4 | 18 |

**Table II - Sand Filter Effluent; Data (18 months ICR)**

The filter was backwashed daily from midnight to 3 am. The filter was then in service at 50% capacity (5 MGD) until sampling. Sample period was routinely in the morning on Monday and Wednesday for the first 8 weeks, and then conducted weekly for the following 8 weeks. The sampling protocol was well defined and repeated with little variation. Effluent samples were collected over the entire filter in a composite manner. Similarly, influent samples were composited concurrently so as to provide a direct

comparison in time of water influent and effluent to the filter. Carbon filter influent data over the full course of the analysis is summarized below in table III.

***Full Scale Sand Filter Effluent data - Jan., Feb., March 1999***

| Item | Units | Average | Std Dev | Min | Max | Count |
|---|---|---|---|---|---|---|
| pH | unit | 6.3 | 0.22 | 5.68 | 6.83 | 80 |
| Turbidity | Ntu | 0.15 | 0.058 | 0.06 | 0.4 | 82 |

**Table III - Test Filter Influent Quality**

Analytical methods and laboratories

Analytical testing was performed by two labs. Manchester Water Works lab provided on site sampling and analysis for basic physical and chemical parameters. Environmental Engineering and Technology of Newport News Va. Provided the balance of the analytical support. A complete list of the laboratory's used, methods and MRL's are shown below in table IV.

**QA/QC Data - Sheet 1**

| Analyte Identification | Units | Laboratory Identification | Start Service Date | End Service Date | Method |
|---|---|---|---|---|---|
| **pH** | unit | Manchester | 1/1/99 | 4/1/99 | SM4500 |
| **Temperature** | C | Manchester | 1/1/99 | 4/1/99 | SM2550 |
| **Alkalinity** | mg/L as $CaCO_3$ | Manchester | 1/1/99 | 4/1/99 | SM2320 |
| **Ammonia** | mg $NH_3$-N/L | EET | 4/28/98 | 1/26/99 | SM450NH3 |
| **Calcium Hardness** | mg/L as $CaCO_3$ | Manchester | 1/1/99 | 4/1/99 | SM3500D |
| **SDS-$Cl_2$ Residual** | mg/L | Manchester | 1/1/99 | 4/1/99 | SM4500 |
| **Total Hardness** | mg/L as $CaCO_3$ | Manchester | 1/1/99 | 4/1/99 | SM2340 |
| **Turbidity** | ntu | Manchester | 1/1/99 | 4/1/99 | SM2130 |
| **Bromide** | µg/L | EET | 4/28/98 | 1/26/99 | EPA 300.0 |
| **$UV_{254}$** | 1/cm | EET | 4/28/98 | 1/26/99 | SM5910B |
| **TOC** | mg/L | EET | 4/28/98 | 1/26/99 | SM5310C |
| **SDS-TOX** | µg Cl-/L | EET | 4/28/98 | 1/26/99 | SM5320B |

| | | | | |
|---|---|---|---|---|
| SDS-$CHCl_3$ | µg/L | EET | 4/28/98 | 1/26/99 EPA 551 |
| SDS-BDCM | µg/L | EET | 4/28/98 | 1/26/99 EPA 551 |
| SDS-DBCM | µg/L | EET | 4/28/98 | 1/26/99 EPA 551 |
| SDS-$CHBr_3$ | µg/L | EET | 4/28/98 | 1/26/99 EPA 551 |
| **THM4** | µg/L | EET | 4/28/98 | 1/26/99 EPA 551 |
| SDS-MCAA | µg/L | EET | 4/28/98 | 1/26/99 EPA 552.2 |
| SDS-DCAA | µg/L | EET | 4/28/98 | 1/26/99 EPA 552.2 |
| SDS-TCAA | µg/L | EET | 4/28/98 | 1/26/99 EPA 552.2 |
| SDS-MBAA | µg/L | EET | 4/28/98 | 1/26/99 EPA 552.2 |
| SDS-DBAA | µg/L | EET | 4/28/98 | 1/26/99 EPA 552.2 |
| SDS-BCAA | µg/L | EET | 4/28/98 | 1/26/99 EPA 552.2 |
| **HAA5** | µg/L | EET | 4/28/98 | 1/26/99 EPA 552.2 |
| **HAA6** | µg/L | EET | 4/28/98 | 1/26/99 EPA 552.2 |

**Table IV, Analytical Methods and Laboratories**

## Section IV: Results and Discussion

As this work was performed full scale, concern over the control and monitoring of water influent to the test filter is important. The test filter influent water consists of water treatment sand filter effluent and carbon filter usage and loading rate are a function of this quality and overall plant flow. In an effort to provide consistency in this effort, steps were taken to assure repetitive sampling and backwash conditions. I've listed our proposal below which we followed through the project period.

*Sampling*

*Based on this criteria, our proposal would be to sample influent and effluent from this GAC filter under controlled flow conditions which would equal 15 minute EBCT, (5 MGD filter flow). The filter would then be put into general service until the next sampling event. To assure steady state flow conditions, the filter would be held at this flow rate at least 4 hours prior to sampling. With this sampling protocol, and cumulative measurement of flow through the filter, overall filter loading and GAC usage rate can be determined.*

*Sample frequency will be difficult to determine based on the 3 --> 7% criteria shown in table 4.0. However, based on past monitoring of these filters, it would seem prudent to concentrate sampling initially, with longer periods between samples as the carbon ages and reaches steady state. I have attached two TOC breakthrough curves for these filters, which indicate that some rate of breakthrough occurs immediately with steady state being achieved in about 60 - 90 days. For this reason, I am proposing that we sample twice a week for the first month and once a week for the period thereafter up till the point where we agree that steady state has been reached. This should be minimum of 15 sample periods as suggested in the ICR manual.*

A significant implication of this proposal also reflects that filter flow rate be used to determine the number of bed volumes which were treated at the time of each sample. Bed volume calculations were performed in the spreadsheet analysis of data through the interpretation of flow totals for the WTP at that sample time. Specifically, this flow total data is entered for two separate flows which comprise the total WTP flow. These total flow numbers are a cumulative value set at zero on January 1 or each year. The bed volume numbers were calculated by systematically subtracting previous from current cumulative total, adding them together, and then dividing by three to produce a product which reflects the volume of water processed through the test filter; one third of the WTP total flow. Based on this calculation, the test filter processed over 7000 bed volumes during the period of the analysis.

Raw water quality, influent to the WTP is shown in table I. This plant influent data, compiled from the ICR, is typical of a soft, moderately colored New England lake system. Tables II and III show the quality of water entering the test filter, as an 18 month average, (ICR) and as a three month compilation of statistics from the test period. The water quality over the testing period was very consistent for temperature and general physical characteristics including color, and turbidity. Of note however is a step change in TOC which occurred about half way through the test period. The applied TOC went down approximately 0.5 ppm during sample period 10 taken on February 10 as a result of a change in coagulant. The primary coagulant during the first month of the study was polyaluminum chloride (PACl). This coagulant has no notable pH impact and coagulates at a pH of approximately 6.3, typical of our plant influent. Early in February, Manchester switched to alum. The resulting reduction in TOC is directly related to this change, as well as a change in pH during coagulation down to 5.8. We did see a marginal increase in turbidity, however as a result. An additional change in coagulant was made approximately two weeks later, when we began feeding a combination of PACl and alum with the logic that the alum would be used only to the extent that it would lower flocculation pH to 5.8. This combination produced the excellent turbidity reductions characteristic of PACl, along with the enhanced TOC removals seen at pH 5.8.

A review of the data with an eye towards breakthrough and what those conditions might mean is presented below. The SDS testing performed on this filter effluent provides some insight into what one might expect after 24 hours of disinfection by product formation. The criteria may be different for any specific set of DBP's or site, however this data presents the breakthrough as if this filter was a single adsorber in an application where it is the sole means for a utility to reach compliance with the Stage I criteria for TOC, TTHM's, and HAA6.

Carbon media details

The media studied in this project was a combination of Calgon filtrasorb 300 and MWW reactivated product. Manchester Water Works owns and operates an on site carbon reactivation facility which was originally studied and built with the aid of the US EPA. (Appendix III) This project, undertaken during the period of 1978 – 1983, looked at the ability of a utility to operate and support the day to day function of a carbon reactivation system. Specific areas of analysis included cost of operation, level of complexity, variability of product and comparison of product to virgin media. This later comparison aspect involved the evaluation of regenerated product vs newly purchased virgin product for removal of TOC, TTHM formation potential, and various physical-chemical parameters.

In 1997, a project to renovate the reactivation furnace structure and equipment was undertaken and its delayed completion and subsequent problems with startup of the renovated system significantly delayed our start date for this project. These restart problems ranged from issues developing as a result of improper operations to a failure of the newly placed refractory.

In the final analysis, MWW studied a filter which was composed of approximately 40% virgin and 60% reactivated material. The media was mixed within the filter and composite samples were analyzed for Iodine number and apparent density. Those results as reported previously were 741 mg/gm and 42.3 gm/100cm3, respectively.

| Criteria | Run Time | Bed Volumes |
|---|---|---|
| TTHM @ 80ppb | Not reached see note 1 | |
| TTHM @ 60ppb | Not reached see note 1 | |
| TTHM @ 50% SDS removal | 1200 hr | 4500 |
| HAA5 @ 60ppb | Not reached see note 2 | |
| HAA5 @ 40ppb | 2038 hr | 7400 |
| HAA5 @ 50% SDS removal | 2038 hr | 7400 |
| HAA6 @ 60ppb | Not reached see note 2 | |
| HAA6 @ 50% SDS removal | 2038 hr | 7400 |
| HAA6 @ 40ppb | 2038 hr | 7400 |
| TOC @ 2ppm | 2038 hr | 7400 |
| TOC @ 50% SDS removal | 1089 | 3900 |

**Table V - GAC Breakthrough benchmarks**

Notes:

1 – TTHM maximum value for SDS influent to filter was 39.3 ppb

2 - HAA5 and HAA6 maximum values for SDS influent to filter was 88 and 90 ppb respectively

## Section V: QA/QC Summary

In support of this project, all analytical methods were performed under strict QA/QC protocols. In addition, three sets of duplicate analyses were run, 4 weeks into the study, 8 weeks into the study, and at the end of the study at 12 weeks. These duplicates combined with adherence to standard protocols called out in the method procedures provide a well assured data base.

The data elements analyzed by both EE&T and MWW were the same essential elements and procedures conducted by both labs for the ICR. As such, the quality assurance protocols followed were based on the ICR criteria. For details of this protocol, reference the ICR data analysis protocol manual.

As required by this report, information regarding Method Reporting Limits (MRL) specific RPE, matrix and % recovery information based on PE sample performance is attached in the summary report spreadsheets.

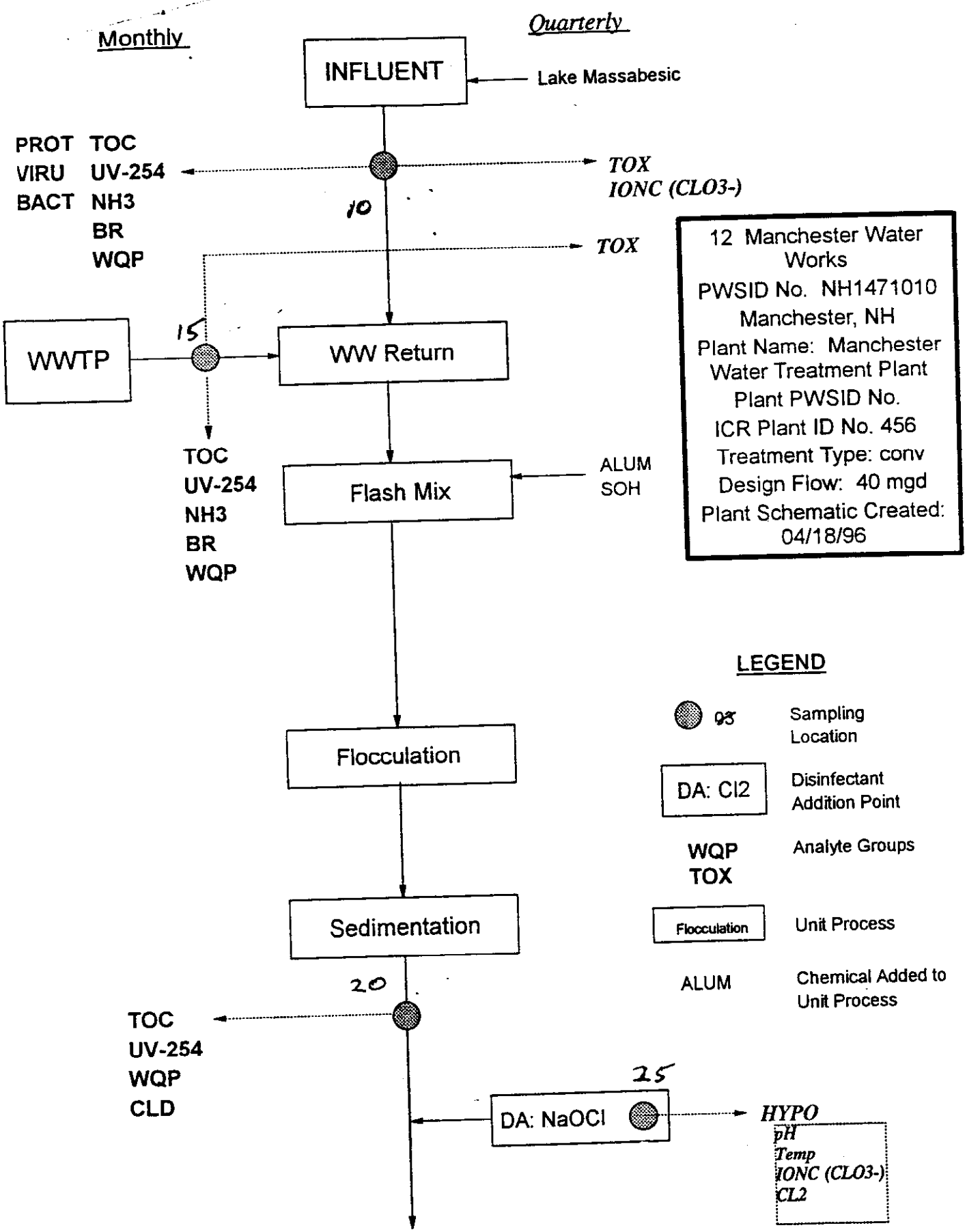
Analyses for laboratory duplicate analysis for DBP, Bromide and TOC testing is reflected in standard deviation statistics also reflected in the summary report spreadsheet. Specific procedural reference to calibration of equipment prior to and during the analytical protocol is based on laboratory Standard Operating Procedure (SOP's) which are available from the labs themselves.

Laboratory information regarding water quality testing performed by MWW laboratory is listed below.

| Analyte | Temperature | PH | Turbidity | Alkalinity | Total Hardness | Calcium Hardness | Chlorine Residual |
|---|---|---|---|---|---|---|---|
| Count | 14 | 14 | 14 | 14 | 14 | 14 | 14 |
| Average | 17.8 | 6.17 | 0.226 | 4.06 | 17.3 | 13.2 | 0.94 |
| Std Dev | 0.051 | 0.012 | 0.022 | 0.458 | 1.23 | 1.78 | 0.041 |
| MDL | 0.135 | 0.032 | 0.058 | 1.20 | 3.23 | 4.66 | 0.108 |

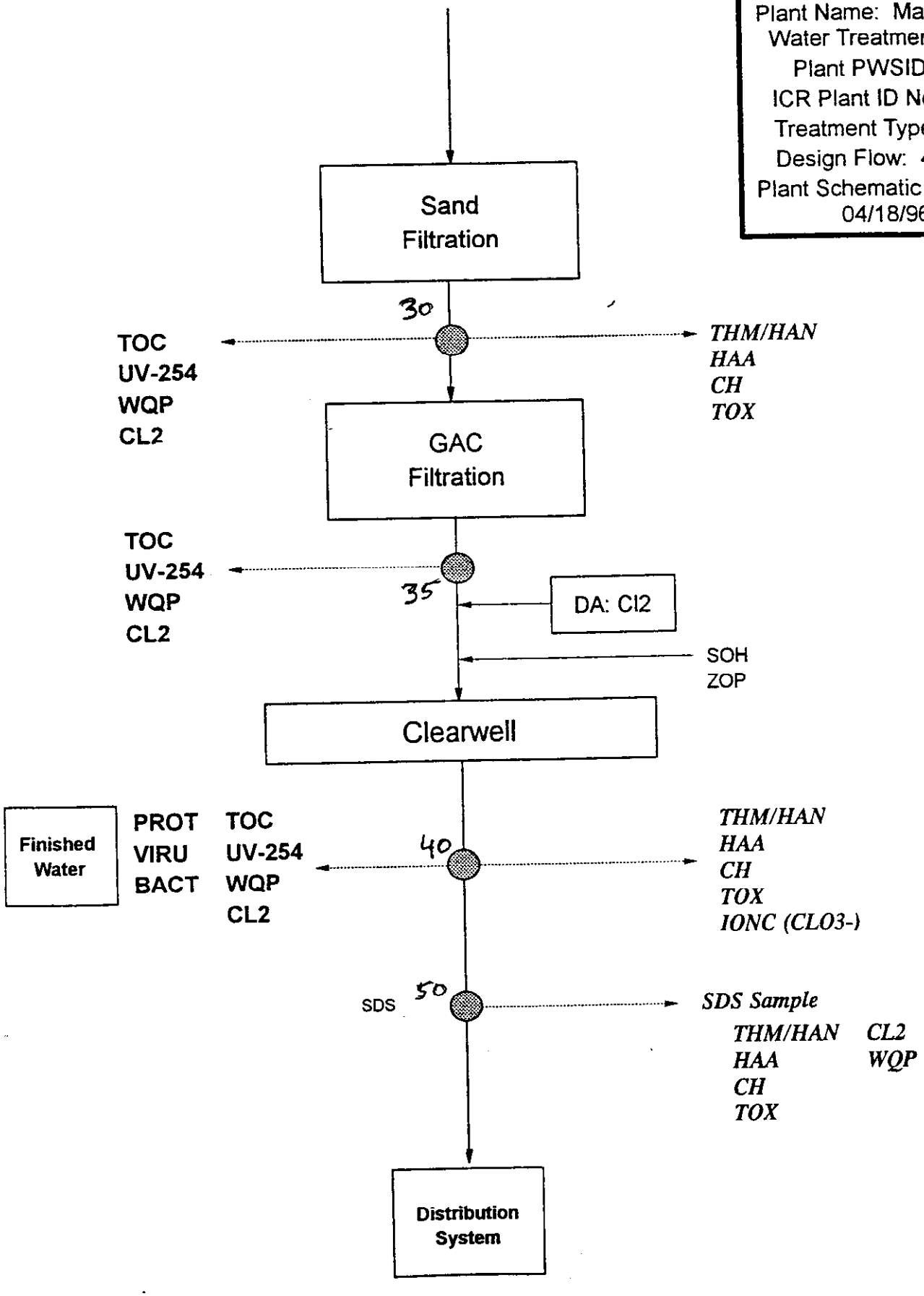
**Table VI – QA/QC information for Water Quality Parameters**

A II (1)


Monthly
Quarterly
INFLUENT
Lake Massabesic
PROT TOC
VIRU UV-254
BACT NH3
BR
WQP
TOX
IONC (CLO3-)
10
TOX
WWTP
15
WW Return
TOC
UV-254
NH3
BR
WQP
Flash Mix
ALUM
SOH
12 Manchester Water Works
PWSID No. NH1471010
Manchester, NH
Plant Name: Manchester Water Treatment Plant
Plant PWSID No.
ICR Plant ID No. 456
Treatment Type: conv
Design Flow: 40 mgd
Plant Schematic Created: 04/18/96
Flocculation
Sedimentation
20
TOC
UV-254
WQP
CLD
25
DA: NaOCl
HYPO
pH
Temp
IONC (CLO3-)
CL2
LEGEND
Sampling Location
DA: Cl2
Disinfectant Addition Point
WQP
TOX
Analyte Groups
Flocculation
Unit Process
ALUM
Chemical Added to Unit Process

A IT (2)

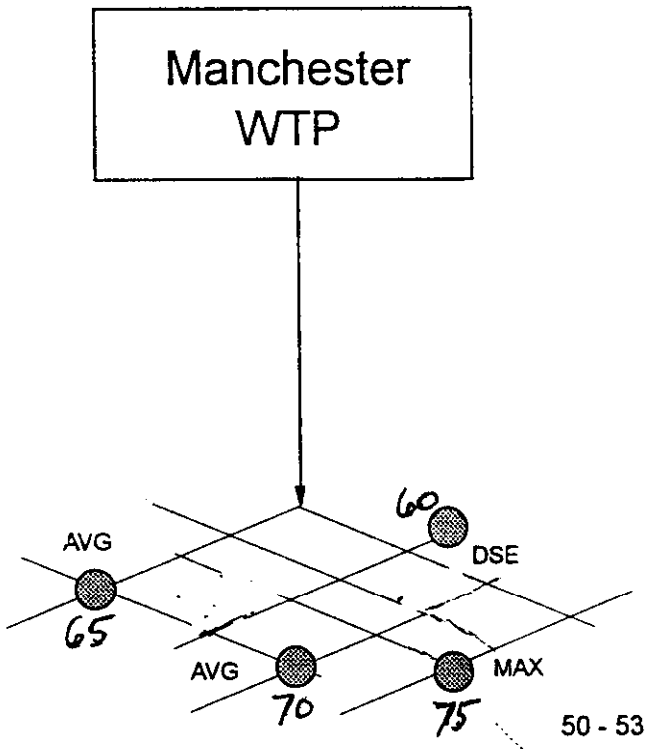
12 Manchester Water Works
PWSID No. NH1471010
Manchester, NH
Plant Name: Manchester Water Treatment Plant
Plant PWSID No.
ICR Plant ID No. 456
Treatment Type: conv
Design Flow: 40 mgd
Plant Schematic Created: 04/18/96



A II (3)

12 Manchester Water Works
PWSID No. NH1471010
Manchester, NH
System Schematic Created:
03/06/96

*Quarterly*




*THM/HAN* *CL2*
*HAA* *WQP*
*CH*
*TOX*

**LEGEND**

| | |
|---|---|
| 50 - 53 | Sampling Locations |
| DSE | Distribution System Equivalent--Corresponds to SDS Residence Time |
| AVG | Average Residence Time in the Distribution System |
| MAX | Maximum Residence Time in the Distribution System |

United States
Environmental Protection
Agency

Municipal Environmental Research
Laboratory
Cincinnati OH 45268

Research and Development

EPA-600/S2-83-104 Feb. 1984

EPA

# Project Summary

# Granular Activated Carbon Adsorption and Fluid-Bed Reactivation at Manchester, New Hampshire

David Kittredge, Robert Beaurivage, and David Paris

This study was designed to evaluate the actual cost and performance of a fluidized-bed, granular activated carbon (GAC) reactivation system, a semiautomatic GAC transport system, and a GAC water treatment system at the Manchester Water Works, Manchester, New Hampshire.

GAC performance was monitored in one of the utility's four 38,000-$m^3$/day (10-mgd) GAC filters to obtain an initial performance comparison of virgin carbon and reactivated 5-year-old service carbon. This filter was divided at its midpoint and then operated and monitored until a steady-state condition was achieved in both filter media studied. Two additional reactivation runs were conducted on this same GAC, providing performance data over three full reactivation-exhaustion cycles. For a portion of the study, the GAC filter medium was educted through a semiautomatic transport system retrofitted to the existing filters. Operation of this semiautomatic system proved to be unreliable, however, and was subsequently abandoned and replaced by a handheld eductor system. GAC from the three remaining plant filters was also reactivated to obtain additional performance data and to restore the adsorptive capacity of the spent service carbon.

Treatment performances of the virgin and reactivated GAC were evaluated during each cycle by measuring total organic carbon (TOC), trihalomethanes (THM), and trihalomethane formation potential (THMFP). GAC adsorptive capacity was also measured using traditional test parameters including iodine number, molasses decolorizing index, Brunauer-Emmett-Teller (BET), and pore-size distribution analyses.

With the cooperation of three regional water utilities, a short-term program of regional reactivation was also investigated. The actual costs and feasibility of transporting and reactivating GAC from these utilities were determined.

*This Project Summary was developed by EPA's Municipal Environmental Research Laboratory, Cincinnati, OH, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).*

## Introduction

In keeping with the research goals of the Safe Drinking Water Act (Public Law 93-523), the U.S. Environmental Protection Agency (EPA) and the Manchester Water Works (MWW) entered into a cooperative agreement to evaluate the cost and performance of a fluidized-bed, GAC reactivation system plus related facilities at the Manchester Water Treatment Plant. GAC effectiveness was assessed before and after reactivation, and GAC reactivation for other water utilities in New England was calculated on a limited basis. All of the work associated with this project was done under actual operating conditions using full-scale water treatment equipment.

On completion of the water treatment plant in 1974, MWW officials began

investigating alternatives for reactivation or replacement of approximately 432,592 kg (500 tons) of GAC used at the 151,000-$m^3$/day (40-mgd) water treatment facility. Results of this investigation demonstrated that onsite reactivation was the most cost-effective method of restoring the adsorptive properties of spent GAC for the conditions studied.

Water treatment at Manchester consists of flash mixing followed by flocculation, sedimentation, and series filtration through individual beds of sand and GAC filter media. Raw water is obtained from a naturally occurring, highly protected surface supply (Lake Massabesic), which contains no volatile organics but occasionally has high color plus taste and odor as a result of algae formation.

Since the research project spanned a period of nearly 5 years (July 1977 to April 1982), the investigation was divided into three major phases. Phase 1 involved the design, construction, and startup of the fluid-bed reactivation system (see Figure 1), semiautomatic carbon transport system, and laboratory monitoring facilities. One of the four GAC filters in the treatment plant called "the test filter" was half filled with virgin carbon and half with reactivated service carbon to compare GAC filter media. After about 90 days, exhausted GAC (as determined by TOC and THMFP) was removed from the filter, reactivated, and then reintroduced to the filter for another 90-day period of service and performance evaluation.

Phase 2 involved two more cycles of reactivation and repeated evaluation of the test filter. The three other GAC filters in the treatment plant were reactivated a total of five times to determine the operational performance capabilities of the reactivator and to develop reactivation cost data. Losses from both reactivation and transport of GAC were also studied.

After all the objectives of the first two phases were achieved, the third phase was undertaken to study the possibility of using the Manchester treatment facility as a regional reactivation center. The major objective of this program was to establish the economic feasibility of providing a future GAC reactivation service for other water utilities in the New England region. Approximately 18,144 kg (40,000 lb) of GAC from each of three separate utilities was reactivated and subsequently returned to service during 1982.

## Significant Findings

The Manchester research project demonstrated that onsite GAC reactivation at a medium-sized water treatment facility is feasible with regard to cost and operation. A fluid-bed reactivation furnace was shown to be a practical addition to a water treatment operation, provided that a properly trained, full-time work force is available to operate and maintain the equipment. During the 10 months from June 1980 to March 1981, more than 1.8 million lb of GAC was reactivated at a total cost of less than 22¢/lb (see Table 1) as compared with a delivered cost of 61.5¢/lb for virgin GAC.

Analytical research showed that without exception, fluidized-bed reactivation of spent GAC is an effective means of restoring its overall adsorptive capacity. The adsorptive performance of GAC reactivated once, twice, or three times equaled and in most cases surpassed the performance levels of virgin carbon.

GAC losses were the largest single cost item in the economic evaluation of onsite carbon reactivation. Consequently, accurate measurement of such losses received considerable attention during the research program. Data gathered at controlled test sites revealed that the average total carbon loss resulting from transportation and reactivation over five reactivation cycles was 11.5% by volume.

Other areas of investigation concerned the physical processes of the fluid-bed reactivator. Off-gas samples were collected to determine compliance with State air emission standards. Results demonstrated that the fluid-bed unit was discharging less than 0.045 kg/hr (0.1 lb/hr) of particulate matter to the atmosphere, compared with an allowable State standard of 0.779 kg/hr (1.73 lb/hr). A stack analysis for volatile organics revealed that only chloroform was detected in the off-gas.

The research project had two distinct periods of operation: the first 14 months, which involved frequent equipment startup problems, and the following 10 months, which were characterized by very successful reactivation operation. The major problem of the first period was a lack of equipment efficiency because of frequent mechanical and electrical difficulties. The operating factor of the reactivation furnace was approximately 30% over this initial period of operation. An expenditure of roughly $100,000 was required to modify the reactivator equipment for successful operation. As a result, the operating factor of the equipment was improved to a level of about 75%.

Use of the carbon transport equipment was eventually abandoned because of incompatibility with existing filter opera-

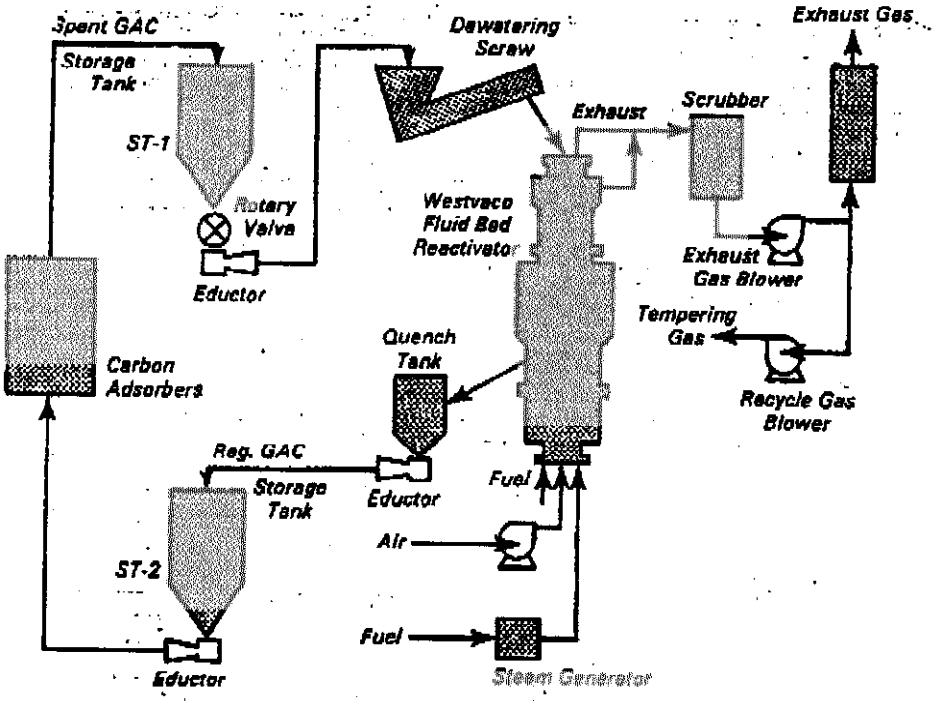



*Figure 1. Process flow for GAC reactivation system at Manchester, New Hampshire.*

*Table 1. Manchester Water Works Reactivation Costs, June 1980 Through March 1981**

| Cost Item | Cost/kg (¢) | Cost/lb (¢) |
|---|---|---|
| Makeup carbon | 15.59 | 7.07 |
| Labor for reactivation | 4.28 | 1.94 |
| Labor for transportation | 0.62 | 0.28 |
| Labor for laboratory | 0.11 | 0.05 |
| Labor for administration | 2.91 | 1.32 |
| Parts and service calls | 5.87 | 2.67 |
| Fuel oil | 4.92 | 2.23 |
| Electrical power | 1.10 | 0.50 |
| Water | 1.63 | 0.74 |
| Laboratory supplies and outside analyses | 0.11 | 0.05 |
| Depreciation | 4.70 | 2.13 |
| Overhead | 6.08 | 2.76 |
| TOTAL | 47.92 | 21.74 |

*Based on reactivation of 842,401 kg (1,857,176 lb) of GAC.

tion, poor reliability, excessive maintenance, and unacceptable removal of filter media. A manually operated hose and eductor system was then substituted and used successfully to transport GAC between the filters and reactivation building.

Because of the success of the research program, the Manchester facility was investigated for use as a regional reactivation center. This final research effort demonstrated that MWW could economically provide a GAC reactivation service for other water utilities in the New England region. The combined average reactivation cost was 49.5¢/lb.

The full report was submitted in fulfillment of Cooperative Agreement No. CR805371 by the Manchester Water Works under the sponsorship of the U.S. Environmental Protection Agency.

*David Kittredge, Rober Beaurivage, and David Paris are with the Manchester Water Works, Manchester, NH 03103.*
***Ben W. Lykins, Jr., is the EPA Project Officer (see below).***
*The complete report, entitled "Granular Activated Carbon Adsorption and Fluid-Bed Reactivation at Manchester, New Hampshire," (Order No. PB 84-110 238; Cost: $25.00, subject to change) will be available only from:*
*National Technical Information Service*
*5285 Port Royal Road*
*Springfield, VA 22161*
*Telephone: 703-487-4650*
*The EPA Project Officer can be contacted at:*
*Municipal Environmental Research Laboratory*
*U.S. Environmental Protection Agency*
*Cincinnati, OH 45268*

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**Table 4-0. Sampling of GAC Pilot-scale Systems**

| Sampling Point | Analyses | Sample Frequency[3,4] |
|---|---|---|
| GAC Influent | pH, alkalinity, turbidity, temperature, total & calcium hardness, ammonia, bromide, TOC and $UV_{254}$. SDS[1] for THM4, HAA6, TOX, and chlorine demand. | A minimum of 15 samples taken at the same time as the samples for GAC effluent[5]. |
| GAC Effluent @ EBCT=10 min | pH, turbidity, temperature, ammonia[2], TOC and $UV_{254}$. SDS[1] for THM4, HAA6, TOX, and chlorine demand. | A minimum of 15 samples. One after one day, and thereafter at 3% to 7% increments of the average influent TOC. |
| GAC Effluent @ EBCT=20 min | pH, turbidity, temperature, ammonia[2], TOC and $UV_{254}$. SDS[1] for THM4, HAA6, TOX, and chlorine demand. | A minimum of 15 samples. One after one day, and thereafter at 3% to 7% increments of the average influent TOC. |

1 - SDS conditions are defined in Part 1, Section 4.6 of this document. Additional guidance is found in Section 6.0 of this Part.

2 - If present in the influent.

3 - More frequent effluent monitoring may be necessary in order to predict the 3% to 7% increments of average influent TOC.

4 - Three duplicate samples are required for the influent and the effluent at each EBCT.

5 - If columns for EBCT=10 min and EBCT=20 min are run simultaneously, then influent samples should be taken at the same sample frequency as that for GAC effluent at EBCT=20 min.

Post-it® Fax Note 7671 | Date | # of pages ▶ 11
To Stuart Hooper | From
Co./Dept. | Co.
Phone # | Phone #
Fax # | Fax #

**Manchester W**
1581 LAKE SHORE RD. MA
PHONE 624-6482 FAX 628-6[redacted]

**to:** Steve Algeier
**from:** Dave Paris
**subject:** Response to memo of Dec. 16, 1997 regarding ICR Treatment Study Plan
**date:** January 9, 1998

In response to your comments concerning our study plan for a GAC contactor analysis, I offer the following solutions:

1. Concerning the addition of Cl2 prior to GAC. Manchester practices a prechlorine addition point located at our sedimentation basin effluent. The dosage of Chlorine applied at this point is regulated to provide no more than a trace of residual at the influent to the GAC filters. However there is sufficient time to form some DBP's during the sand filtration process. For THM's this quantity is usually less than 10 ppb. However, as you point out, this quantity of DBP formation prior to SDS inoculation may produce a somewhat higher result.

   I am reluctant to assume that the water quality prior to sand filtration and chlorination would be a suitable substitute for sand filtered water, without some form of turbidity removal. This approach might entail sampling prior to prechlorination, filtering out carryover turbidity with a fluted and washed Whatman paper filter and then using the product from this course filtration step to provide the basis for the GAC influent SDS sampling. I feel this protocol will provide a reasonable method to address your concerns over confounding due to the prechlorine step.

2. We will provide the replicate sampling as requested.

3. Data submission can be done electronically as you propose, however, the use of Lotus based spreadsheets rather than Excel would be preferred.

4. Volume of filter flow will be extracted from our SCADA records based on the overall daily flows for the WTP and what fraction of that flow is attributable to this filter. This should not be a problem to quantify quite accurately. I do feel that sampling must occur under a standard set of conditions for the filter which will be 15 minute EBCT in every case.

5. The cost information which I can provide most accurately will be related to operational costs. As you are aware, the cost of GAC operation is related to carbon replacement frequency and this frequency varies with what you are trying

to achieve. For DBP precursor control, carbon usage rate or replacement frequency will directly related to the quantitative level where we agree that the GAC is no longer useful for this overall purpose. My point is that depending on the criteria, the cost of operation can be varied substantially, especially when the criteria is not clearly defined. It is this type of problem that plagues the overall discussion of GAC costs. I believe that we can work this out, with information developed on the cost of replacing the carbon through onsite reactivation providing the basis. In so far as developing costs on the capital investment necessary to build GAC filters, all I can provide is the 1974 costs of our facility, or an engineering estimate, whichever is preferred. We will be happy to provide either or both sets of costs as requested.

Steve, I hope that this satisfies the issues presented in your memo. As I mentioned, it will be sometime in March before we achieve reactivation of a filter full of GAC. I will be in touch with you prior to our startup.

Cc: Dave Miller, Cheryl Wood, MWW

# facsimile

TRANSMITTAL

[redacted]

to: Dave Paris

fax #: 603-628-6030

re: ICR Treatment Study Plan

date: December 16, 1997

pages: 1, including this cover sheet.

From the desk of...

Steven C. Allgeier
U.S. EPA OGWDW-TSC
26 W. Martin Luther King Drive
Cincinnati, Ohio 45268

513-569-7131
Fax: 513-569-7191

Dave, thank you for the submission of a plan for a full-scale GAC treatment study. However, there are some issues that we should address prior to approve of this study plan. Please provide clarification / additional information on these issues in a fax (513-569-7191) or a letter to EPA. If you have any questions please call me at 513-569-7131.

1. The addition of chlorine prior to the GAC contactor could complicate the interpretation of the SDS test results. I have thought of two ways to mitigate the impact of chlorine on the SDS test results. (1) Start the SDS test (i.e., dose the SDS samples with chlorine) as soon as possible after collection of influent and effluent samples from the GAC contactor. This will minimize the levels of DBPs that could form during sample storage. (2) Collect the influent sample upstream of the chlorine addition point; thus avoiding the potential problems of DBP formation occurring during sample storage. This approach assumes that the water quality of the sed basin effluent is comparable that of the GAC influent (excluding turbidity), and that the effluent from the GAC contactor does not contain a chlorine residual. If one of these approaches is acceptable, or if you have another approach, please let me know.
2. In addition to collecting 15 influent and effluent samples we request that you collect 3 duplicate influent samples and 3 duplicate effluent samples as described in the ICR Manual for Bench- and Pilot-Scale Treatment Studies. These samples will be used for QA/QC.
3. We would like you to use the *ICR Treatment Study Data Collection Spreadsheets* to capture most of the raw data from your study. These Excel based spreadsheets were mailed to affected utilities in June of 1997. If you did not receive these spreadsheets or need them in another version (i.e., Lotus), please let me know. You may need to modify these spreadsheets slightly to accommodate the reporting requirements for a full-scale study.
4. In your plan you propose to control the flow conditions in the test filter to achieve a 15 minute EBCT during sampling events. This is acceptable, but I'm not sure that it is critical to the interpretation of the results. I think it is more important to track the variations in the EBCT and the cumulative volume of water processed on a frequent basis (i.e., daily, twice per day?).
5. I wanted to clarify our request for cost information for your full-scale GAC process. What we are looking for is an estimate of the cost of constructing and operating a post filter GAC adsorber for DBP precursors removal. This may be what you have in mind, but I wanted to make sure that we have the same understanding of the costs that EPA is interested in obtaining.

# MANCHESTER WATER WORKS

1581 LAKE SHORE ROAD, MANCHESTER, NEW HAMPSHIRE 03109 Tel. (603) 624-6482
Fax (603) 628-5030

December 4, 1997

Mr. Steve Allgeier, Environmental Engineer
ICR Precursor Removal Studies Coordinator
US Environmental Protection Agency
26 W. Martin Luther King Drive
Cincinnati, Ohio 45268

Dear Steve:

As a follow up to our conversation of Thursday December 4, I would formally propose that Manchester perform a full scale study of GAC performance following reactivation of our filter #3. This reactivation, as well as the reactivation of filters #4 & #1 is scheduled for winter-spring of 1998. Reactivation will take about one month for each filter, and will begin on or about February 1, following completion of renovations to our reactivation system. The protocol adopted for this evaluation would be based on table 4.0 of Section 2 of the ICR pilot scale testing manual.

## Sampling

Based on this criteria, our proposal would be to sample influent and effluent from this GAC filter under controlled flow conditions which would equal 15 minute EBCT, (5 MGD filter flow). The filter would then be put into general service until the next sampling event. To assure steady state flow conditions, the filter would be held at this flow rate at least 4 hours prior to sampling. With this sampling protocol, and cumulative measurement of flow through the filter, overall filter loading and GAC usage rate can be determined.

Sample frequency will be difficult to determine based on the 3 --> 7% criteria shown in table 4.0. However, based on past monitoring of these filters, it would seem prudent to concentrate sampling initially, with longer periods between samples as the carbon ages and reaches steady state. I have attached two TOC breakthrough curves for these filters, which indicate that some rate of breakthrough occurs immediately with steady state being achieved in about 60 - 90 days. For this reason, I am proposing that we sample twice a week for the first month and once a week for the period thereafter up till the point where we agree that steady state has been reached. This should be minimum of 15 sample periods as suggested in the ICR manual.

## Analysis

Analytes studied will be based on table 4.0, and testing will be performed by our ICR lab, EE&T, with the following exceptions to be run at Manchester; pH, turbidity, temperature, and chlorine demand. Certain samples of this testing will be duplicative of the current ICR protocol, (GAC influent) and will be timed to coincide with this effort. Manchester will supplement this protocol with physical GAC testing for apparent density and iodine #, to provide a reference to the adsorption capacity of the GAC vs its performance for TOC removal.

## Reporting

I'd anticipate the final report for this study to graphically compile breakthrough information for TOC, UV 254, HAA and TOX. I'd also propose to assemble the carbon loading and removal in terms of a carbon usage rate graphic, specifically with regards to TOC. All results will be compiled in a single report with spreadsheet summaries of data and graphics. (Lotus 5.1)

Additionally, cost information regarding the use of GAC here in Manchester will also be reported, as requested. These costs will reflect the use of on site carbon regeneration, and will be essentially an update of the costs reported in our 1984 report.

I've attached the TOC breakthrough curves as previously mentioned, as well as tables 5-1 and 5-11 to comply with data requests in the manual. I've also enclosed our WTP brochure which provides basic plant process and engineering information on the Manchester facility. The last attachment is the summary of our final report done in conjunction with the USEPA sponsored regeneration project in 1984.

I trust that this approach will be acceptable to the agency and meet the requirements of the unit testing portion of the ICR. We appreciate EPA's willingness to allow Manchester to perform full scale studies. Our experience with monitoring these contactors will hopefully be of value to the development of some useful applied data. Please feel free to give me a call if you have any questions or concerns regarding the plan.

Sincerely yours,

Dave Paris
Water Supply Division Manager

cc: Thomas Bowen PE, Director
Robert Beaurivage PE, Asst. Director
David Miller PE, Water Supply Engineer

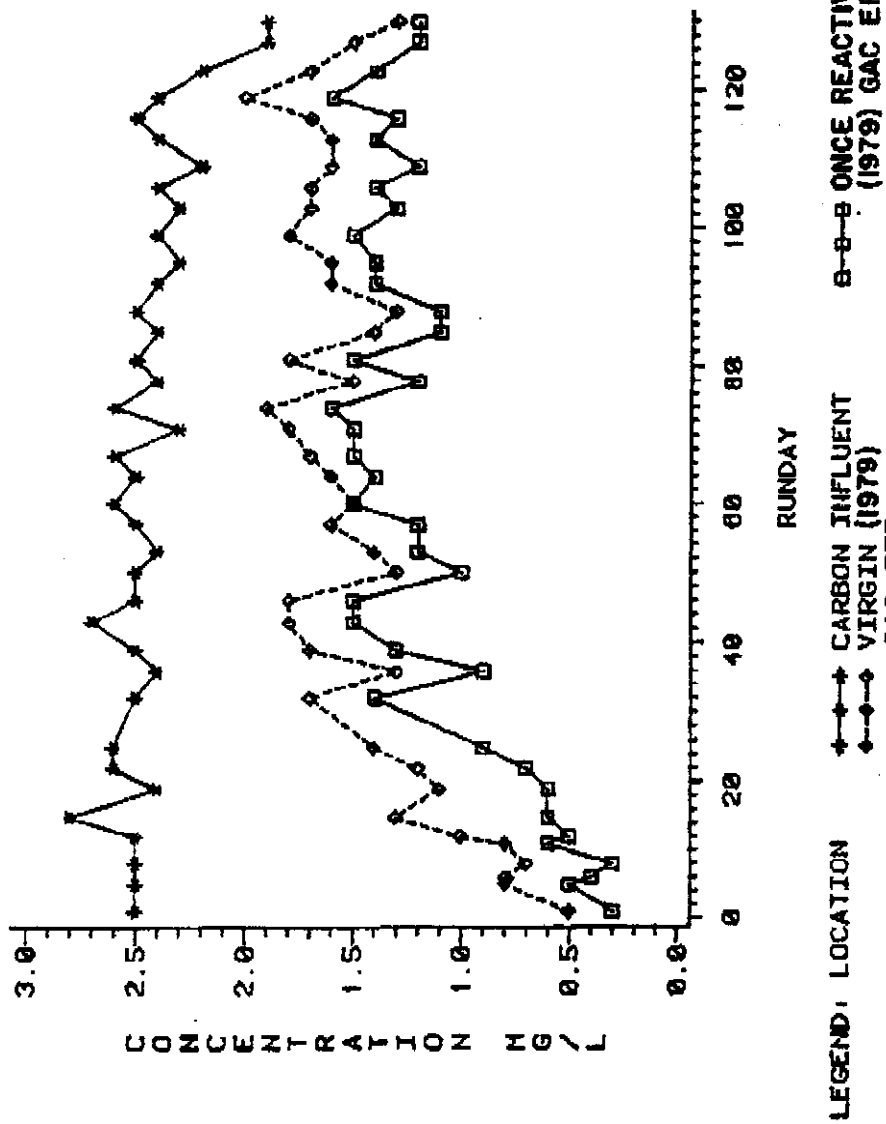


Figure 67. Run 1.—Test filter TOC breakthrough curves.

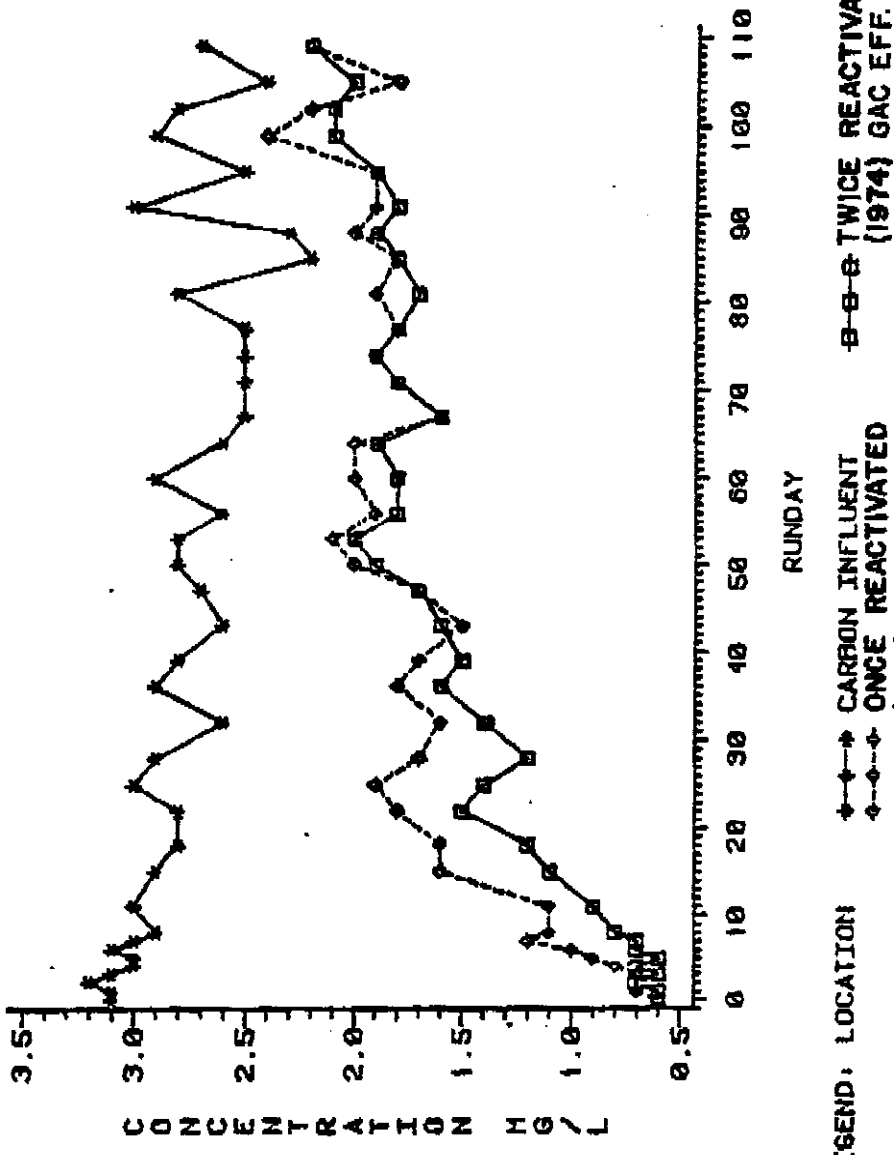


Figure 68. Run 2.—Test filter TOC breakthrough curves.