JOHN N. HUGHES
Attorney at Law
Professional Service Corporation
124 West Todd Street
Frankfort, Kentucky 40601

Telephone: (502) 227-7270 jnhughes@fewpb.net **Telefax (502) 875-7059**

April 15, 2010

RECEIVED
APR 15 2010
PUBLIC SERVICE
COMMISSION

Jeff Derouen
Executive Director
Public Service Commission
211 Sower Blvd.
Frankfort, KY40601

Re: Northern Kentucky Water District
Case No. 2010-0038

Dear Mr. Derouen:

Northern Kentucky Water District has been asked by the Staff to provide additional information about the design elements of the Memorial Parkway Treatment Plant. Attached is a copy of the GRW Engineers Design Report and supplemental documentation of the value of ultraviolet treatment. Because levels of Crypto and Giardia can change throughout the year, the addition of UV to our treatment plants is an important extra barrier against Crypto and Giardia to protect the public drinking water.

This information provides additional support for the design of the facility and the treatment options that have been recommended by the consulting engineers as well as the District's engineering staff.

Because the bids on this project expire on April 18th, the District urges the Commission to act as quickly as possible to approve this project and the companion project - Case No. 2010-0094. As you are well aware, the bids are substantially below the original cost estimates. If the projects have to be re-bid, the cost may increase significantly, which will increase the cost to our customers. Additionally, the 24 month construction schedule is very time sensitive as explained in Richard Harrison's recent letter.

If there is additional information that the District can provide to resolve these last minute issues, please let me know.

Very truly yours,

John N Hughes

John N. Hughes
Attorney for Northern Kentucky
Water District

Table 1-3.
Compliance Strategies

Approach	Minimum	Moderate	Aggressive
Percent of MCL Permitted for LRAA	100%	80%	60%
Target Maximum TTHM Value on LRAA Basis (µg/L)	80	64	48
Target Maximum HAA5 Value on LRAA Basis (µg/L)	60	48	36

1.4. Summary of Reviewed Compliance Strategies

Prior to beginning the Preliminary Design of GAC Systems Project, NKWD explored many compliance strategies for organics removal at all three treatment plants. Table 1-4 summarizes the strategies that have been investigated to date.

Table 1-4.
Summary of Reviewed Compliance Strategies for Organics Removal

Treatment Type	Description	Disadvantages	Is Treatment Strategy Effective for NKWD?
Riverbank Infiltration	Drill well near river (natural filtration)	Geology is not right in the area, very costly	NO
Powered Carbon	Add chemical	Cannot add enough carbon to be effective	NO
Actiflo®	Sand aids organic removal	Process alone does not remove enough organics	NO
Enhanced Coagulation[1]	Lower pH to aid in organics removal	Process alone does not remove enough organics	NO
Membranes[2]	Tightly woven mesh in large cartridges	Very expensive, pilot studies show bacteriological buildup	NO
Granular Activated Carbon	Additional filters in treatment process filled with carbon	Carbon needs to be regenerated, facility has large footprint1	YES
MIEX®[3]	Use resin to take out organics (similar to Actiflo®)	Only a few locations in US, discharge is a problem, a proprietary process, was not effective at TMTP	NO

Notes: 1. Enhanced coagulation study was completed in July 2007 by CDM.
2. Membranes study was completed in 2004 by B&V.
3. MIEX pilots were completed in 2001 and 2007 by B&V and NKWD..

Based on the past studies, GAC appears to be the most feasible strategy that will enable NKWD to comply with the upcoming Stage 2 D/DBP Rule for the FTTP and the MPTP. For the TMTP, several treatment strategies may be available and were reviewed as part of this project, including:

- Add MIEX for DOC removal
- Blend TMTP water with FTTP GAC treated water
- Add GAC for TOC removal

This report reviews the compliance alternatives for the TMTP and summarizes the design criteria for the selected compliance strategy for FTTP, MPTP and the TMTP. The TMTP strategies are reviewed in Section 2 of this report.

1.5. UV Disinfection

Contingencies for including a UV disinfection facility at each of the plants was included as part of this project. The Long-Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR), which will be finalized soon by the EPA, will require some WTPs to implement additional treatment to achieve certain levels of removal/inactivation of *Cryptosporidium* depending on their source water *Cryptosporidium* concentrations. Current knowledge of NKWD water quality indicates that *Cryptosporidium* detections are low and that additional treatment is not likely to be required. However, in the event that regulatory requirements or source water quality characteristics change, or if the District desires to add an additional microbial barrier to the WTP process, UV disinfection is a cost-effective treatment alternative approved for *Cryptosporidium* removal/ inactivation by LT2ESWTR.

USEPA Method 1623 for *Giardia* and *Cryptosporidium*

Sample	Collection Date	Analyte	Total Microscopic Count/Volume examined	Calculated #/L	Bin No.
FT. Thomas Raw Water	2/13/2002	*Giardia*	6	0.6	
		Cryptosporidium	1	0.1	2
Taylor Mill Raw Water	2/20/2002	*Giardia*	0	0	
		Cryptosporidium	0	0	1
Taylor Mill Raw Water	4/16/2002	*Giardia*	1	0.1	
		Cryptosporidium	0	0	1
FT. Thomas Raw Water	4/24/2002	*Giardia*	8	1	
		Cryptosporidium	1	0.1	2
Taylor Mill Raw Water	9/9/2002	*Giardia*	1	0.1	
		Cryptosporidium	0	0	1
Memorial Pkwy. Raw Water	10/1/2002	*Giardia*	0	0	
		Cryptosporidium	0	0	1
FT. Thomas Raw Water	10/29/2002	*Giardia*	2	0.2	
		Cryptosporidium	0	0	1

FT. Thomas Raw Water	4/29/2003	*Giardia*	0	0	
		Cryptosporidium	0	0	1
Taylor Mill Raw Water	4/29/2003	*Giardia*	0	0	
		Cryptosporidium	0	0	1
Memorial Pkwy. Raw Water	4/29/2003	*Giardia*	0	0	
		Cryptosporidium	0	0	1

FT. Thomas Raw Water	5/28/2003	*Giardia*	0	0	
		Cryptosporidium	0	0	1
Taylor Mill Raw Water	5/28/2003	*Giardia*	0	0	
		Cryptosporidium	0	0	1
Memorial Pkwy. Raw Water	5/28/2003	*Giardia*	0	0	
		Cryptosporidium	0	0	1
FT. Thomas Raw Water	6/24/2003	*Giardia*	1.0	0.1	
		Cryptosporidium	0	0	1
Taylor Mill Raw Water	6/24/2003	*Giardia*	1.0	0.1	
		Cryptosporidium	0	0	1
Memorial Pkwy. Raw Water	6/24/2003	*Giardia*	0	0	
		Cryptosporidium	0	0	1
FT. Thomas Raw Water	7/29/2003	*Giardia*	0	0	
		Cryptosporidium	0	0	1
Taylor Mill Raw Water	7/29/2003	*Giardia*	0	0	
		Cryptosporidium	0	0	1
Memorial Pkwy. Raw Water	7/29/2003	*Giardia*	0	0	
		Cryptosporidium	0	0	1
FT. Thomas Raw Water	8/27/2003	*Giardia*	0	0	
		Cryptosporidium	0	0	1
Taylor Mill Raw Water	8/26/2003	*Giardia*	1.0	0.1	
		Cryptosporidium	0	0	1

Memorial Pkwy. Raw Water	8/26/2003	*Giardia*	0	0	
		Cryptosporidium	0	0	1
FT. Thomas Raw Water	9/23/2003	*Giardia*	0	0	
		Cryptosporidium	0	0	1
Taylor Mill Raw Water	9/23/2003	*Giardia*	2.0	0.2	
		Cryptosporidium	0	0	1
Memorial Pkwy. Raw Water	9/23/2003	*Giardia*	0	0	
		Cryptosporidium	0	0	1
FT. Thomas Raw Water	10/28/2003	*Giardia*	1.0	0.1	
		Cryptosporidium	0	0	1
Taylor Mill Raw Water	10/28/2003	*Giardia*	0	0	
		Cryptosporidium	0	0	1
Memorial Pkwy. Raw Water	10/28/2003	*Giardia*	0	0	
		Cryptosporidium	0	0	1
FT. Thomas Raw Water	11/18/2003	*Giardia*	0	0	
		Cryptosporidium	0	0	1
Taylor Mill Raw Water	11/18/2003	*Giardia*	1.0	0.1	
		Cryptosporidium	1.0	0.1	2
Memorial Pkwy. Raw Water	11/18/2003	*Giardia*	0	0	
		Cryptosporidium	1.0	0.1	2
FT. Thomas Raw Water	12/16/2003	*Giardia*	4.0	0.4	
		Cryptosporidium	0	0	1

Taylor Mill Raw Water	12/16/2003	*Giardia*	4.0	0.4	
		Cryptosporidium	0	0	1
Memorial Pkwy. Raw Water	12/16/2003	*Giardia*	0	0	
		Cryptosporidium	0	0	1
FT. Thomas Raw Water	1/27/2004	*Giardia*	5.0	0.5	
		Cryptosporidium	0	0	1
Taylor Mill Raw Water	1/27/2004	*Giardia*	4.0	0.4	
		Cryptosporidium	0	0	1
Memorial Pkwy. Raw Water	1/27/2004	*Giardia*	0	0	
		Cryptosporidium	0	0	1
FT. Thomas Raw Water	2/24/2004	*Giardia*	2.0	0.2	
		Cryptosporidium	0	0	1
Taylor Mill Raw Water	2/24/2004	*Giardia*	0	0	
		Cryptosporidium	0	0	1
Memorial Pkwy. Raw Water	2/24/2004	*Giardia*	0	0	
		Cryptosporidium	0	0	1
FT. Thomas Raw Water	3/23/2004	*Giardia*	0	0	
		Cryptosporidium	0	0	1
Taylor Mill Raw Water	3/23/2004	*Giardia*	0	0	
		Cryptosporidium	0	0	1
Memorial Pkwy. Raw Water	3/23/2004	*Giardia*	0	0	
		Cryptosporidium	0	0	1
FT. Thomas Raw Water	4/26/2004	*Giardia*	0	0	

		Cryptosporidium	0	0	1
Taylor Mill Raw Water	4/26/2004	*Giardia*	2.0	0.38	
		Cryptosporidium	0	0	1
Memorial Pkwy. Raw Water	4/26/2004	*Giardia*	0	0	
		Cryptosporidium	0	0	1
FT. Thomas Raw Water	5/25/2004	*Giardia*	0	0	
		Cryptosporidium	0	0	1
Taylor Mill Raw Water	5/25/2004	*Giardia*	0	0	
		Cryptosporidium	0	0	1
Memorial Pkwy. Raw Water	5/25/2004	*Giardia*	0	0	
		Cryptosporidium	0	0	1
FT. Thomas Raw Water	6/29/2004	*Giardia*	0	0	
		Cryptosporidium	0	0	1
Taylor Mill Raw Water	6/29/2004	*Giardia*	0	0	
		Cryptosporidium	0	0	1
Memorial Pkwy. Raw Water	6/29/2004	*Giardia*	0	0	
		Cryptosporidium	0	0	1
FT. Thomas Raw Water	7/27/2004	*Giardia*	0	0	
		Cryptosporidium	0	0	1
Taylor Mill Raw Water	7/27/2004	*Giardia*	1.0	0.1	
		Cryptosporidium	1.0	0.1	2
Memorial Pkwy. Raw Water	7/27/2004	*Giardia*	0	0	
		Cryptosporidium	0	0	1

FT. Thomas Raw Water	8/23/2004	*Giardia*	0	0	
		Cryptosporidium	0	0	1
Taylor Mill Raw Water	8/23/2004	*Giardia*	0	0	
		Cryptosporidium	0	0	1
Memorial Pkwy. Raw Water	8/23/2004	*Giardia*	0	0	
		Cryptosporidium	0	0	1
FT. Thomas Raw Water	9/27/2004	*Giardia*	2.0	0.2	
		Cryptosporidium	0	0	1
Taylor Mill Raw Water	9/27/2004	*Giardia*	0	0	
		Cryptosporidium	0	0	1
Memorial Pkwy. Raw Water	9/27/2004	*Giardia*	0	0	
		Cryptosporidium	0	0	1
FT. Thomas Raw Water	10/26/2004	*Giardia*	0	0	
		Cryptosporidium	0	0	1
Taylor Mill Raw Water	10/27/2004	*Giardia*	1.0	0.1	
		Cryptosporidium	0	0	1
Memorial Pkwy. Raw Water	10/26/2004	*Giardia*	0	0	
		Cryptosporidium	0	0	1
FT. Thomas Raw Water	11/29/2004	*Giardia*	11.0	1.1	
		Cryptosporidium	2.0	0.2	2
Taylor Mill Raw Water	11/29/2004	*Giardia*	6.0	0.6	
		Cryptosporidium	3.0	0.3	2

Memorial Pkwy. Raw Water	11/29/2004	*Giardia*	0	0	
		Cryptosporidium	0	0	1
FT. Thomas Raw Water	12/27/2004	*Giardia*	1.0	0.1	
		Cryptosporidium	0	0	1
Taylor Mill Raw Water	12/28/2004	*Giardia*	3.0	0.3	
		Cryptosporidium	2.0	0.2	2
Memorial Pkwy. Raw Water	12/27/2004	*Giardia*	6.0	0.6	
		Cryptosporidium	0	0	1
FT. Thomas Raw Water	1/25/2005	*Giardia*	2.0	0.25	
		Cryptosporidium	0	0	1
Taylor Mill Raw Water	1/25/2005	*Giardia*	0	0	
		Cryptosporidium	0	0	1
Memorial Pkwy. Raw Water	1/25/2005	*Giardia*	0	0	
		Cryptosporidium	0	0	1
FT. Thomas Raw Water	2/28/2005	*Giardia*	3.0	0.29	
		Cryptosporidium	0	0	1
Taylor Mill Raw Water	2/22/2005	*Giardia*	0	0	
		Cryptosporidium	0	0	1
Memorial Pkwy. Raw Water	2/28/2005	*Giardia*	1.0	0.1	
		Cryptosporidium	0	0	1
FT. Thomas Raw Water	3/29/2005	*Giardia*	0	0	
		Cryptosporidium	0	0	1
Taylor Mill Raw Water	3/29/2005	*Giardia*	0	0	

		Cryptosporidium	0	0	1
Memorial Pkwy. Raw Water	3/29/2005	*Giardia*	0	0	
		Cryptosporidium	0	0	1
FT. Thomas Raw Water	4/26/2005	*Giardia*	0	0	
		Cryptosporidium	0	0	1
Taylor Mill Raw Water	4/26/2005	*Giardia*	1.0	0.1	
		Cryptosporidium	0	0	1
Memorial Pkwy. Raw Water	4/26/2005	*Giardia*	0	0	
		Cryptosporidium	0	0	1
FT. Thomas Raw Water	5/23/2005	*Giardia*	2.0	0.2	
		Cryptosporidium	0	0	1
Taylor Mill Raw Water	5/23/2005	*Giardia*	0	0	
		Cryptosporidium	0	0	1
Memorial Pkwy. Raw Water	5/23/2005	*Giardia*	0	0	
		Cryptosporidium	0	0	1
FT. Thomas Raw Water	6/27/2005	*Giardia*	0	0	
		Cryptosporidium	0	0	1
Taylor Mill Raw Water	6/27/2005	*Giardia*	0	0	
		Cryptosporidium	0	0	1
Memorial Pkwy. Raw Water	6/27/2005	*Giardia*	0	0	
		Cryptosporidium	0	0	1
FT. Thomas Raw Water	7/26/2005	*Giardia*	0	0	
		Cryptosporidium	0	0	1

Taylor Mill Raw Water	7/26/2005	*Giardia*	0	0	
		Cryptosporidium	0	0	1
Memorial Pkwy. Raw Water	7/26/2005	*Giardia*	0	0	
		Cryptosporidium	0	0	1
FT. Thomas Raw Water	8/22/2005	*Giardia*	0	0	
		Cryptosporidium	0	0	1
Taylor Mill Raw Water	8/22/2005	*Giardia*	0	0	
		Cryptosporidium	0	0	1
Memorial Pkwy. Raw Water	8/22/2005	*Giardia*	0	0	
		Cryptosporidium	0	0	1
FT. Thomas Raw Water	9/26/2005	*Giardia*	0	0	
		Cryptosporidium	0	0	1
Taylor Mill Raw Water	9/26/2005	*Giardia*	0	0	
		Cryptosporidium	2.0	0.2	2
Memorial Pkwy. Raw Water	9/26/2005	*Giardia*	0	0	
		Cryptosporidium	0	0	1
FT. Thomas Raw Water	10/24/2005	*Giardia*	1.0	0.1	
		Cryptosporidium	0	0	1
Taylor Mill Raw Water	10/24/2005	*Giardia*	0	0	
		Cryptosporidium	0	0	1
Memorial Pkwy. Raw Water	10/24/2005	*Giardia*	0	0	
		Cryptosporidium	0	0	1

FT. Thomas Raw Water	11/28/2005	*Giardia*	1.0	0.1	
		Cryptosporidium	0	0	1
Taylor Mill Raw Water	11/28/2005	*Giardia*	6.0	0.6	
		Cryptosporidium	0	0	1
Memorial Pkwy. Raw Water	11/28/2005	*Giardia*	0	0	
		Cryptosporidium	0	0	1
FT. Thomas Raw Water	12/27/2005	*Giardia*	1.0	0.1	
		Cryptosporidium	1.0	0.1	2
Taylor Mill Raw Water	12/27/2005	*Giardia*	0	0	
		Cryptosporidium	0	0	1
Memorial Pkwy. Raw Water	12/27/2005	*Giardia*	0	0	
		Cryptosporidium	1.0	0.1	2
FT. Thomas Raw Water	1/24/2006	*Giardia*	0	0	
		Cryptosporidium	0	0	1
Taylor Mill Raw Water	1/24/2006	*Giardia*	0	0	
		Cryptosporidium	0	0	1
Memorial Pkwy. Raw Water	1/24/2006	*Giardia*	0	0	
		Cryptosporidium	0	0	1
FT. Thomas Raw Water	2/27/2006	*Giardia*	2.0	0.18	
		Cryptosporidium	0	0	1
Taylor Mill Raw Water	2/27/2006	*Giardia*	0	0	
		Cryptosporidium	0	0	1
Memorial Pkwy. Raw Water	2/27/2006	*Giardia*	0	0	

		Cryptosporidium	0	0	1
FT. Thomas Raw Water	3/28/2006	*Giardia*	0	0	
		Cryptosporidium	0	0	1
Taylor Mill Raw Water	3/28/2006	*Giardia*	1.0	0.16	
		Cryptosporidium	0	0	1
Memorial Pkwy. Raw Water	3/28/2006	*Giardia*	0	0	
		Cryptosporidium	0	0	1
FT. Thomas Raw Water	4/25/2006	*Giardia*	1.0	0.09	
		Cryptosporidium	0	0	1
Taylor Mill Raw Water	4/25/2006	*Giardia*	0.0	0	
		Cryptosporidium	0	0	1
Memorial Pkwy. Raw Water	4/25/2006	*Giardia*	1.0	0.9	
		Cryptosporidium	0	0	1
FT. Thomas Raw Water	5/22/2006	*Giardia*	0	0	
		Cryptosporidium	0	0	1
Taylor Mill Raw Water	5/22/2006	*Giardia*	0.0	0	
		Cryptosporidium	1	0.09	2
Memorial Pkwy. Raw Water	5/22/2006	*Giardia*	0	0	
		Cryptosporidium	0	0	1
FT. Thomas Raw Water	6/27/2006	*Giardia*	0	0	
		Cryptosporidium	1	0.09	2
Taylor Mill Raw Water	6/27/2006	*Giardia*	1.0	0.09	
		Cryptosporidium	0	0	1

Memorial Pkwy. Raw Water	6/28/2006	*Giardia*	0	0	
		Cryptosporidium	0	0	1
FT. Thomas Raw Water	7/25/2006	*Giardia*	0	0	
		Cryptosporidium	0	0	1
Taylor Mill Raw Water	7/25/2006	*Giardia*	0	0	
		Cryptosporidium	0	0	1
Memorial Pkwy. Raw Water	7/25/2006	*Giardia*	0	0	
		Cryptosporidium	0	0	1
FT. Thomas Raw Water	8/29/2006	*Giardia*	0	0	
		Cryptosporidium	0	0	1
Taylor Mill Raw Water	8/29/2006	*Giardia*	0	0	
		Cryptosporidium	0	0	1
Memorial Pkwy. Raw Water	8/29/2006	*Giardia*	0	0	
		Cryptosporidium	0	0	1
FT. Thomas Raw Water	9/25/2006	*Giardia*	0	0	
		Cryptosporidium	0	0	1
Taylor Mill Raw Water	9/25/2006	*Giardia*	0	0	
		Cryptosporidium	1	0.27	2
Memorial Pkwy. Raw Water	9/25/2006	*Giardia*	0	0	
		Cryptosporidium	0	0	1
FT. Thomas Raw Water	10/23/2006	*Giardia*	0	0	
		Cryptosporidium	0	0	1

Taylor Mill Raw Water	10/23/2006	*Giardia*		0.11	
		Cryptosporidium		0.22	2
Memorial Pkwy. Raw Water	10/23/2006	*Giardia*	0	0	
		Cryptosporidium	0	0	1
FT. Thomas Raw Water	11/28/2006	*Giardia*		0.27	
		Cryptosporidium		0	1
Taylor Mill Raw Water	11/28/2006	*Giardia*		0.09	
		Cryptosporidium		0.09	2
Memorial Pkwy. Raw Water	11/28/2006	*Giardia*		0	
		Cryptosporidium		0.09	2
FT. Thomas Raw Water	12/18/2006	*Giardia*		0.09	
		Cryptosporidium		0	1
Taylor Mill Raw Water	12/18/2006	*Giardia*		0	
		Cryptosporidium		0	1
Memorial Pkwy. Raw Water	12/18/2006	*Giardia*		0	
		Cryptosporidium		0	1
FT. Thomas Raw Water	1/23/2007	*Giardia*		0.77	
		Cryptosporidium		0	1
Taylor Mill Raw Water	1/23/2007	*Giardia*		0	
		Cryptosporidium		0	1
Memorial Pkwy. Raw Water	1/23/2007	*Giardia*		0	
		Cryptosporidium		0	1
FT. Thomas Raw Water	5/23/2007	*Giardia*		0	

		Cryptosporidium	0	1
Taylor Mill Raw Water	5/22/2007	*Giardia*	0	
		Cryptosporidium	0	1
Memorial Pkwy. Raw Water	5/22/2007	*Giardia*	0	
		Cryptosporidium	0	1
FT. Thomas Raw Water	7/23/2007	*Giardia*	0	
		Cryptosporidium	0	1
Taylor Mill Raw Water	7/23/2007	*Giardia*	0	
		Cryptosporidium	0	1
Memorial Pkwy. Raw Water	7/23/2007	*Giardia*	0	
		Cryptosporidium	0	1
FT. Thomas Raw Water	11/27/2007	*Giardia*	0	
		Cryptosporidium	0	1
Taylor Mill Raw Water	11/27/2007	*Giardia*	0.44	
		Cryptosporidium	0.44	2
Memorial Pkwy. Raw Water	11/27/2007	*Giardia*	0	
		Cryptosporidium	0	1
FT. Thomas Raw Water	1/28/2008	*Giardia*	0.09	
		Cryptosporidium	0	1
Taylor Mill Raw Water	1/28/2008	*Giardia*	0	
		Cryptosporidium	0	1
FT. Thomas Raw Water	5/20/2008	*Giardia*	0.18	
		Cryptosporidium	0	1

Taylor Mill Raw Water	5/20/2008	*Giardia*	0.35	
		Cryptosporidium	0.18	2
Memorial Pkwy. Raw Water	5/20/2008	*Giardia*	0	
		Cryptosporidium	0	1
FT. Thomas Raw Water	8/26/2008	*Giardia*	0	
		Cryptosporidium	0	1
Taylor Mill Raw Water	8/26/2008	*Giardia*	0	
		Cryptosporidium	0	1
Memorial Pkwy. Raw Water	8/26/2008	*Giardia*	0	
		Cryptosporidium	0	1
FT. Thomas Raw Water	3/17/2009	*Giardia*	0	
		Cryptosporidium	0	1
Memorial Pkwy. Raw Water	3/17/2009	*Giardia*	0	
		Cryptosporidium	0	1
***Taylor Mill Shutdown**	**3/17/2009**			
FT. Thomas Raw Water	6/16/2009	*Giardia*	0	
		Cryptosporidium	0	1
Taylor Mill Raw Water	6/16/2009	*Giardia*	0	
		Cryptosporidium	0	1
Memorial Pkwy. Raw Water	6/16/2009	*Giardia*	0	
		Cryptosporidium	0	1
FT. Thomas Raw Water	11/17/2009	*Giardia*	0	

		Cryptosporidium	0	1
Taylor Mill Raw Water	11/17/2009	*Giardia*	0.09	
		Cryptosporidium	0	1
Memorial Pkwy. Raw Water	11/17/2009	*Giardia*	0	
		Cryptosporidium	0	1
FT. Thomas Raw Water	1/20/2010	*Giardia*	0	
		Cryptosporidium	0	1
Taylor Mill Raw Water	1/20/2010	*Giardia*	0.67	
		Cryptosporidium	0	1
Memorial Pkwy. Raw Water	1/20/2010	*Giardia*	0	
		Cryptosporidium	0	1

WATER TREATMENT PLANT DESIGN

American Water Works Association
American Society of Civil Engineers

Edward E. Baruth, Technical Editor

Fourth Edition

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CHAPTER 29
ULTRAVIOLET DISINFECTION

Paul D. Swaim, P.E.
CH2M HILL
Englewood, Colorado

Christine A. Cotton, P.E.
Malcolm Pirnie, Inc.
Tucson, Arizona

Samuel S. Jeyanayagam, Ph.D., P.E., D.E.E.
Malcolm Pirnie, Inc.
Columbus, Ohio

Ultraviolet (UV) light has been used for many decades for disinfection of drinking water supplies worldwide. In North America, the use of UV light was more widespread for wastewater disinfection in the last quarter-century, and only more recently has UV light been considered for drinking water disinfection for a wide range of potable water systems. For disinfection of drinking water supplies in North America, UV disinfection was long assumed to provide effective inactivation of bacteria and viruses, but UV light was believed to be ineffective for inactivating protozoa at UV doses that would be cost-effective for implementation.

In 1998 and 1999, new research was published demonstrating that UV disinfection was capable of cost-effectively inactivating *Cryptosporidium* oocysts (Clancy et al., 1998; Dyksen et al., 1998; Bukhari et al., 1999). Where previous studies had focused on in vitro assays to indicate oocyest viability, these new studies utilized animal infectivity assays to directly determine the ability of the pathogen to replicate and cause disease. In the following years, several more studies confirmed these findings and demonstrated the effectiveness of UV disinfection for the inactivation of *Giardia* cysts as well (Craik et al., 2000; Danielson et al., 2001; Hayes et al., 2001; Oppenheimer et al., 2002; Campbell and Wallis, 2002; Linden et al., 2002a; Mofidi et al., 2002). Concurrently, new research showed that higher UV doses were needed for inactivation of adenovirus compared to previous virus inactivation data (Thompson, 2003).

At the same time as the effectiveness of UV disinfection was being established for *Giardia* and *Cryptosporidium*, the U.S. Environmental Protection Agency (USEPA) was developing drinking water regulations to specifically target *Cryptosporidium* inactivation for surface water systems that demonstrate the presence of *Cryptosporidium* in their untreated water supplies. The effectiveness of UV disinfection for the inactivation of *Giardia* and material to more degradable components. For groundwater and filtered drinking water, UV disinfection at typical doses has been shown not to impact the formation of trihalomethanes or haloacetic acids, two categories of DBPs currently regulated by the USEPA (Malley et al., 1995; Kashinkunti et al., 2003).

Several studies have shown the formation of low levels of nonregulated DBPs (e.g., aldehydes) as a result of applying UV light to wastewater and raw drinking water sources. However, a study performed with filtered drinking water indicates no significant change in aldehydes, carboxylic acids, or total organic halides (TOX) (Kashinkunti et al., 2003). The different results can be attributed to the difference in water quality, most notably the higher concentration of organic material in raw waters and wastewaters.

Finally, the conversion of nitrate to nitrite is possible with MP lamps that emit at low wavelengths (von Sonntag and Schuchmann, 1992). However, due to the low conversion rate (about 1%; Sharpless and Linden, 2001), this should be a minimal concern in drinking water applications.

APPLICATIONS FOR UV DISINFECTION

Water utilities are faced with many treatment challenges in today's regulatory climate and the shifts in focus to new contaminants of concern. In addition, often several tools can be used to achieve the utility's objectives. UV disinfection can be used to address these treatment challenges: (1) disinfection of pathogenic microorganisms, (2) reduction of DBP formation, and (3) photolysis and advanced oxidation of contaminants.

Comparison of UV Light and Chemical Disinfection

UV disinfection is fundamentally different from chemical disinfection with respect to the inactivation mechanism, the response of microorganisms, and the factors that impact disinfection. The differences between UV light and chemical disinfection are summarized in Table 29.1.

Disinfection of Target Microorganisms

As discussed later under potential regulatory requirements, UV light can be used to inactivate different types of pathogenic microorganisms. From a regulatory perspective, UV disinfection can be used to inactivate *Giardia lamblia*, *Cryptosporidium parvum*, bacteria, and viruses. In addition, some utilities may have specific disinfection objectives beyond these regulatory requirements.

A comprehensive disinfection strategy provides multiple barriers to reduce microbial risk while minimizing DBP formation. UV disinfection is a tool that can contribute to a comprehensive disinfection strategy by providing a cost-effective method of inactivating target pathogens that are more resistant to more traditional disinfection methods. For UV projects, the target pathogen(s) should be clearly defined during the planning stages (USEPA, 2003a). This can ensure that the design meets the utility's and the primacy agency's expectations based on the regulatory requirements, target microorganism(s), and overall disinfection strategy. An overview of general regulatory requirements for drinking water systems is provided in Chapter 2, and an overview of the potential regulatory requirements for UV disinfection of *Giardia lamblia*, *Cryptosporidium parvum*, bacteria, and viruses is presented at the end of this chapter.

TABLE 29.1 Comparison of Chemical and UV Disinfection

Factor	Chemical disinfection	UV disinfection
Disinfection mechanism	Pathogen is killed by exposure to chemical (e.g., destruction of cell wall). Associated chemical reactions well understood	DNA is damaged by UV light, and pathogen replication is prevented. Cell structure is left intact. Associated optical interactions relatively more complex
DBP formation	High potential for DBP formation	No measurable DBPs formed at typical doses for disinfection
Flow-through reactor	Water, disinfectant, and pathogens flow together	Water and pathogens flow past a fixed UV light field
Detention time	Relatively long and measurable. A key variable in determination of regulatory compliance	Very short. Path taken by pathogen more important
Residual	Used, along with detention time, for determining regulatory compliance	No residual. UV intensity sensors provide a surrogate measurement. Need another measure of disinfection effectiveness
Primary factors impacting disinfection effectiveness	• Water quality • Residual concentration • Contact time • Temperature • pH • Type of chemical	• Water quality (e.g., UVT) • Characteristics of UV equipment • UV intensity and dose distribution • Power quality • Sensor performance

The UV doses necessary for *Cryptosporidium* and *Giardia* inactivation are lower than those required to inactivate viruses. Accordingly, the capital costs for inactivating *Cryptosporidium* and *Giardia* should be lower than the capital costs for virus inactivation by UV disinfection alone. One study estimated capital costs for virus inactivation by UV disinfection are approximately 50% higher than the costs associated with inactivation of *Cryptosporidium* and *Giardia* inactivation by UV disinfection (Cotton et al., 2002). Therefore, the target microorganism(s) and required inactivation level should be determined early in the planning process (USEPA, 2003a).

Reduction of Disinfection By-product Formation

To a degree, UV disinfection can be used to replace chemicals for disinfection of chlorine-resistant pathogens (i.e., *Cryptosporidium* and *Giardia*), thereby potentially reducing DBP formation. However, UV disinfection is not as efficient at inactivating viruses as more traditional, chlorine-based disinfection processes. Because of its effectiveness at inactivating viruses and the need to maintain a disinfectant residual in the distribution system, some chlorine-based disinfection (chlorine or chloramines) will be needed even if UV disinfection is implemented. To achieve a free chlorine residual, the chlorine demand in the water must be satisfied. Thus, chlorine-based disinfection by-products will still be formed if is necessary for successful implementation. Consequently, these steps are not included in the implementation flowchart (Figure 29.7). More important than any testing step is the collection of UVT data for use in facility design, as described previously.

Bench-scale inactivation tests can be used to evaluate the dose response of microorganisms, potentially to confirm the consistency of results in comparison to research findings. Jar tests may be useful for a new water supply in estimating the resulting UVT following treatment, or in evaluating the impacts of coagulation conditions on UVT for an existing supply.

Pilot testing can provide information about the operation, maintenance, and control of specific equipment. This information can include gaining an understanding of sleeve fouling for the particular water, although scale-up issues and the fact that pilot testing occurs for a limited time can limit the usefulness of the data collected. Pilot testing may also be used to generate information on the steps and time commitment associated with typical maintenance activities associated with UV equipment such as sensor calibration checks and parts replacement.

Demonstration testing, like pilot testing, can provide useful information but is not necessary as part of project implementation. Depending on the reactor size selected for demonstration, scale-up issues can be minimized or eliminated. With the correct piping and with the reactor size equivalent to the future full-scale reactors, demonstration testing can be used for validation of UV reactor performance and establishing safety factors under the USEPA requirements. Demonstration testing also provides an opportunity for plant operations and maintenance staff to become familiar with the UV system prior to commissioning of the full facility.

Regulator Involvement

UV disinfection is a relatively new technology for WTPs, and it is important that regulators from the primacy agency be involved early in decision making and throughout the implementation process. The USEPA's proposed *UV Disinfection Guidance Manual* (USEPA, 2003a) recommends regulator involvement throughout the planning and design phases of implementation. Key milestones for regulator involvement include reviews of the conceptual planning or preliminary design report, equipment procurement documents; approval of drawings and specifications; review of planning for on-site validation testing (if applicable); review of the validation testing report; and final approval upon UV facility start-up.

Define Goals for UV Disinfection

A comprehensive disinfection strategy provides multiple barriers to reduce microbial risk while minimizing DBP formation. UV disinfection can contribute to a comprehensive disinfection strategy by providing a cost-effective method of inactivating target pathogens that are more resistant to more traditional chemical disinfection methods. The specific objectives of a given UV installation should be clearly defined during the planning stages. This can ensure that the design meets the utility's and the regulator's expectations based on the regulatory requirements, target microorganism(s), and the overall disinfection strategy. The potential applications for UV disinfection were described previously. The most important goal to define is the target pathogen because viruses will require higher doses compared to *Cryptosporidium* and *Giardia* inactivation and will significantly affect the UV facility design.

Northern Kentucky Water District
2835 Crescent Springs Road • Erlanger, KY 41018-0640

Preliminary Design of GAC Systems

March 2008

Report Prepared By:

Malcolm Pirnie, Inc.
8600 Governor's Hill Drive
Suite 210
Cincinnati, OH 45249
513-677-8380

4775-010

GRW, Inc.

MALCOLM PIRNIE

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ES - Executive Summary

This report presents the basis of design for incorporating post-filtration granular activated carbon (GAC) adsorption facilities into the Northern Kentucky Water District's (NKWD, District) three water treatment facilities (WTP), Fort Thomas WTP (FTTP), Taylor Mill WTP (TMTP), and Memorial Parkway WTP (MPTP), located in Kenton and Campbell Counties. In addition, this report discusses the blending of GAC treated finished water from FTTP with finished water from TMTP and flocculation/sedimentation facility recommendations for the TMTP.

ES.1. Project Driver

The Stage 2 Disinfectant/Disinfection By-product (D/DBP) Rule will require utilities to transition from meeting system-wide running annual averages (RAAs) for TTHMs and HAA5 to meeting locational running annual averages (LRAAs) at each sampling location by 2012. The Stage 2 D/DBP Rule requires that the LRAA concentrations of TTHMs and HAA5 remain at or below 80 and 60 µg/L, respectively. Based on testing completed as part of this and past projects, it was found that NKWD will not meet the regulations with the current treatment approach.

ES.2. Compliance Approach

To maintain the philosophy for this project initiated with the 2004 Asset Management Program and to determine the future water quality goals, NKWD adopted the strategy of analyzing treatment objectives based on a Minimum/Moderate/Aggressive approach.

Minimum Approach – Maintain a TOC target and corresponding empty bed contact time (EBCT) to achieve compliance with the LT2 regulations. For this approach, satisfying the LRAA is the ultimate goal. Therefore, this approach would allow for some individual sampling events above the LRAA, and some below, so that the LRAA was met.

Moderate Approach – Maintain a TOC target so that all individual samples are at or below the MCL and the LRAA is 80% of the MCL. This approach is more conservative, but allows for some samples to be at the MCL. This approach would allow NKWD to meet the LRAA easily even under a single excursion or plant upset.

Aggressive Approach – Maintain a TOC target so that the LRAA is 60% of the MCL. This approach would possibly allow for future compliance if the regulations were tightened.

The three treatment approaches are presented in Table ES-1.

Table ES-1.
Compliance Strategies

Approach	Minimum	Moderate	Aggressive
Percent of MCL Permitted for LRAA	100%	80%	60%
Target Maximum TTHM Value on LRAA Basis (µg/L)	80	64	48
Target Maximum HAA5 Value on LRAA Basis (µg/L)	60	48	36

ES.3. Selected Compliance Strategies

To determine the number and size of contactors for each facility, the following approach was utilized:

1. Determine treatment approaches to evaluate (*e.g.*, maximum TTHM and HAA5 concentrations in the distribution system).
2. Determine the TOC target (for GAC contactor effluent) which corresponds to the maximum TTHM and HAA5 concentrations in the distribution system for each treatment approach (minimum/moderate/aggressive).
3. Select the treatment approach and final EBCT that achieves the TOC targets for a sufficient duration (duration = carbon change-out frequency), based on life cycle costs.
4. Determine the corresponding GAC facility layout to achieve the selected treatment approach.

Through the analysis detailed in this report, NKWD selected the moderate treatment approach at each facility. This selected treatment approach resulted in the targets summarized in Table ES-2.

Table ES-2.
Selected Treatment Approach Targets

Facility	Target Maximum TTHM Value on LRAA Basis (µg/L)	Target Maximum HAA5 Value on LRAA Basis (µg/L)	Target TOC (mg/L)	EBCT (mins)
FTTP	64	48	1.25	20
MPTP			1.25	20
TMTP			1.1	20

ES.4. Site Alternative Analysis

ES.4.1. FTTP

Several site alternatives were analyzed and the selected alternative was to locate the GAC facility adjacent to the existing laboratory building. The following assumptions for capacity and redundancy were made in developing the basis of design for the GAC facilities:

- The GAC facility will include 8 GAC contactors, a GAC feed pump station, GAC backwash system, contactor-to-waste function, combination backwash waste/contactor-to-waste/filter-to-waste equalization basin, and carbon loading/unloading facilities.
- Normal operation will provide at least a 20-minute EBCT with all contactors in-service at a maximum production rate of 44 MGD.
- Duty and standby pumps are provided for each of the pumping systems required for these facilities.
- Provisions to enable incorporation of UV disinfection at the current treatment capacity of 44 MGD.
- A GAC supplier will provide virgin carbon to the site and truck the spent GAC off-site.

All eight GAC contactors will have the same type of equipment and operational mode as shown in Table ES-3.

Table ES-3.
Design Criteria for GAC Contactors-FTTP

Parameter	**Value**
No. of Contactors	8
Contactor Length (feet)	44
Contactor Width (feet)	20
Surface Area per Contactor (sf)	880
GAC Media Depth (inches to top of underdrain)	144
Design Flow per Contactor at Design Capacity (MGD)	5.5
Surface Loading Rate at Design Capacity (gpm/sf)	4.3

As the preliminary design progressed, a final opinion of probable costs was developed. The cost opinion is considered a Class 3 estimate in accordance AACE and has a predicted accuracy of -20% to +30%. The detailed cost opinion is shown in Table ES-4, and includes the UV disinfection facility.

Table ES-4.

Opinion of Probable Project Costs-FTTP

Item	Capital Cost ($ Million)
GAC Facilities (Contactor building, site work, GAC PS, EQ Basin)	$33.5
UV Facility	$2.8
Contingency	$7.3
Engineering (Legal, administration)	$5.4
Total	**$49.0**

ES.4.2. MPTP

Several site alternatives were analyzed and the selected alternative was to locate the GAC facility in the footprint of Sedimentation Basins No. 5 and No. 6. The following assumptions for capacity and redundancy were made in developing the basis of design for the GAC facilities:

- The GAC facility will include 6 GAC contactors, GAC feed pump station, GAC backwash system, contactor-to-waste function, combination backwash waste/contactor-to-waste equalization basin, and carbon loading/unloading facilities.
- Normal operation will provide at least a 20-minute EBCT with all contactors in-service at a maximum production rate of 20 MGD.
- Duty and standby pumps are provided for each of the pumping systems required for these facilities.
- Provisions to enable incorporation of UV disinfection at the future treatment capacity of 20 MGD.

All six GAC contactors will have the same type of equipment and operational mode as shown in Table ES-5.

Table ES-5.
Design Criteria for GAC Contactors-MPTP

Parameter	Value
No. of Contactors	6
Contactor Length (feet)	34
Contactor Width (feet)	15
Surface Area per Contactor (sf)	510
GAC Media Depth (inches to top of underdrain)	144
Design Flow per Contactor at Current Design Capacity (MGD)	3.3
Surface Loading Rate at Current Design Capacity (gpm/sf)	4.5

As the preliminary design progressed, a final opinion of probable costs was developed. The cost opinion is considered a Class 3 estimate in accordance AACE and has a predicted accuracy of -20% to +30%. The detailed cost opinion is shown in Table ES-6, and includes the UV disinfection facility.

Table ES-6.
Opinion of Probable Project Costs-MPTP

Item	Capital Cost ($ Million)
GAC Facilities (Contactor building, site work, GAC PS, EQ Basin)	$18.5
UV Facility	$2.3
Contingency	$4.1
Engineering (Legal, administration)	$3.1
Total	**$28.0**

ES.4.3. TMTP

Both basin-style and vessel-style contactors were investigated for the GAC facility to be located west of the current treatment processes at the TMTP. Vessel-style contactors were selected and the following assumptions for capacity and redundancy were made in developing the basis of design for the GAC facilities:

- The GAC facility will include 28 GAC pressurized vessels, GAC feed pump station, GAC backwash system, contactor-to-waste function, combination backwash waste/contactor-to-waste equalization basin, and carbon loading/unloading facilities.
- Normal operation will provide at least a 20-minute EBCT with all contactors in-service at a maximum production rate of 10 MGD.
- Duty and standby pumps are provided for each of the pumping systems required for these facilities.

Twenty-eight pressurized contactors will be provided. It is anticipated that the contactors will have the following characteristics as shown in Table ES-7.

Table ES-7.
Design Criteria for GAC Contactors-TMTP

Parameter	Value
No. of Contactors	28
Contactor diameter (feet)	10
Approximate Contactor height (feet)	22
Design Flow per Contactor at Design Capacity (MGD)	0.42

As the preliminary design progressed, a final opinion of probable costs was developed. The cost opinion is considered a Class 3 estimate in accordance AACE and has a predicted accuracy of -20% to +30%. The detailed cost opinion, which includes the UV disinfection facility, is shown in Table ES-8.

Table ES-8.
Opinion of Probable Project Costs-TMTP

Item	Capital Cost ($ Million)
GAC Facilities (Contactor building, site work, GAC PS, EQ Basin)	$15.3
Contingency	$3.1
Engineering (Legal, administration)	$2.3
Total	**$20.7**

ES.5. UV Disinfection

Contingencies for including a UV disinfection facility at each of the plants was included as part of this project. The Long-Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR), which will be finalized soon by the EPA, will require some WTPs to implement additional treatment to achieve certain levels of removal/inactivation of *Cryptosporidium* depending on their source water *Cryptosporidium* concentrations. Current knowledge of NKWD water quality indicates that *Cryptosporidium* detections are low and that additional treatment is not likely to be required. However, in the event that regulatory requirements or source water quality characteristics change, or if the District desires to add an additional microbial barrier to the WTP process, UV disinfection is a cost-effective treatment alternative approved for *Cryptosporidium* removal/ inactivation by LT2ESWTR.

1. Introduction

This report presents the basis of design for incorporating post-filtration granular activated carbon (GAC) adsorption facilities into the Northern Kentucky Water District's (NKWD, District) three water treatment facilities (WTP), Fort Thomas WTP (FTTP), Taylor Mill WTP (TMTP), and Memorial Parkway WTP (MPTP), located in Kenton and Campbell Counties. In addition, this report discusses the blending of GAC treated finished water from FTTP with finished water from TMTP.

The goal of the GAC adsorption facilities is to improve finished water quality by reducing total organic carbon (TOC) and taste and odor (T&O) causing compounds. Reducing TOC concentrations in the finished water will result in lower concentrations of total trihalomethanes (TTHMs) and five haloacetic acids (HAA5), which are regulated disinfection by-products (DBPs) formed when water containing organic precursor material comes in contact with free chlorine. TTHM and HAA5 concentrations must be reduced to acceptable levels throughout the potable water distribution system to comply with more stringent upcoming regulations by the U.S. Environmental Protection Agency (EPA) under authority of the Federal Safe Drinking Water Act (SDWA). In addition, GAC adsorption is a very effective means of mitigating seasonal taste and odor occurrences by removing 2-methylisoborneol (MIB) and geosmin, the compounds primarily responsible for the taste and odor episodes periodically experienced.

The water quality improvements provided by GAC will benefit all customers throughout the service area and will assist NKWD in controlling DBP formation in remote portions of the distribution system where longer travel and detention times result in increased water age. To meet the project goals, post-filtration GAC facilities will be added to the existing treatment facilities. This Preliminary Design Report (PDR) establishes the agenda to be followed as the detailed design is developed.

1.1. Overview of Existing Water Treatment Facilities

The FTTP and MPTP are located in Campbell County. Both plants receive their source water from the Ohio River. The FTTP is a 44 MGD conventional treatment facility and supplies water to approximately 80% of all the NKWD customers. The plant completed capacity upgrades in 1990, a sodium hypochlorite conversion in 1999, and most recently a new chemical building was constructed at the site. The MPTP is a 10 MGD Actiflo® plant that was purchased from the City of Newport in 2002. An additional 10 MGD of capacity is anticipated to be added to the plant in the future. The improvements currently underway at the facility include new chemical storage and feed systems, the rehabilitation of filters 1-3, and clearwell repairs which will incorporate the addition of baffles.

The TMTP is located in Kenton County and receives its source water from the Licking River, a tributary of the Ohio River. Approximately 45% of the District's customers rely on the TMTP for their water supply, which is more than TMTP's rated capacity. The balance of the demand is met by blending water treated by FTTP. The plant is a 10 MGD conventional treatment facility. Chemical feed system improvements occurred at the plant in 1998 and the addition of post-filtration ultraviolet (UV) disinfection is currently under construction.

A summary of the current and future proposed production capacity of the WTPs are noted in Table 1-1.

Table 1-1.
Current and Future Plant Production Capacities

Facility	Current Capacity (MGD)	Future Capacity (MGD)
FTTP	44	44
MPTP	10	20
TMTP	10	10

1.2. Current Water Quality Goals

The District's current distribution system water quality goals for DBP's are shown in Table 1-2.

Table 1-2.
Distribution System Water Quality Goals for DBPs

Parameter	System-Wide Running Annual Averages (RAAs) (currently applicable rule)
Total trihalomethanes (TTHMs)	80 µg/L
Five haloacetic acids (HAA5)	60 µg/L

The Stage 2 Disinfectant/Disinfection By-product (D/DBP) Rule will require utilities to transition from meeting system-wide running annual averages (RAAs) for TTHMs and HAA5 to meeting locational running annual averages (LRAAs) at each sampling location by 2012. The Stage 2 D/DBP Rule requires that the LRAA concentrations of TTHMs and HAA5 remain at or below 80 and 60 µg/L, respectively.

Compliance with the LRAA requirements poses particular challenges for the outlying areas of the District with prolonged residence times. TTHM data from 2006 suggest that 14 of 16 sample points will not meet the 2012 compliance. TTHM data from 2007 suggest that 3 of 16 sample points will not meet the 2012 compliance. The number of sample points not meeting compliance in 2007 was significantly lower due to a prolonged drought that lasted most of the summer. The drought caused an increase in customer's water usage, which resulted in more tank turnover and lower system hydraulic detention times. As a result, the DBP formation was lower compared to what is seen in a typical year. This variability in results from year to year is indicative of changes in raw water quality and system conditions. Figures 1-1 and 1-2 present historical TTHM and HAA5 results for distribution system sites that typically exhibit high DBP levels (as compared to other NKWD DBP sampling locations). Notably, the TTHM and HAA5 levels at these sites are normally well above the target criteria during June – November. Conversely, the levels fall well below the criteria during other months of the year. These seasonal variations are not unique, as the combination of higher TOC concentrations in the summer and higher temperatures typically increases DBP formation. These trends suggest that NKWD water quality goals will mainly target the summer months when DBP formation is of greater concern.

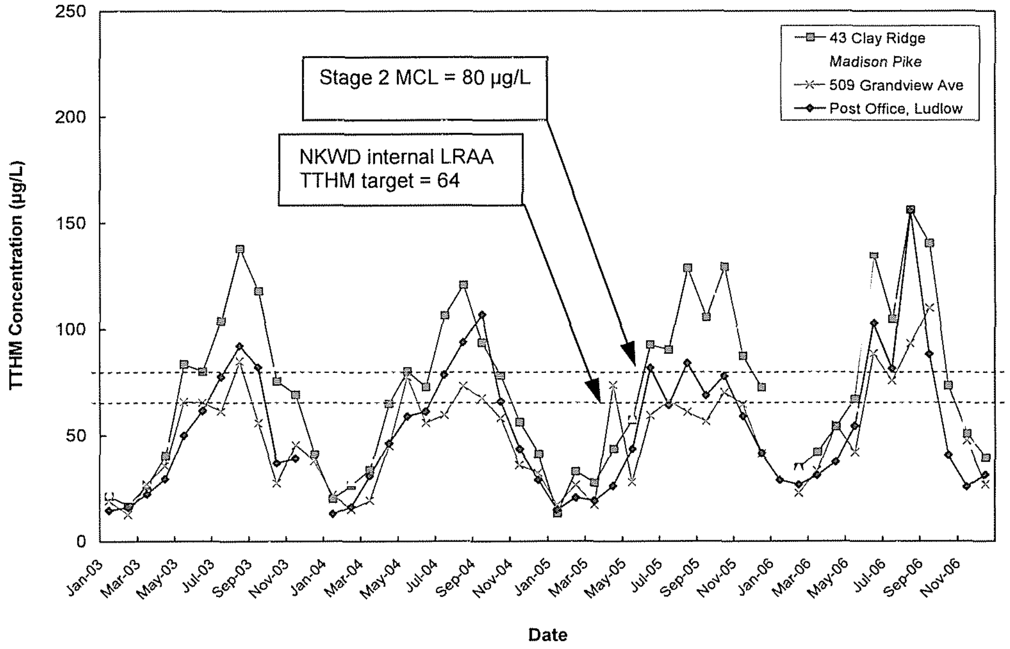


Figure 1-1: Monthly TTHM Results - Highest DBP Concentrations

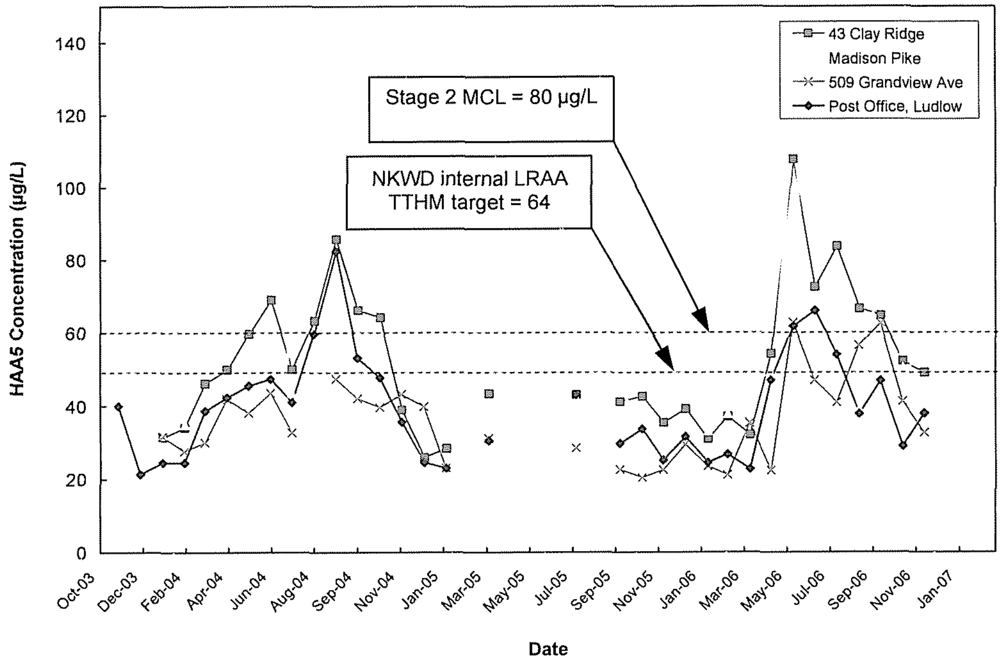


Figure 1-2: Monthly HAA5 Results - Highest DBP Concentrations

1.3. Future Water Quality Goals

As stated above, NKWD will have to comply with the Stage 2 D/DBP Rule by 2012. To maintain the philosophy for this project initiated with the 2004 Asset Management Program and to determine the future water quality goals, NKWD adopted the strategy of analyzing treatment objectives based on a Minimum/Moderate/Aggressive approach.

Minimum Approach – Maintain a TOC target and corresponding empty bed contact time (EBCT) to achieve compliance with the LT2 regulations. For this approach, satisfying the LRAA is the ultimate goal. Therefore, this approach would allow for some individual sampling events above the LRAA, and some below, so that the LRAA was met.

Moderate Approach – Maintain a TOC target so that all individual samples are at or below the MCL and the LRAA is 80% of the MCL. This approach is more conservative, but allows for some samples to be at the MCL. This approach would allow NKWD to meet the LRAA easily even under a single excursion or plant upset.

Aggressive Approach – Maintain a TOC target so that the LRAA is 60% of the MCL. This approach would possibly allow for future compliance if the regulations were tightened.

The three treatment approaches are presented in Table 1-3.

Table 1-3.
Compliance Strategies

Approach	Minimum	Moderate	Aggressive
Percent of MCL Permitted for LRAA	100%	80%	60%
Target Maximum TTHM Value on LRAA Basis (µg/L)	80	64	48
Target Maximum HAA5 Value on LRAA Basis (µg/L)	60	48	36

1.4. Summary of Reviewed Compliance Strategies

Prior to beginning the Preliminary Design of GAC Systems Project, NKWD explored many compliance strategies for organics removal at all three treatment plants. Table 1-4 summarizes the strategies that have been investigated to date.

Table 1-4.
Summary of Reviewed Compliance Strategies for Organics Removal

Treatment Type	Description	Disadvantages	Is Treatment Strategy Effective for NKWD?
Riverbank Infiltration	Drill well near river (natural filtration)	Geology is not right in the area, very costly	NO
Powered Carbon	Add chemical	Cannot add enough carbon to be effective	NO
Actiflo®	Sand aids organic removal	Process alone does not remove enough organics	NO
Enhanced Coagulation[1]	Lower pH to aid in organics removal	Process alone does not remove enough organics	NO
Membranes[2]	Tightly woven mesh in large cartridges	Very expensive, pilot studies show bacteriological buildup	NO
Granular Activated Carbon	Additional filters in treatment process filled with carbon	Carbon needs to be regenerated, facility has large footprint1	YES
MIEX®[3]	Use resin to take out organics (similar to Actiflo®)	Only a few locations in US, discharge is a problem, a proprietary process, was not effective at TMTP	NO

Notes.
1 Enhanced coagulation study was completed in July 2007 by CDM
2 Membranes study was completed in 2004 by B&V
3 MIEX pilots were completed in 2001 and 2007 by B&V and NKWD

Based on the past studies, GAC appears to be the most feasible strategy that will enable NKWD to comply with the upcoming Stage 2 D/DBP Rule for the FTTP and the MPTP. For the TMTP, several treatment strategies may be available and were reviewed as part of this project, including:

- Add MIEX for DOC removal
- Blend TMTP water with FTTP GAC treated water
- Add GAC for TOC removal

This report reviews the compliance alternatives for the TMTP and summarizes the design criteria for the selected compliance strategy for FTTP, MPTP and the TMTP. The TMTP strategies are reviewed in Section 2 of this report.

1.5. UV Disinfection

Contingencies for including a UV disinfection facility at each of the plants was included as part of this project. The Long-Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR), which will be finalized soon by the EPA, will require some WTPs to implement additional treatment to achieve certain levels of removal/inactivation of *Cryptosporidium* depending on their source water *Cryptosporidium* concentrations. Current knowledge of NKWD water quality indicates that *Cryptosporidium* detections are low and that additional treatment is not likely to be required. However, in the event that regulatory requirements or source water quality characteristics change, or if the District desires to add an additional microbial barrier to the WTP process, UV disinfection is a cost-effective treatment alternative approved for *Cryptosporidium* removal/ inactivation by LT2ESWTR.

2. Development of TMTP Compliance Strategy

This section presents the process used to ultimately select the recommended compliance strategy for the TMTP. As part of this report, the following alternatives were investigated:

- Add MIEX for DOC removal
- Blend TMTP water with FTTP GAC treated water
- Add GAC for TOC removal

2.1. MIEX® DOC at TMTP

MIEX® DOC is a proprietary advanced treatment process that removes dissolved organic matter from raw water prior to treatment by the conventional treatment processes. A slurry of small ion exchange resin particles is mixed with raw water, allowed to react for a period of time, separated from the raw water, and then regenerated for reuse. The pretreated water is then treated using conventional treatment processes.

NKWD performed bench testing on April 24, 2007 using MIEX® DOC ion exchange resin. This testing was intended to determine a testing regime for upcoming months when TOC concentrations are typically at their highest. The testing results are summarized in Table 2-1.

Table 2-1.
TMTP MIEX DOC Bench Testing Results

Sample Source	TOC[1] (mg/L)	UV-254[1]	14 Day TTHM Formation Potential (µg/L)	14 Day HAA5 Formation Potential (µg/L)
Raw Water	1.88	0.062	--	--
Settled Water with Chlorine from Full-Scale Plant	0.75	0.021	65[2]	47[2]
Finished Water from Full-Scale Plant	0.67	0.015	63[1]	--
MIEX® Only	.85	.02	99[1]	--
MIEX® plus Coagulation & Settling	0.62	0.014	51[2]	34[2]

Notes: 1 Analyses performed by NKWD and/or a local commercial laboratory Samples prepared and shipped by NKWD
2. Analyses performed by the University of Colorado Samples prepared and shipped by NKWD

The ion exchange process coupled with coagulation and settling reduced the 14-day TTHM formation potential by 22 percent when compared to coagulation and settling alone. It reduced the 14-day HAA5 formation potential by 28 percent when compared to coagulation and settling alone.

However, the data suggest that the MIEX® DOC process may not remove enough additional organic matter to achieve the project goals when the raw water TOC is normally high in the summer. In addition, due to the proprietary nature of the resin and the inherent cost risks associated with constructing major improvements based on a single supplier, the stakeholders eliminated MIEX® DOC from further consideration.

2.2. Effect of Blending FTTP and TMTP Water

The FTTP has the capability of sending flows to the TMTP and either pumping directly to the service level or diverting FTTP water into the clearwell and blending the two waters prior to pumping. The result is blended water in a large part of Kenton County service area. In 2006, approximately 8 MGD on average of treated water was supplied to the TMTP from the FTTP for use within the TMTP service area. Under current demand conditions, the FTTP has the potential to supply up to 20 MGD to the TMTP. The potential for blending GAC treated water from the FTTP with TMTP effluent was investigated to determine if blending would allow NKWD to remain in compliance with the upcoming Stage 2 D/DBP rules, and, if so, how long it would be feasible to delay the construction of a GAC facility at the TMTP.

To assist in determining the minimum amount of blending required between FTTP GAC treated water and TMTP effluent with current treatment conditions, two phases of SDS tests were conducted. These tests included 7-day and 14-day SDS-TTHM and SDS-HAA5 tests conducted on various TMTP and FTTP simulated blends. To simulate the blends, TMTP source water was mixed with GAC treated water from the Richard Miller Treatment Plant (RMTP) of Greater Cincinnati Water Works (GCWW). Since the FTTP and the RMTP both use the Ohio River as their source, the RMTP samples were used to represent the future FTTP GAC effluent.

Phase 1 of the SDS tests were conducted with April 2007 TMTP samples with a TOC of 1.4 mg/L to represent the lower TOC months experienced in the spring/winter. These samples were then used to test blends of 33% GAC treated water and 66% GAC treated water with the remainder being water treated with current TMTP processes. A summary of the April, 2007 blending results is presented in Table 2-2.

Table 2-2.
TMTP SDS Blending Results - Phase 1 (April Samples)

Percent Current TMTP Treated Water	Percent GAC Treated Water[1]	TTHM, 14-day (µg/L)	HAA5, 14-day (µg/L)	TTHM Meets Compliance Goal[2]			HAA5 Meets Compliance Goal[2]		
				100% MCL (Min.)	80% MCL (Mod.).	60% MCL (Agg.)	100% MCL (Min.)	80% MCL (Mod.)	60% MCL (Agg.)
100%	0%	65.0	47.1	YES	NO	NO	YES	YES	NO
66%	33%	57.2	65.1	YES	YES	NO	NO	NO	NO
33%	66%	54.3	42.0	YES	YES	NO	YES	YES	NO

Notes: 1. The GAC treated water was estimated to have a TOC of 0.8 mg/L.
2. Minimal (Min.), Moderate (Mod.), and Aggressive (Agg.) approaches.

Under the low TOC conditions experienced in April, the SDS blending test results show that the TMTP without GAC could comply with the Stage 2 D/DBP Rule utilizing the Minimum treatment approach (100% of the MCL). However, the results show that the 33% blend would allow NKWD to comply up to a Moderate treatment approach (80% of the MCL) for TTHMs, but not for HAA5. These HAA5 results are much higher than expected, which is probably related to the pH, and may not represent actual conditions. With the 66% blend (33% TMTP), the results show that NKWD would comply up to a Moderate treatment approach (80% of the MCL). Therefore, to comply with the upcoming regulation, the results suggest that a GAC facility is not needed during the lower TOC months if the FTTP has a lower TOC target. To evaluate the need for additional treatment in the higher TOC months, Phase 2 of the RSSCT/SDS results was completed.

Phase 2 of the SDS tests were conducted with September, 2007 TMTP samples with a TOC of 3.0 mg/L to represent the higher TOC months experienced in the summer/fall. It is important to note that the RMTP samples with a TOC of 0.7 mg/L have a lower TOC than the expected conservative effluent TOC at the FTTP (1.25 mg/L). A summary of the September, 2007 blending results is presented in Table 2-3.

Table 2-3.
TMTP SDS Blending Results - Phase 2 (September Samples)

Percent Current TMTP Treated Water	Percent GAC Treated Water	TTHM, 14-day (µg/L)	HAA5, 14-day (µg/L)	TTHM Meets Compliance Goal[1]			HAA5 Meets Compliance Goal		
				100% MCL (Min.)	80% MCL (Mod.)	60% MCL (Agg.)	100% MCL (Min.)	80% MCL (Mod.)	60% MCL (Agg.)
100%	0%	142	59.8	NO	NO	NO	YES	NO	NO
66%	33%	152	47.9	NO	NO	NO	YES	YES	NO
33%	66%	128	35.2	NO	NO	NO	YES	YES	YES
0%	100%	70.3	32.6	YES	NO	NO	YES	YES	YES

Notes: 1. Minimal (Min.), Moderate (Mod.), and Aggressive (Agg.) approaches.

Under the higher TOC conditions, all blends are able to meet the HAA5 regulations under some treatment approaches. However, the results show that none of the blending scenarios tested can comply with the TTHM regulations. This suggests that with a target TOC of 1.25 mg/L at the FTTP and no GAC treatment at the TMTP, NKWD will not be able to meet the regulations during the higher TOC months. This suggests that the TMTP would require a GAC facility (or other treatment) to comply with the Stage 2 D/DBP Rule effective in 2012.

Since the SDS tests are highly variable, this single test run may not accurately represent what blending may produce in reality. Also since NKWD will have operational flexibility at the FTTP to reduce TOC through carbon change-outs, the possibility for blending may still exist. To investigate this option further, a blending spreadsheet analysis was completed where various blending scenarios were analyzed under various TOC targets. This analysis assumes that the blending occurs in a linear fashion, which may not be completely accurate. The Phase 2 SDS results were used in the analysis for the TMTP data with the exception of the "No GAC" TTHM formation and are shown in Table 2-4. The Phase 2 results predict a TTHM formation potential of 142 µg/L for current TMTP treated water, which is higher than has been observed at the TMTP in the past. Therefore, a value of 120 µg/L was selected for "No GAC" 14-day TTHM formation potential at the TMTP.

Table 2-4.
Predicted TTHM Formation Potential

Treatment Plant	TOC Target (mg/L)	TTHM Formation Potential (µg/L)
FTTP	1.0	48
	1.25	64
	1.4	80
TMTP	0.8	49
	1.2	69
	1.6	87
	No GAC	120

The data in Table 2-4 was used to complete the simulated blending, shown in Table 2-5.

Table 2-5.
Blending Spreadsheet Analysis

Fort Thomas TOC Target = 1.0 mg/L							
Blending Scenario		Percentages		Predicted TTHM Formation Potential (µg/L)			
				Taylor Mill			
Volume Fort Thomas Water (MG)	Volume Taylor Mill Water (MG)	Percent Fort Thomas Water	Percent Taylor Mill Water	TOC Target = 0.8 mg/L	TOC Target = 1.2 mg/L	TOC Target = 1.6 mg/L	No GAC
0	10	0%	100%	49	69	87	142
1	10	9%	91%	49	67	83	133
2	10	17%	83%	49	66	81	126
3	10	23%	77%	49	64	78	120
4	10	29%	71%	49	63	76	115
5	10	33%	67%	49	62	74	111
6	10	38%	63%	49	61	72	107
7	10	41%	59%	49	60	71	103
8	10	44%	56%	49	60	70	100
9	10	47%	53%	49	59	69	97
10	10	50%	50%	49	59	68	95
11	10	52%	48%	48	58	67	93
12	10	55%	45%	48	58	66	91
13	10	57%	43%	48	57	65	89
14	10	58%	42%	48	57	64	87
15	10	60%	40%	48	56	64	86
20	10	67%	33%	48	55	61	79
25	10	71%	29%	48	54	59	75
27	10	73%	27%	48	54	59	73

Fort Thomas TOC Target = 1.25 mg/L							
Blending Scenario		Percentages		Predicted TTHM Formation Potential (µg/L)			
				Taylor Mill			
Volume Fort Thomas Water (MG)	Volume Taylor Mill Water (MG)	Percent Fort Thomas Water	Percent Taylor Mill Water	TOC Target = 0.8 mg/L	TOC Target = 1.2 mg/L	TOC Target = 1.6 mg/L	No GAC
0	10	0%	100%	49	69	87	142
1	10	9%	91%	50	69	85	135
2	10	17%	83%	52	68	83	129
3	10	23%	77%	52	68	82	124
4	10	29%	71%	53	68	80	120
5	10	33%	67%	54	67	79	116
6	10	38%	63%	55	67	78	113
7	10	41%	59%	55	67	78	110
8	10	44%	56%	56	67	77	107
9	10	47%	53%	56	67	76	105
10	10	50%	50%	57	67	76	103
11	10	52%	48%	57	66	75	101
12	10	55%	45%	57	66	74	99
13	10	57%	43%	57	66	74	98
14	10	58%	42%	58	66	74	97
15	10	60%	40%	58	66	73	95
20	10	67%	33%	59	66	72	90
25	10	71%	29%	60	65	71	86
27	10	73%	27%	60	65	70	85

Fort Thomas TOC Target = 1.4 mg/L							
Blending Scenario		Percentages		Predicted TTHM Formation Potential (µg/L)			
				Taylor Mill			
Volume Fort Thomas Water (MG)	Volume Taylor Mill Water (MG)	Percent Fort Thomas Water	Percent Taylor Mill Water	TOC Target = 0.8 mg/L	TOC Target = 1.2 mg/L	TOC Target = 1.6 mg/L	No GAC
0	10	0%	100%	49	69	87	142
1	10	9%	91%	52	70	86	136
2	10	17%	83%	54	71	86	132
3	10	23%	77%	56	72	85	128
4	10	29%	71%	58	72	85	124
5	10	33%	67%	59	73	85	121
6	10	38%	63%	61	73	84	119
7	10	41%	59%	62	74	84	116
8	10	44%	56%	63	74	84	114
9	10	47%	53%	64	74	84	113
10	10	50%	50%	65	75	84	111
11	10	52%	48%	65	75	83	110
12	10	55%	45%	66	75	83	108
13	10	57%	43%	67	75	83	107
14	10	58%	42%	67	75	83	106
15	10	60%	40%	68	76	83	105
20	10	67%	33%	70	76	82	101
25	10	71%	29%	71	77	82	98
27	10	73%	27%	72	77	82	97

The results for "No GAC" at the TMTP showed that the Moderate and Aggressive treatment approaches are not feasible under any TOC target at the FTTP. However, with the Minimum treatment approach (100% of MCL) and a TOC target of 1.0 mg/L at FTTP, a 60%/40% FTTP/TMTP blend is possible. Also with the Minimum treatment approach and a TOC target of 1.25 mg/L at FTTP, a 75%/25% FTTP/TMTP blend is feasible.

These results suggest that blending may be possible at the TMTP given the operational flexibilities at the FTTP with carbon change-outs and TOC targets. Also, NKWD has the ability to serve a larger area with the MPTP than it currently serves. This could also help alleviate the demands on the FTTP to allow blending at TMTP to be prolonged. This could assist in delaying the construction of a GAC facility while the facilities are being constructed at both the FTTP and the MPTP. The ability to operate the plants in such a tight range of blended water ratios should be examined if used as a compliance strategy.

Another key factor used in the blending analysis was demand projections, which were used to determine when either of the plants would reach a limiting capacity. The blending analysis was based on not exceeding the current plant ratings. The demand projections confirm that around the year of compliance, 2012, the FTTP will be reaching its capacity to send the quantity of water needed for blending at the TMTP. As aforementioned, NKWD has the operational flexibility to aid in delaying the construction of a GAC facility at the TMTP; however, the construction of a GAC facility at the TMTP will ultimately be required to ensure regulatory compliance.

2.3. GAC at TMTP

The design and operation of GAC contactors are often based upon the concentration of TOC in the treated water, which then needs to be correlated to DBP formation within the distributed water. To develop this relationship for the TMTP, which uses the Licking River as its source water, data were derived through RSSCT and SDS testing. Since no previous data were available for the Licking River as was for the Ohio River, NKWD performed the testing. RSSCTs are commonly used to simulate full-scale breakthrough performance, and various studies, including an AWWARF study[1], have confirmed that RSSCT data are highly reliable. The SDS tests were conducted to determine the TTHM and HAA5 formation potential of the TMTP source water. In order to capture both the low TOC months (spring/winter) and the high TOC months (summer/fall), two phases of the testing were conducted and are discussed below.

2.3.1. Phase 1 Testing Results

Phase 1 of the RSSCT and SDS testing were conducted with April TMTP samples with a TOC of 1.4 mg/L to represent the lower TOC months experienced in the spring/winter.

RSSCT RESULTS

The goal of the Phase 1 of the RSSCTs was to represent the breakthrough profiles at a low TOC and to compare the performance of three different carbons. The carbons that were tested include: Calgon Filtrasorb® 400 (F400), Norit GAC 1240 (N 1240), and Norit HYDRODARCO® 4000 (HD 4000). Figure 2-1 presents the RSSCT results for each carbon in full-scale operation time and Figure 2-2 presents the data in bed volumes. The data shows that the lignite based carbon (HD 4000) performed significantly worse than the two bituminous carbon products (F400 and N 1240). As a result, the lignite based carbon was not tested in Phase 2 or recommended for use in the GAC facility.

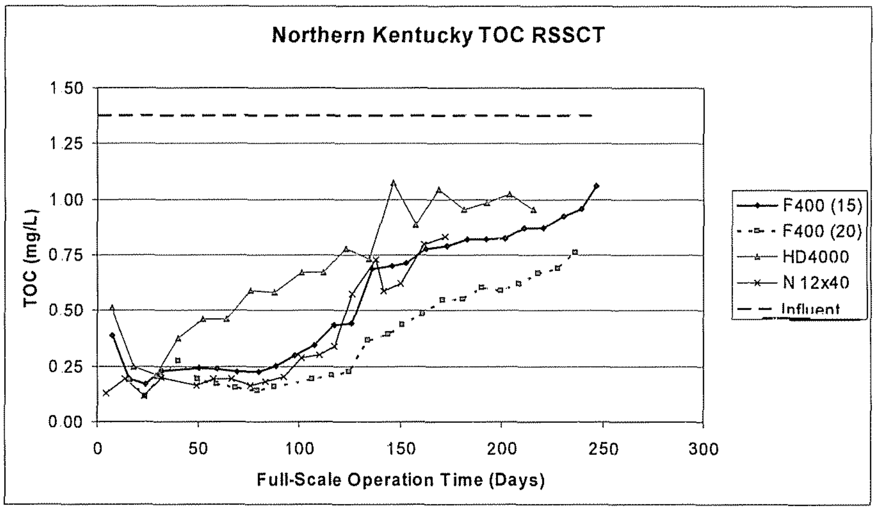


Figure 2-1: TMTP TOC Breakthrough Curve as Scaled Operation Time - Phase 1 (April Samples)

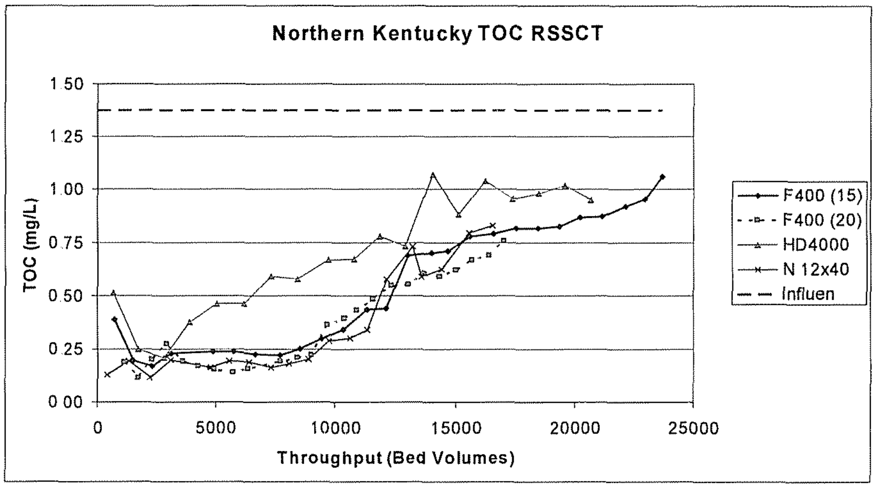


Figure 2-2: TMTP TOC Breakthrough as Throughput (Bed Volumes) - Phase 1 (April Samples)

SDS RESULTS

The goal of the Phase 1 SDS tests was to determine the TTHM and HAA5 14-day formation potential under low TOC conditions. The 7-day results were also determined and are presented in Appendix B. The 14-day results are presented in Table 2-6. The high HAA5 results are most likely due to the pH conditions of the testing. The testing results show that under current treatment conditions and low TOC conditions, the TTHM and THAA concentrations are not going to exceed the MCL. However, this is not the case for months having higher TOC as discussed in Section 2.3.2.

Table 2-6.
TMTP SDS Results - Phase 1 (April Samples)

Sample Description	TOC (mg/L)	TTHM, 14-day (µg/L)	HAA5, 14-day (µg/L)	TTHM Meets Compliance Goal			HAA5 Meets Compliance Goals		
				100% MCL (Min.)	80% MCL (Mod.)	60% MCL (Agg.)	100% MCL (Min.)	80% MCL (Mod.)	60% MCL (Agg.)
TMTP GAC Influent	1.4	65.0	47.1	YES	NO	NO	YES	YES	YES
Bituminous GAC Effluent	0.55	28.3	28.2	YES	YES	YES	YES	YES	YES
Bituminous GAC Effluent	0.82	36.2	32.5	YES	YES	YES	YES	YES	YES
Bituminous GAC Effluent	0.94	42.1	44.4	YES	YES	YES	YES	YES	YES

Notes: 1. Minimal (Min.), Moderate (Mod.), and Aggressive (Agg.) approaches.

2.3.2. Phase 2 Testing Results

Phase 2 of the SDS tests were conducted with September TMTP samples with a TOC of 3.0 mg/L to represent the higher TOC months experienced in the summer/fall.

RSSCT RESULTS

Continuing with Phase 2, only the bituminous carbon samples were utilized since Phase 1 showed poor performance of the lignite carbon. The goal of the Phase 2 RSSCT was to represent breakthrough profiles at high TOC levels. Figure 2-3 presents the RSSCT results with EBCTs of 10, 15, and 20-minutes in full-scale operation time. The TOC in the RSSCT effluent showed an immediate breakthrough of approximately 0.3 mg/L (about 10 percent of the influent TOC), which represents the non-adsorbable fraction of organic carbon in the source water. As expected, increasing the EBCT led to longer run times, as shown in Figure 2-3.

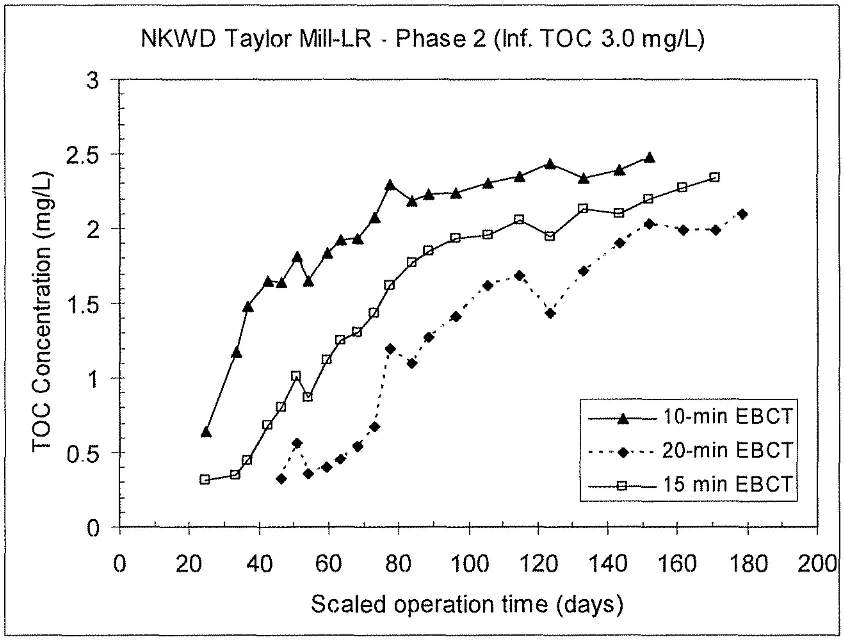


Figure 2-3: TMTP TOC Breakthrough as Scaled Operation Times - Phase 2 (September Samples)

To account for the different EBCTs or GAC mass, the run time is normalized by the EBCT to yield throughput in bed volumes. The TOC concentration breakthrough as a function of throughputs is shown in Figure 2-4. Increasing the EBCT from 10 minutes to 15 minutes yielded more throughput to a given target effluent TOC; however, little difference (< 10%) outside the beginning of the breakthrough was found when the EBCT was increased from 15-minute to 20-minute.

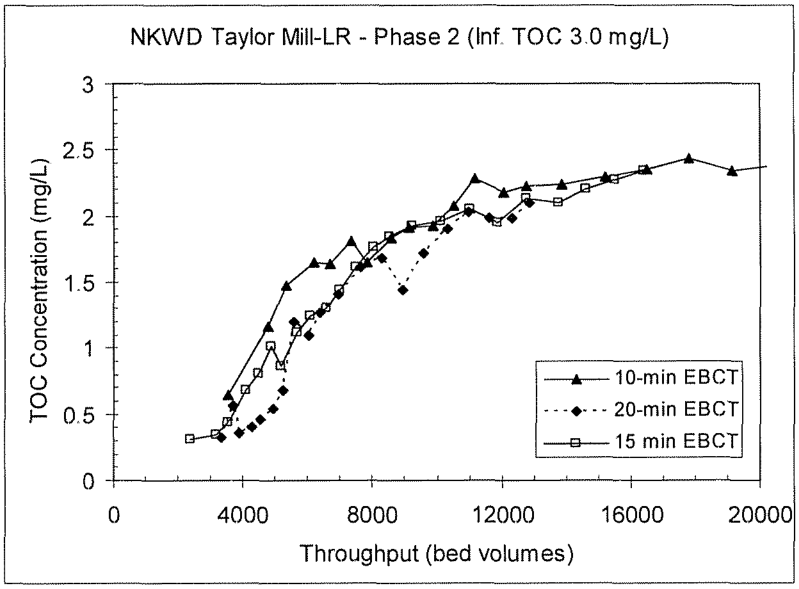


Figure 2-4: TMTP TOC Breakthrough as Throughput (Bed Volumes) - Phase 2 (September Samples)

Figures 2-5 and 2-6 show the prediction of the TOC breakthrough at an EBCT of 15 minutes and a prediction of operating the GAC contactors in staggered mode. The blended model predictions are based on an assumption of ten contactors running in parallel each with the single-contactor predicted breakthrough. The GAC in each contactor is separately replaced at equal intervals, which are dictated by the blended water objective. The interval between GAC replacement in a given contactor under such a staggered operation is the operation time or bed volumes predicted at the blended water objective.

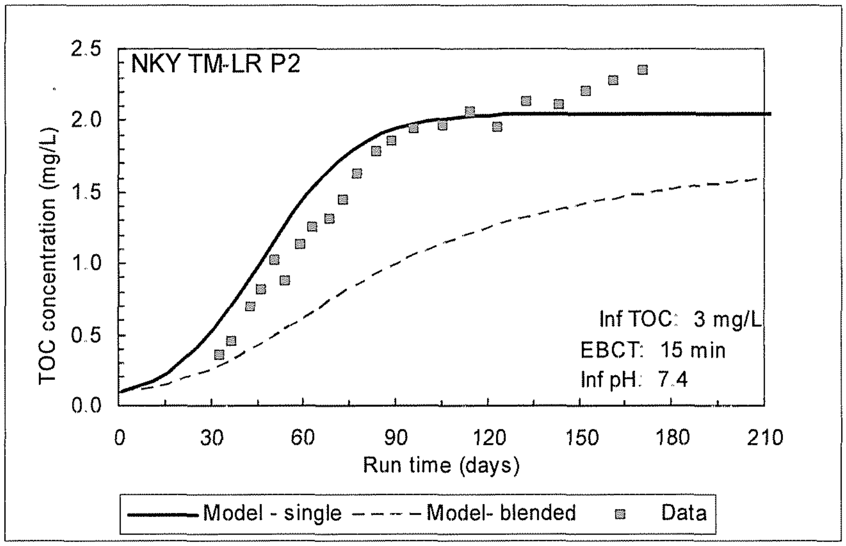


Figure 2-5: TMTP TOC Breakthrough as Scaled Operation Time with Staggered Operation Prediction (15- min EBCT) - Phase 2 (September Samples)

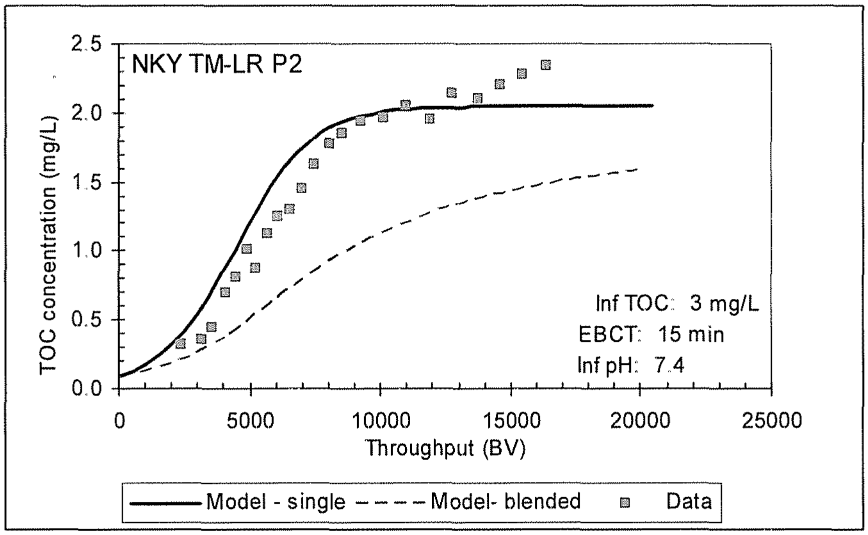


Figure 2-6: TMTP TOC Breakthrough as Throughput (Bed Volumes) with Staggered Operation Prediction (15-min EBCT) - Phase 2 (September Samples)

Figures 2-7 and 2-8 show the prediction of the TOC breakthrough at an EBCT of 20 minutes and a prediction of operating the GAC contactors in staggered mode. The model predictions used the same assumptions as were used for the 15-minute EBCT.

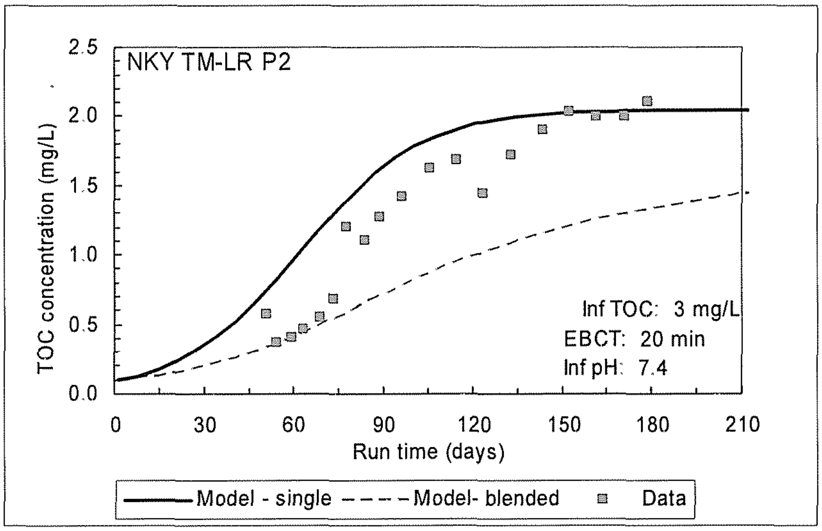


Figure 2-7: TMTP TOC Breakthrough as Scaled Operation Time with Staggered Operation Prediction (20- min EBCT) - Phase 2 (September Samples)

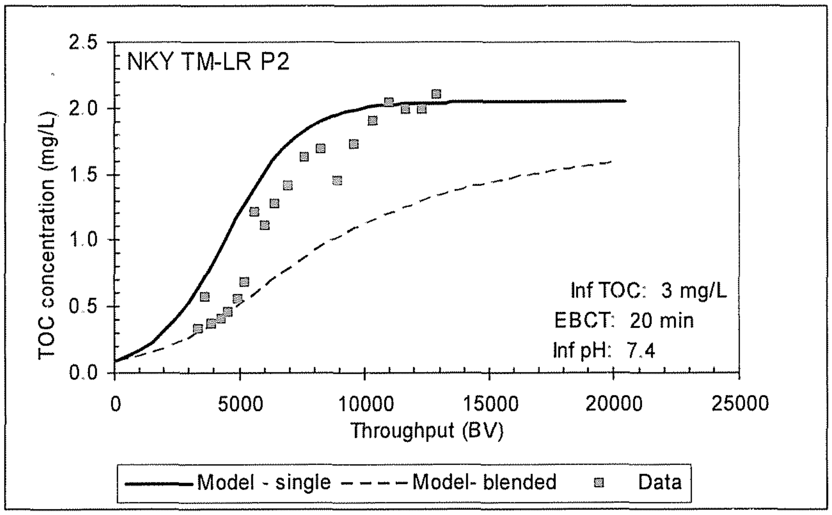


Figure 2-8: TOC Breakthrough as Throughput (Bed Volumes) with Staggered Operation Prediction (20-min EBCT) - Phase 2 (September Samples)

SDS RESULTS

The goal of the Phase 2 SDS tests was to determine the TTHM and HAA5 14-day formation potential under high TOC conditions at the TMTP. The 7-day results were also determined and are presented in Appendix A. The 14-day results are presented in Table 2-7. Although the 14-day HAA5 results show that almost all the samples will meet compliance, these results show that the TMTP will not meet the TTHM goals using existing treatment conditions with a 3.0 mg/L TOC.

Table 2-7.
TMTP SDS Results - Phase 2 (September Samples)

Sample Description	TOC (mg/L)	TTHM, 14-day (µg/L)	HAA5, 14-day (µg/L)	TTHM Meets Compliance Goal			HAA5 Meets Compliance Goals		
				100% MCL (Min.)	80% MCL (Mod.)	60% MCL (Agg.)	100% MCL (Min.)	80% MCL (Mod.)	60% MCL (Agg.)
TMTP GAC Influent	3.0	142.0	59.8	NO	NO	NO	YES	YES	YES
Bituminous GAC Effluent	0.79	48.5	19.1	YES	YES	NO	YES	YES	YES
Bituminous GAC Effluent	1.17	68.9	28.4	YES	NO	NO	YES	YES	YES
Bituminous GAC Effluent	1.61	86.8	33.9	NO	NO	NO	YES	YES	YES
Bituminous GAC Effluent	1.99	123.0	39.6	NO	NO	NO	YES	YES	NO

Using the results in Table 2-4, a graph of TOC versus TTHM Formation Potential was created as shown in Figure 2-9. The trendline was used to estimate the target TOC values required to meet the treatment approach discussed in Section 2.3.2. These targets are summarized in Table 2-5 and show that to meet the Moderate treatment approach, a TOC of 1.1 mg/L is recommended at the TMTP.

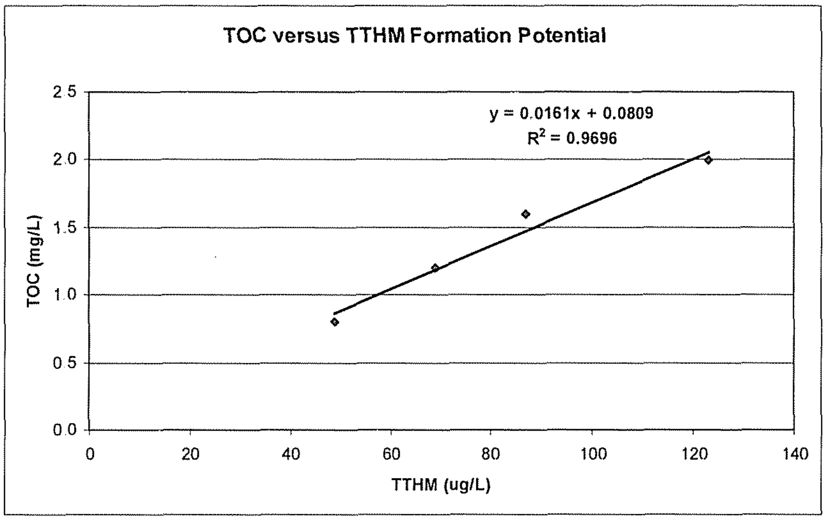


Figure 2-9: TMTP TOC versus TTHM Formation Potential

Table 2-8.
TMTP TOC Targets Based on Phase 2 SDS Results (September Samples)

Treatment Approach	Target Maximum TTHM Value on LRAA Basis (µg/L)	TOC (mg/L) Target Required to Meet Treatment Approach
Minimum	80	1.4
Moderate	64	1.1
Aggressive	48	0.9

2.4. Recommendation

The MIEX® DOC advanced treatment process did not perform as well in bench tests as did the GAC process at the TMTP. It was also concluded that MIEX® DOC might not be able to meet TOC removal objectives during periods of high raw water TOC. It is recommended that the MIEX® DOC process not be considered further as an alterative for advanced treatment at TMTP and that GAC be the considered alternative.

---

[1] Owen, D.M., Z.M. Chowdhury, R.S. Summers, S.M. Hooper, G. Solarik, and K. Grey. 1997. Removal of DBP Precursors by GAC Adsorption. AWWARF.

3. Design Criteria Selection Process

This section presents the process used to ultimately select the recommended preliminary GAC facility design criteria for each plant. To determine the number and size of contactors for each facility, the following approach was utilized:

1. Determine treatment approaches to evaluate (*e.g.*, maximum TTHM and HAA5 concentrations in the distribution system).
2. Determine the TOC target (for GAC contactor effluent) which corresponds to the maximum TTHM and HAA5 concentrations in the distribution system for each treatment approach (minimum/moderate/aggressive).
3. Select the treatment approach and final EBCT that achieves the TOC targets for a sufficient duration (duration = carbon change-out frequency), based on life cycle costs.
4. Determine the corresponding GAC facility layout to achieve the selected treatment approach.

This section summarizes the process of each facility. The sizing and layout is discussed further in the individual plant sections.

3.1. Treatment Approaches

In Section 1, the future water quality goals for NKWD utilizing the minimum, moderate and aggressive approach were summarized. Table 3-1 summarizes the target TTHM and HAA5 based on each approach:

Table 3-1.
GAC Treatment Approaches

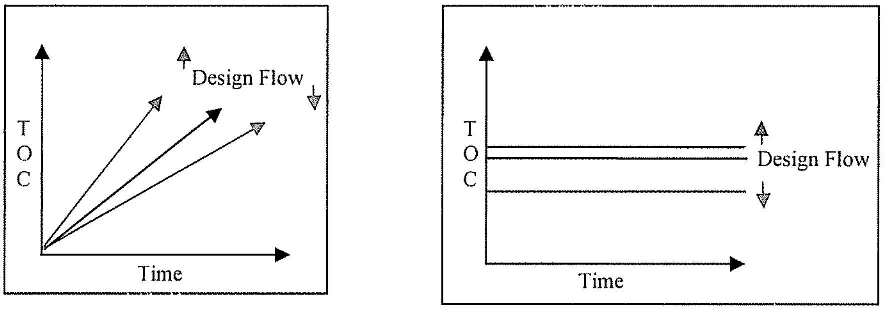
Approach	Minimum	Moderate	Aggressive
Percent of MCL Permitted for LRAA	100%	80%	60%
Target Maximum TTHM Value on LRAA Basis (µg/L)	80	64	48
Target Maximum HAA5 Value on LRAA Basis (µg/L)	60	48	36

3.2. TOC Targets

To determine the appropriate TOC target, the contactor operational mode must be selected.

3.2.1. Evaluation of Contactor Operational Modes

The TOC breakthrough curves generated from actual (TMTP) and representative RSSCTs (FTTP and MPTP) are indicative of the TOC breakthrough that would be observed in a single GAC contactor. However, there can be a significant advantage in operation and maintenance (O&M) costs and consistency of treated water quality by staggering the operation of multiple contactors and blending the effluent concentrations. The advantage is realized because the contactors are allowed to move closer to a point of complete exhaustion of adsorption sites rather than just initial breakthrough. With the single contactor change-out configuration the TOC goes from below detectable to the allowable limit. The staggered contactor configuration yields consistent water quality at or near target. This affect on TOC compliance is shown in Figure 3-1.



Single Contactor Configuration **Staggered Contactor Configuration**

Figure 3-1: Contactor Configuration Affect on TOC Compliance

Research also shows the blended effluent curve for an infinite number of contactors is the integral of the single contactor effluent curve. The EPA document *Analysis of GAC Effluent Blending During the ICR Treatment Studies*[1] presents one method for converting between single and blended effluent curves. First, the RSSCT data are fit to a step-logistic function in the form of Equation 1.

$$C(t) = A_0 + \frac{A}{1 + Be^{-Dt}} \qquad (1)$$

where:

C(t) = the TOC concentration at time t
A_0 = the initial GAC-contacted water TOC concentration
A, B, and D = logistic curve fit parameters
t = time (can be in days or bed volumes)

The logistic curve fit parameters were determined using the "fit curve" function of SigmaPlot software. The integral of Equation 1 is the blended curve for an infinite number of contactors, and it is shown in Equation 2.

$$C_{blend} = A_0 + A + \frac{A}{Dt}\ln\left(\frac{1+Be^{-Dt}}{1+B}\right) \qquad (2)$$

where C_{blend} is the blended effluent concentration.

The EPA analysis also presents a method for correcting the assumption of an infinite number of contactors to a specific finite number. The method is as follows:

- Define the number of contactors for the analysis.
- Assume a GAC changeout frequency.
- Assume the contactors are brought into operation on equal intervals.
- At the assumed changeout frequency, calculate the effluent concentration from each contactor, and average them to determine the blended effluent concentration.
- Change the replacement frequency, and recalculate the blended effluent concentration until the blended effluent concentration curve is complete.

During normal operation, all GAC contactors will be in-service. For limited periods when GAC change-out is being performed, one contactor will be out of service to discharge spent GAC to the delivery trucks and then to receive virgin GAC from delivery tanker trucks. Once the change-out is complete, the contactor will go back into service, a backwash will be performed, and normal operations will resume.

This evaluation of contactor operational modes has built in conservatisms. This analysis assumes that the plants will be operating at maximum flow at all times. Since the plants do not operate at maximum capacity 100% of the time, the carbon life will be increased. This will increase the bed life and decrease the number of carbon change-outs required. Since NKWD will control the schedule of carbon change-outs, they will have complete control of the GAC facility and be able to adjust operations to meet compliance goals.

Figure 3-2 shows the bed life of staggered contactors approximately doubles compared to a single contactor. Through research conducted by Dr. Summers, it has been determined that 11 contactors is the ideal number to obtain a similar level of efficiency as an infinite number of contactors. Although there is benefit to operating any number of contactors in staggered mode, the benefit decreases dramatically with less than six. Therefore, the recommendation is to operate in a staggered contactor configuration, where the carbon change-outs are staggered over time and the effluent from each contactor is blended, and to aim to have a design with six or more contactors for each treatment plant. Site constraints, change-out frequency goals, EBCT, and hydraulic loading are significant factors to be considered when finalizing the size and number of contactors. These factors are discussed further in the individual plant sections.

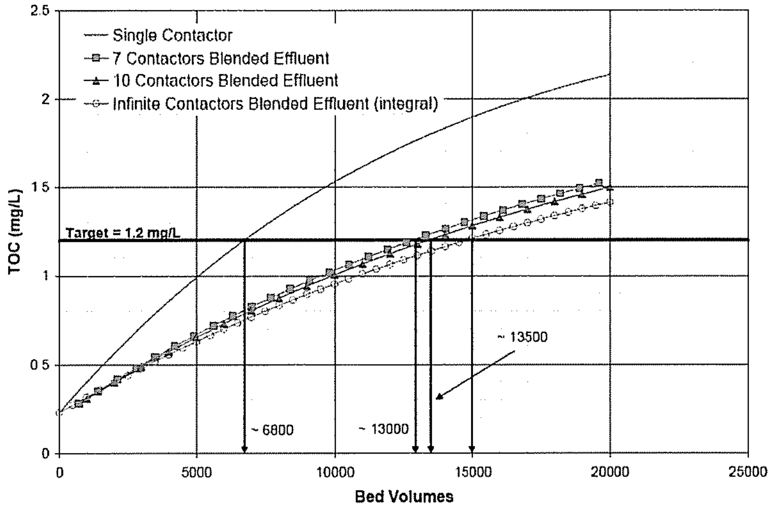


Figure 3-2: Staggered Contactors versus Single Contactors

3.2.2. TOC Target Recommendations

Once the operational mode (staggered carbon replacement) was selected, the TOC target for each treatment approach was determined using the TTHM formation potential results. The TOC targets are summarized in Table 3-2.

Table 3-2.
GAC Treatment Approaches with TOC Targets

Approach	Minimum	Moderate	Aggressive
FTTP TOC Target (mg/L)	1.4	1.25	1.0
MPTP TOC Target (mg/L)	1.4	1.25	1.0
TMTP TOC Target (mg/L)	1.4	1.1	0.9

3.3. Empty Bed Contact Time (EBCT) Selection

Once the operational mode, treatment approaches, and TOC targets were established, the EBCT and the change-out frequency need to be determined. These factors aid in the selection of both the number and the size of the GAC contactors. Based on conversations with NKWD and the experience of other operating facilities, a minimum change-out frequency of one month was selected. A key consideration for the selection of the change-out interval was based on logistical concerns (coordination of truck traffic, vendors, etc.).

TOC breakthrough profiles for each facility were used to determine the appropriate EBCT to achieve a carbon change out frequency of one month or greater. For each plant, this resulted in a 15-minute EBCT for the minimum approach, a 20-minute EBCT for the moderate approach, and a 25-minute EBCT for the aggressive approach which is summarized in Table 3-3.

Table 3-3.
GAC Treatment Application with EBCT

Approach	Minimum	Moderate	Aggressive
EBCT	15	20	25

3.4. Treatment Approach Selection

The selection of the treatment approach (minimum, moderate or aggressive) is discussed in the individual plant sections. The methodology utilized to select the ultimate treatment approach for each facility included a review of the following:

- Existing plant information.
- RSSCT/SDS results.
- Current treatment information.
- Treatment objectives for the facility.

Following the selections of the appropriate EBCT for each treatment approach (minimum/moderate/aggressive), the 1997 AWWARF costing tool[2] was utilized to develop capital and O&M costs for each option. Selections of the final treatment approach were made by the stakeholders during project workshops. The methodology for each facility is presented in the individual plant sections.

3.5. GAC Facility Layout Selection

Once the treatment approach was selected for each facility, the selected EBCT was used to determine the size for the GAC contactors at each location. Each site was investigated in detail to determine the optimum GAC facility layout. Each layout is discussed in detail in each plant section.

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[1] USEPA. 1999. *Analysis of GAC Effluent Blending During the ICR Treatment Studies.*

[2] Owen, D.M., Z.M. Chowdhury, R.S. Summers, S.M. Hooper, G. Solarik, and K. Grey. 1997. Removal of DBP Precursors by GAC Adsorption. AWWARF.

4. FTTP GAC Preliminary Design

As mentioned in Section 1, NKWD will be installing post-filter carbon contactors at the FTTP to comply with the Stage 2 D/DBP rule. This study investigates various options at the FTTP for installing a GAC facility paying close attention to geotechnical concerns, plant accessibility, and possible future improvements.

4.1. General Information Review

The sizing of the GAC contactors and ultimately the GAC facilities begins with the selection of the appropriate TOC target, and corresponding EBCT to achieve a reasonable carbon change-out frequency. Decisions concerning the FTTP were based on existing data for the Ohio River. The data were derived from various sources, including NKWD operating records, a bench-scale GAC performance study that was conducted for the FTTP, an American Water Works Association Research Foundation (AWWARF) report[1] on removing DBP precursors using GAC, and various reports/records concerning the post-filter contactors at the Richard Miller Water Treatment Plant (Greater Cincinnati Water Works). A detailed analysis of the above information is presented in the *Information Collection and Data Review Technical Memorandum*[2] found in Appendix B.

The FTTP has a design capacity of 44 MGD. Based on a review of the Monthly Operating Reports (MORs) for 2004 through 2006, the current average daily demand is 21.7 MGD and maximum daily demand is 36.6 MGD. Figure 4-1 presents a summary of the information review.

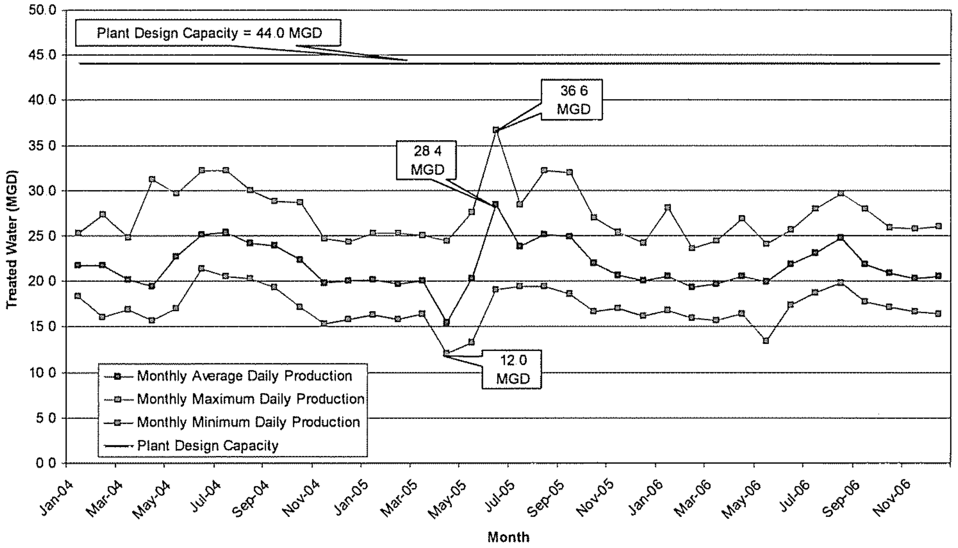


Figure 4-1: FTTP Treated Raw Water (2004 - 2006)

4.2. EBCT Selection

In selecting an EBCT for a GAC system it is important to consider that: a) longer EBCTs generally improve GAC performance, but require greater capital investment (to build larger adsorbers/contactors), and b) shorter EBCTs result in lower capital costs, but increase the GAC change-out frequency. The impacts of EBCT on GAC performance (change-out frequency) can be determined using breakthrough curves for the contaminant of interest. Breakthrough curves show the contaminant concentration in the GAC effluent over time. Various breakthrough curves showing TOC removal from Ohio River water were utilized in selecting an EBCT for the FTTP, along with NKWD's goal to explore a minimum, moderate and aggressive approach to compliance.

Figure 4-2 shows TOC breakthrough profiles for Ohio River water that were generated during the previous bench-scale GAC evaluation for the FTTP. The profiles were developed using miniature GAC contactors according to the "rapid small-scale column test" (RSSCT) protocol. RSSCTs are commonly used to simulate full-scale breakthrough performance and various studies (including the AWWARF study referenced above) have confirmed that RSSCT data are highly reliable. These results are further validated by full-scale breakthrough data from the Richard Miller Water Treatment Plant in Cincinnati.

The data points in Figure 4-2 demonstrate the performance associated with 15- and 20-minute EBCTs. In addition, the graph includes an estimated breakthrough profile for a 25-minute EBCT. Importantly, the influent TOC concentration during these tests was approximately 2.5 mg/L; which is the average finished (filtered) water TOC level at the FTTP during a typical June – November period. Therefore the results depict the GAC performance that could be expected (at FTTP) during the warmer months The data in the figure and the corresponding change-out frequencies are based on complete carbon replacement.

As discussed in Section 2.1, the GAC change-out cycles for multiple post-filter contactors are commonly staggered so as to maximize the time between change-outs. Figure 4-3 shows the 20-minute breakthrough data from Figure 4-2, as well as "multi-contactor" TOC profiles that indicate the optimal change-out frequencies if six or more contactors are operating in staggered mode.

According to Figure 4-3, utilizing six or more 20-minute contactors in staggered mode would increase the change-out frequency for achieving an effluent TOC concentration of 1.0 mg/L to about 170 days. Thus, one or two contactors would receive fresh GAC every 170/6 or 28 days. A summary of the estimated change-out frequencies associated with 15-, 20-, and 25-minute EBCTs for staggered replacement is provided in Table 4-1.

Table 4-1.
Estimated Change-out Frequencies Associated with Various EBCTs

EBCT (min)	Yearly change-out possible?	Staggered change-out frequency
15	No	1-2 contactors every 18 days
20	No	1-2 contactors every 28 days
25	Yes	1-2 contactors every 35 days

Notes: Initial assessment assumed a six contactor design with a TOC target of 1.0 mg/L.

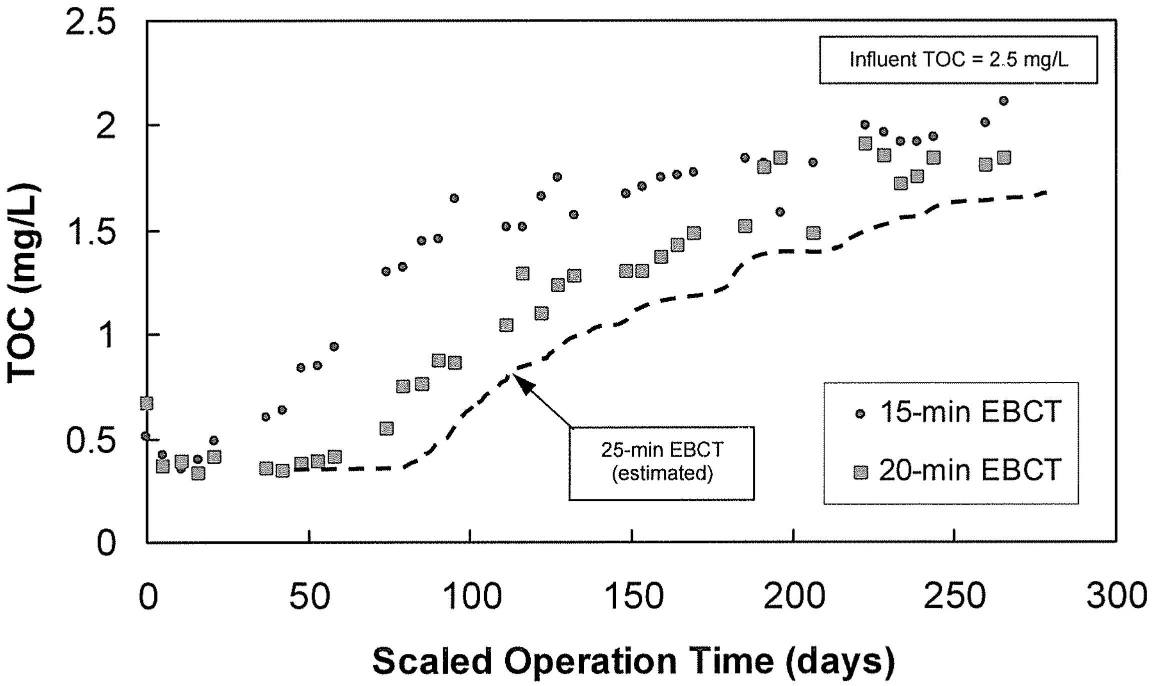


Figure 4-2: TOC Breakthrough Profiles for Bench-scale (RSSCT) Contactors - Ohio River Water

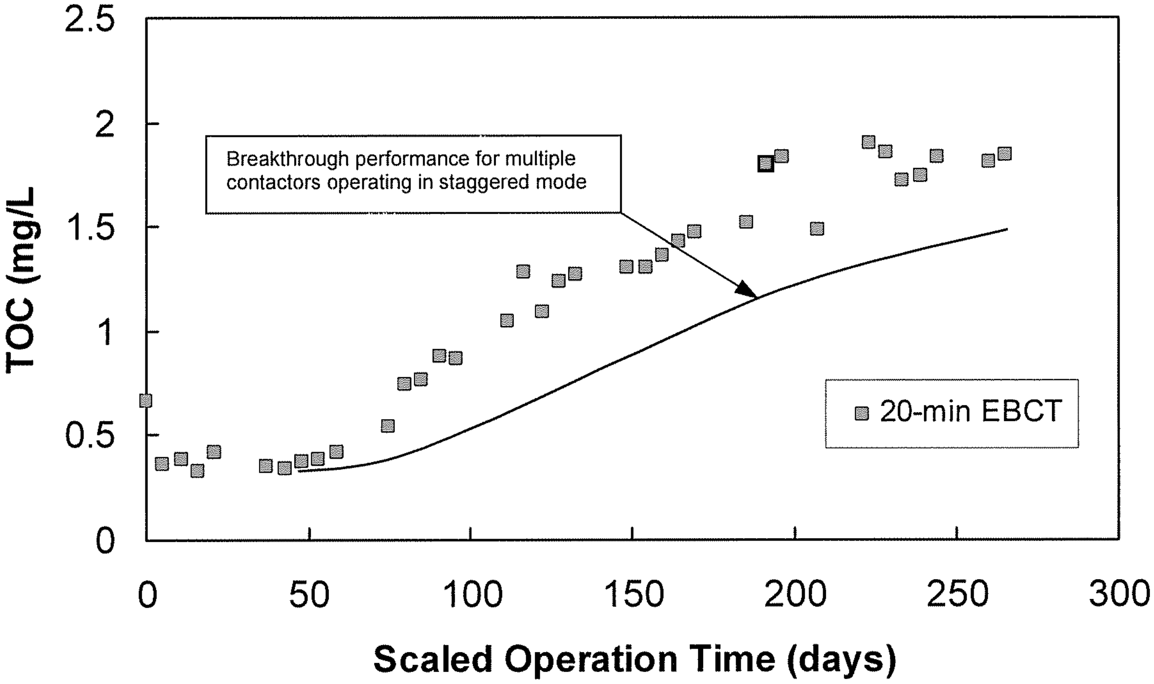


Figure 4-3: 20-minute EBCT TOC Breakthrough Data with Staggered GAC Change-out Performance

4.3. Minimum/Moderate/Aggressive Approach to Compliance

As discussed in Section 2.2, NKWD adopted the strategy of analyzing treatment objectives based on a Minimum/Moderate/Aggressive approach to sizing the GAC contactors. To aid in determining the appropriate approach to follow at the FTTP, a TOC target, EBCT, and replacement frequency were obtained for each approach using the RSSCT data discussed in Section 3.2 and is summarized in Table 4-2. The EBCT selection for each approach was based on a monthly change-out frequency. Since the GAC design includes eight contactors, only change-out frequencies between 200-240 days were considered. This criterion resulted in only one EBCT for each approach as shown in Table 4-2.

Table 4-2.
GAC Treatment Strategies

Approach	Minimum	Moderate	Aggressive
Percent of MCL Permitted for LRAA	100%	80%	60%
Target Maximum TTHM Value on LRAA Basis (mg/L)	80	64	48
Target Maximum HAA5 Value on LRAA Basis (mg/L)	60	48	36
EBCT (min)	15	20	25
TOC Target (mg/L)	1.4	1.25	1.0
Replacement Frequency (days)	200	200	210

To further aid in the approach selection, high level costs were developed by utilizing cost curves for GAC facilities from a 1997 AWWARF report[1] and escalated to 2009 dollars using current ENR interest projections. The costing tool includes the following:

- Contactor feed pump station
- GAC contactors
- Backwash pump station
- Carbon storage
- 25% contingency

An equalization (EQ) basin is not included in the high level cost assumptions, but would increase relative to the contactor size.

Figures 4-4 and 4-5 depict the results of the cost tool with the various treatment strategies.

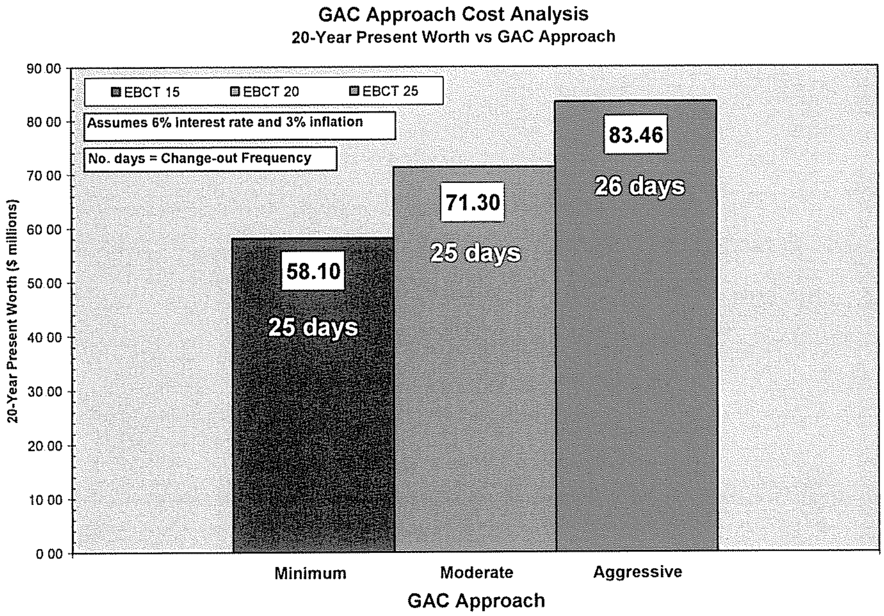


Figure 4-4: GAC Approach Cost Analysis - 20-Year Present Worth

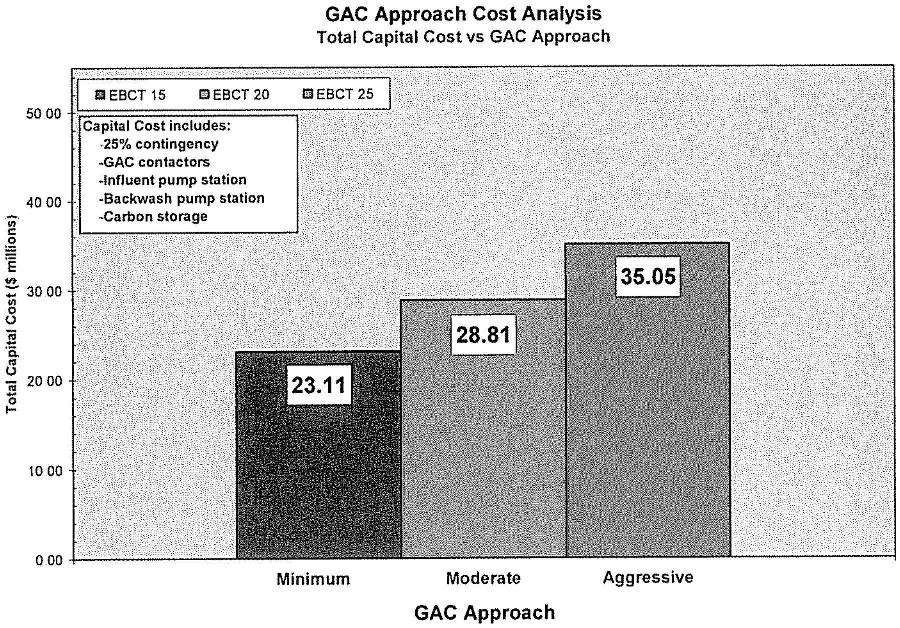


Figure 4-5: GAC Approach Cost Analysis - Total Capital Cost

Based on the high level costing and the preferences of NKWD to maintain cost effective production and delivery of high quality drinking water, the moderate treatment approach was selected. This resulted in a 20-minute EBCT selection with a TOC target of 1.25 mg/L.

4.4. General Considerations

A site plan is shown in Figure 4-6 and the current treatment plant schematic[1] is shown in Figure 4-7. The existing site is extremely congested and is nearly completely developed. The raw water reservoirs lay uphill from the rest of the treatment facility which is protected by an earthen dam, adjacent to the settling process. The majority of the site was once a large reservoir and the dam was installed and fill was utilized to develop the flat land that is now the site of the main treatment facilities. The fill was placed directly on the reservoir's rock liner. These geotechnical considerations are important to note as facility locations are analyzed.

Raw water is conveyed from the Ohio River Pump Station No. 1 to two raw water reservoirs located at the FTTP. Flow from the reservoirs is fed to the flocculation/sedimentation process, and then to gravity filtration. After filtration, flow from Filters 1-6 is conveyed to Clearwell No. 1 (located under the existing filter building which has a 3.0 MGD capacity) and flow from Filters 7-12 is conveyed to Clearwell No. 2 (which has a 3.5 MGD capacity). This is a consideration for phasing and tie-in of the future post-filter contactors. The current treatment hydraulic profile[3] for the FTTP is shown in Figure 4-8.

The new facilities will include the following new structures and subprocesses:

- Tie-in to the Filter Effluent lines
- GAC feed pump station
- Contactors
- Contactor effluent tie-in to clearwells
- Backwash supply pumps
- Backwash equalization facility, equipped with reservoir feed pumps
- Contactor-to-waste piping
- Ultraviolet (UV) disinfection facility

Given the hydraulic profile, plant site constraints and new facilities required, five GAC site location alternatives were presented to NKWD and are shown in Figure 4-9. Each GAC design is based on 20-minute EBCT. Each layout includes a GAC building housing eight contactors, GAC feed pump station(s), backwash basin, and connections from the filter building and to the two clearwells, and a UV disinfection facility. The layouts were analyzed based on the following criteria:

- Impact on plant operability during construction
- Geotechnical concerns and associated costs
- Provisions for future expansion of plant
- Impact on nearby residents (both during construction and daily operations)
- Limited crossing of buried piping corridor
- Proximity to existing treatment processes

PRELIMINARY – NOT FOR CONSTRUCTION

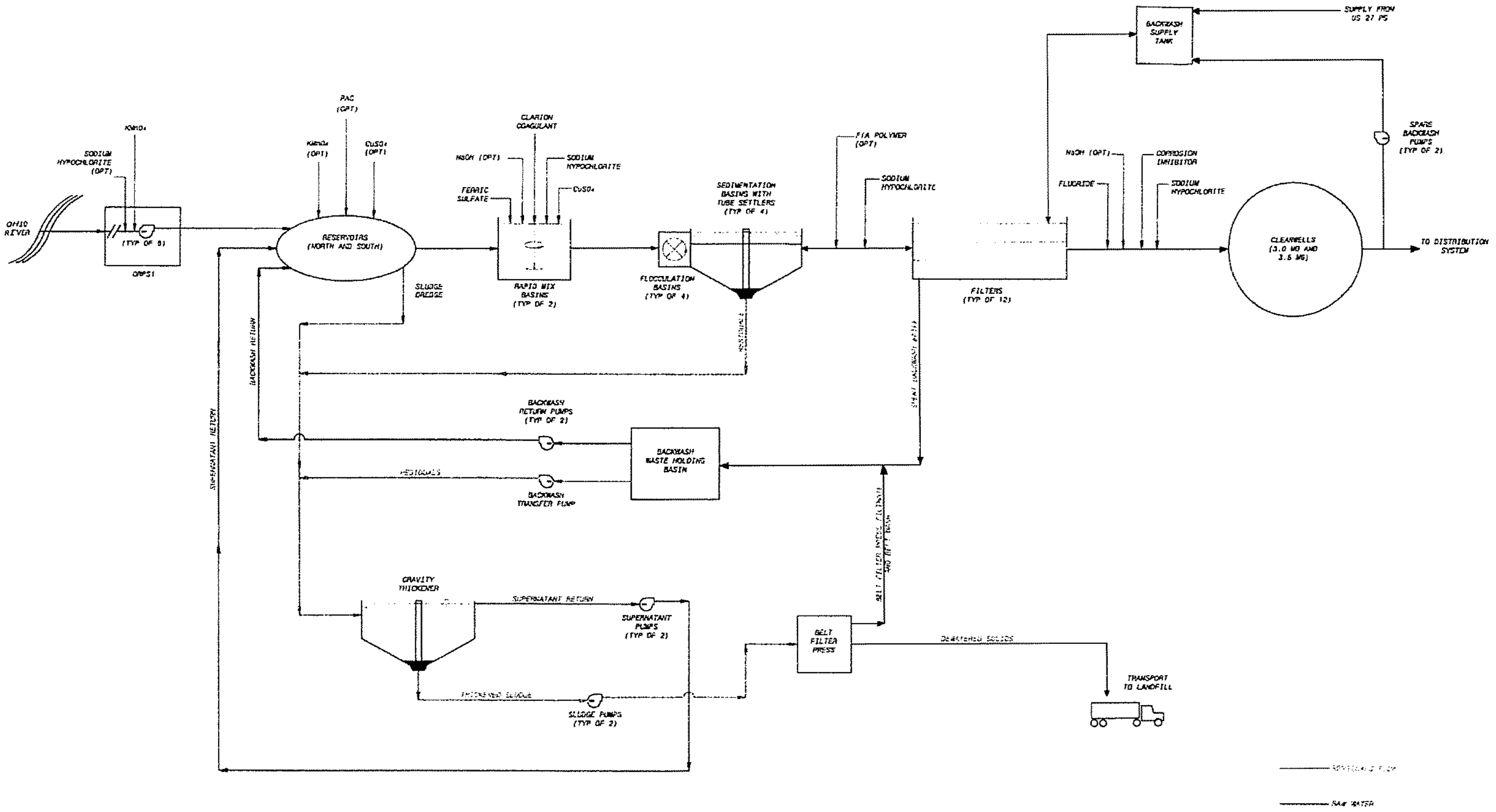
MALCOLM PIRNIE

NORTHERN KENTUCKY WATER DISTRICT PRELIMINARY DESIGN OF GAC SYSTEMS
FORT THOMAS WATER TREATMENT PLANT

SITE PLAN

MALCOLM PIRNIE, INC.

FIGURE 4–6



NOTE: SCHEMATIC OBTAINED FROM ASSET MANAGEMENT PROGRAM REPORT, BLACK & VEATCH, MAY 2004.

NOT TO SCALE

PRELIMINARY – NOT FOR CONSTRUCTION

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NORTHERN KENTUCKY WATER DISTRICT PRELIMINARY DESIGN OF GAC SYSTEMS
FORT THOMAS WATER TREATMENT PLANT

CURRENT TREATMENT SCHEMATIC

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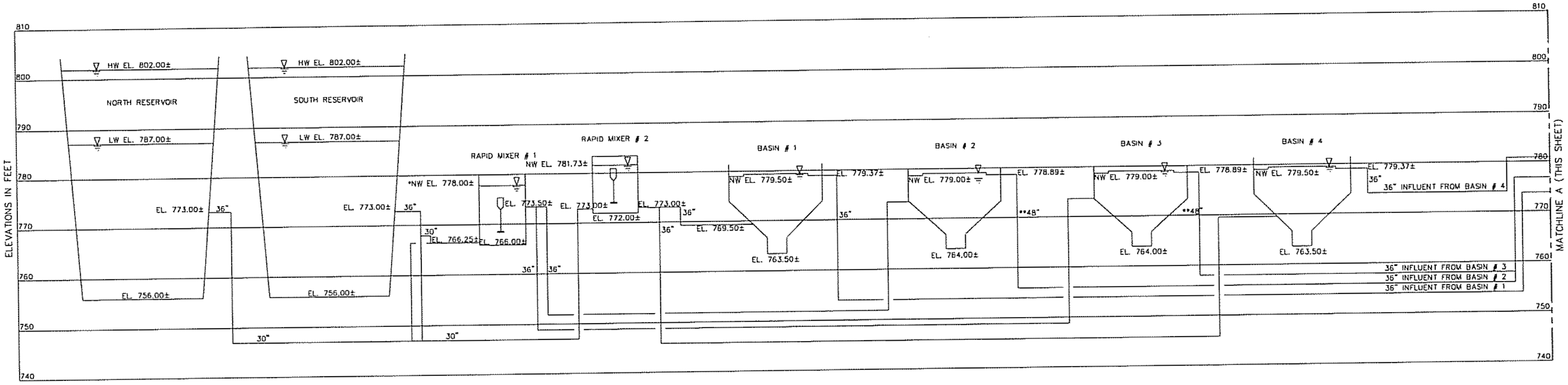
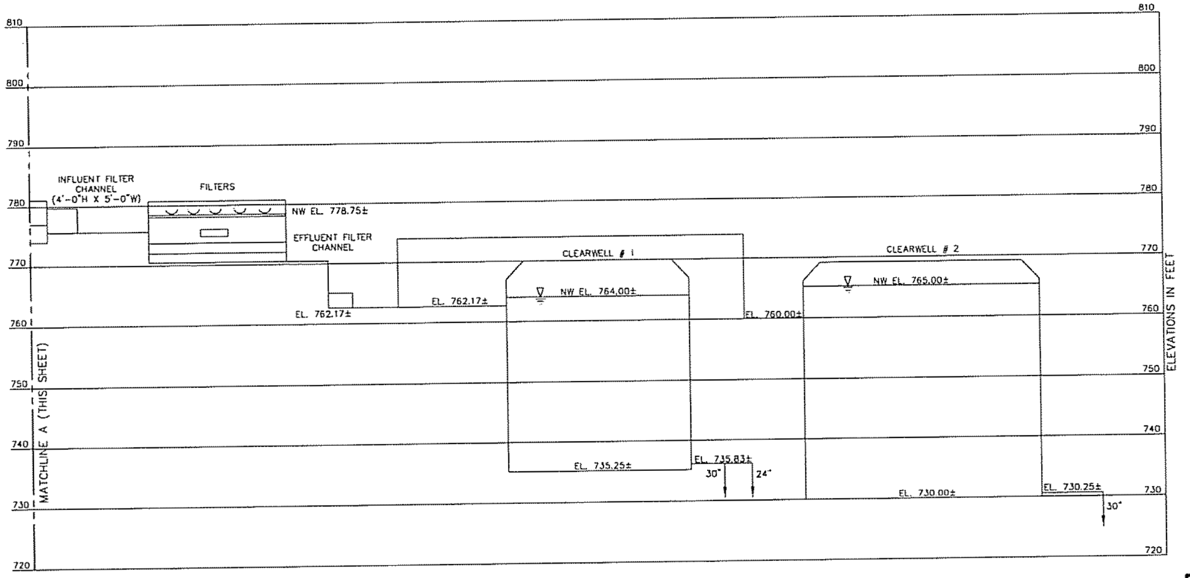
FIGURE 4–7

User:Wells Spec:PIRNIE STANDARD File:I:\4775010\15-CADD\FT THOMAS\GEN\FIGURE 4-7.DWG Scale:1:1 Date:03/03/2006 Time:11:29 Layout:FIG 4-7





NOTES:

1. ALL EXISTING STRUCTURES ELEVATIONS AND LAYOUTS OBTAINED FROM ASSET MANAGEMENT PROGRAM REPORT, BLACK AND VEATCH, MAY 2004.
2. * NW EL. IN RAPID MIXER #1 IS ASSUMED BASED ON NW EL. IN RAPID MIXER #2.
3. ** EFFLUENTS FROM BASINS #2 AND #3 GO STRAIGHT FROM BASINS TO FILTER INFLUENT CHANNEL THROUGH 48" SLUICE GATES.
4. HW EL. = HIGH WATER ELEVATION
   LW EL. = LOW WATER ELEVATION
   NW EL. = NORMAL WATER ELEVATION

HORIZONTAL: NOT TO SCALE
VERTICAL SCALE: ½" = 10'-0"

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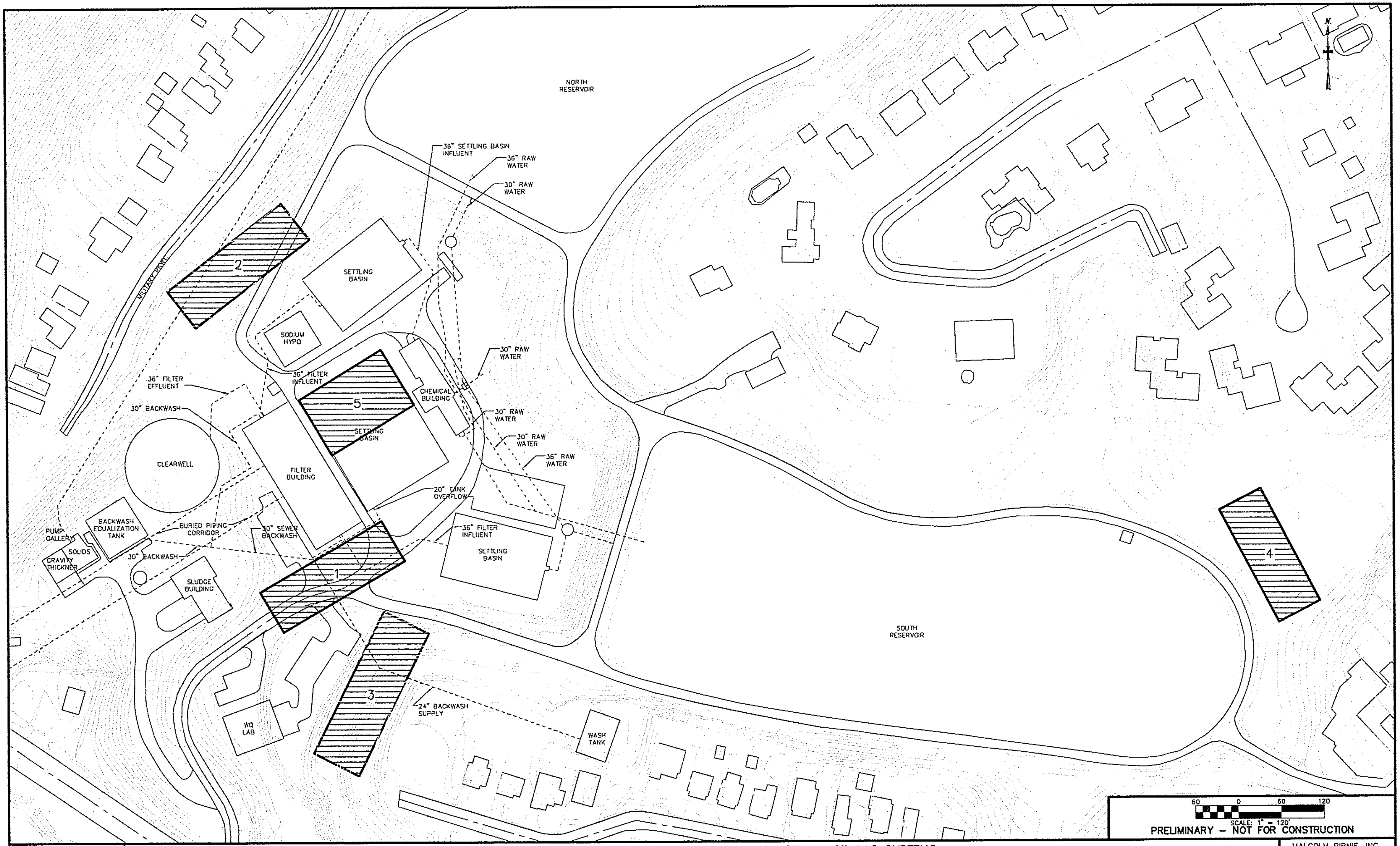
NORTHERN KENTUCKY WATER DISTRICT PRELIMINARY DESIGN OF GAC SYSTEMS
FORT THOMAS WATER TREATMENT PLANT

CURRENT TREATMENT HYDRAULIC PROFILE

FIGURE 4–8

User:HORLANDER Spec:PIRNIE STANDARD File:\4775010\15-CADD\FT THOMAS\GEN\FIGURE 4-8.DWG Scale:1:1 Date:03/04/2008 Time:10:15 Layout:FIG 4-8



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NORTHERN KENTUCKY WATER DISTRICT PRELIMINARY DESIGN OF GAC SYSTEMS
FORT THOMAS WATER TREATMENT PLANT

GAC SITE PLAN OPTIONS

MALCOLM PIRNIE, INC.

FIGURE 4–9

User:Wade Spec:PIRNIE STANDARD File:\4775010\15-CADD\FT THOMAS\GEN\FIGURE 4-9.DWG Scale:1:1 Date:03/03/2008 Time:13:31 Layout:FIG 4-9

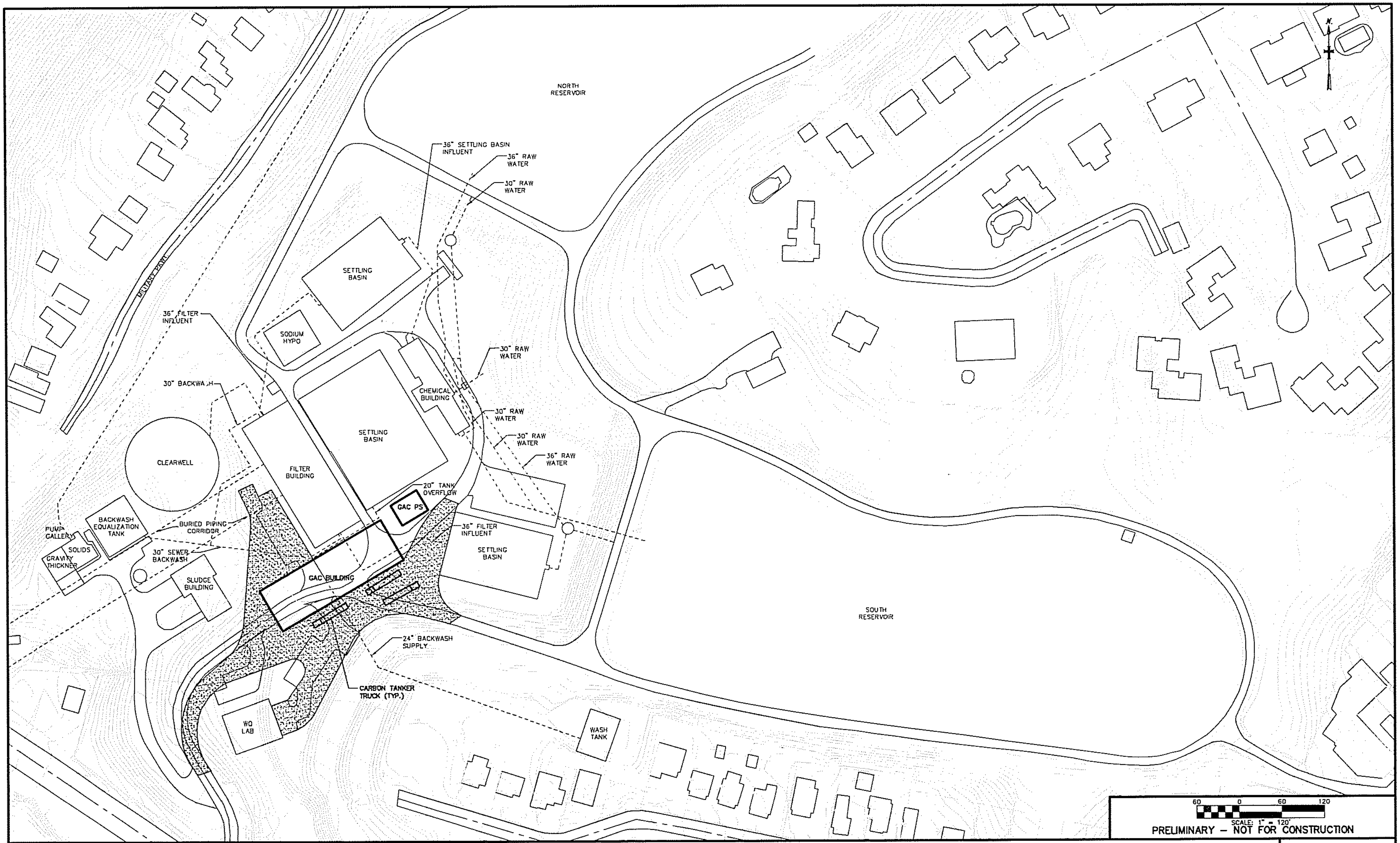
4.5. GAC Site Location Alternatives

4.5.1. Option 1 – Adjacent to Filter Building

Option 1, shown in Figure 4-10, consists of constructing the GAC building adjacent to the existing filter building in the main plant access roadway. The filter effluent would be intercepted at the south end of the filter gallery and re-routed to the GAC feed pump station. The station is located adjacent to the existing sedimentation basins. This option allows for easy access by operational staff, requires shorter runs of pipe to connect the GAC process, and no tie-backs are required for shoring. However, there is an additional cost associated with the extensive roadwork and associated retaining walls, redirection of traffic flow, and difficult routing of GAC feed piping and effluent piping to clearwells. Other drawbacks include: option requires relocation of numerous large and small diameter pipes, requires complicated construction phasing to keep plant operational, and this layout occupies potential location for future filter building expansion. Given these disadvantages, this option was not recommended as the final location for the GAC facility.

4.5.2. Option 2 – Adjacent to Sodium Hypochlorite Building

Option 2, shown in Figure 4-11, consists of constructing the GAC building adjacent to Military Parkway and north of the Sodium Hypochlorite building. The filter effluent would be intercepted at the north end of the filter gallery and re-routed to the GAC feed pump station. The station is located north of the filter building and west of the Sodium Hypochlorite building. This option's simple connections to the filter building and clearwells, as well as its proximity to plant processes, make it a viable option to consider. This location would result in limited plant interruption during construction. However, due to the steep elevation changes from the front of the GAC building to the back, the side and back walls will be constructed as retaining walls. To help blend the building into the surrounding area, a green roof is proposed for this option. During piping and foundation excavation in this area, significant amounts of weathered and unweathered bedrock are expected. Another drawback to this option is the construction vehicle access as well as future carbon tanker truck traffic, which will be disruptive to the entire plant as well as the neighbors along Military Parkway. This option provides little possibility for expansion of the GAC building. For the drawbacks discussed, this option was not recommended for the final site location.



User: Wade Spec: PIRNIE STANDARD File: \4775010\15-CADD\FT THOMAS\GEN\FIGURE 4-10.DWG Scale: 1:1 Date: 03/03/2008 Time: 13:24 Layout: FIG 4-10

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NORTHERN KENTUCKY WATER DISTRICT PRELIMINARY DESIGN OF GAC SYSTEMS
FORT THOMAS WATER TREATMENT PLANT

OPTION 1 GAC LAYOUT

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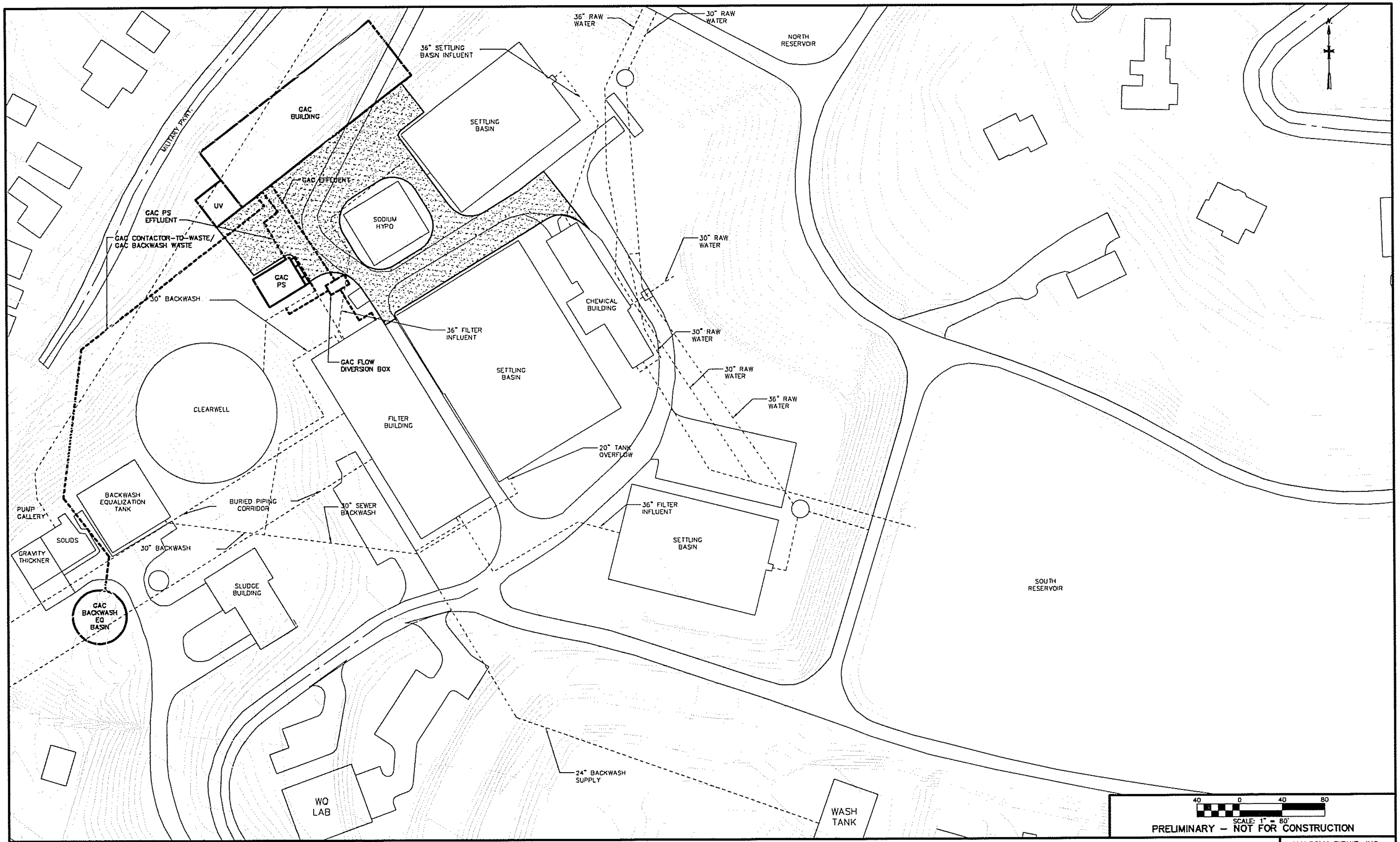
FIGURE 4–10



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NORTHERN KENTUCKY WATER DISTRICT PRELIMINARY DESIGN OF GAC SYSTEMS
FORT THOMAS WATER TREATMENT PLANT

OPTION 2 GAC LAYOUT

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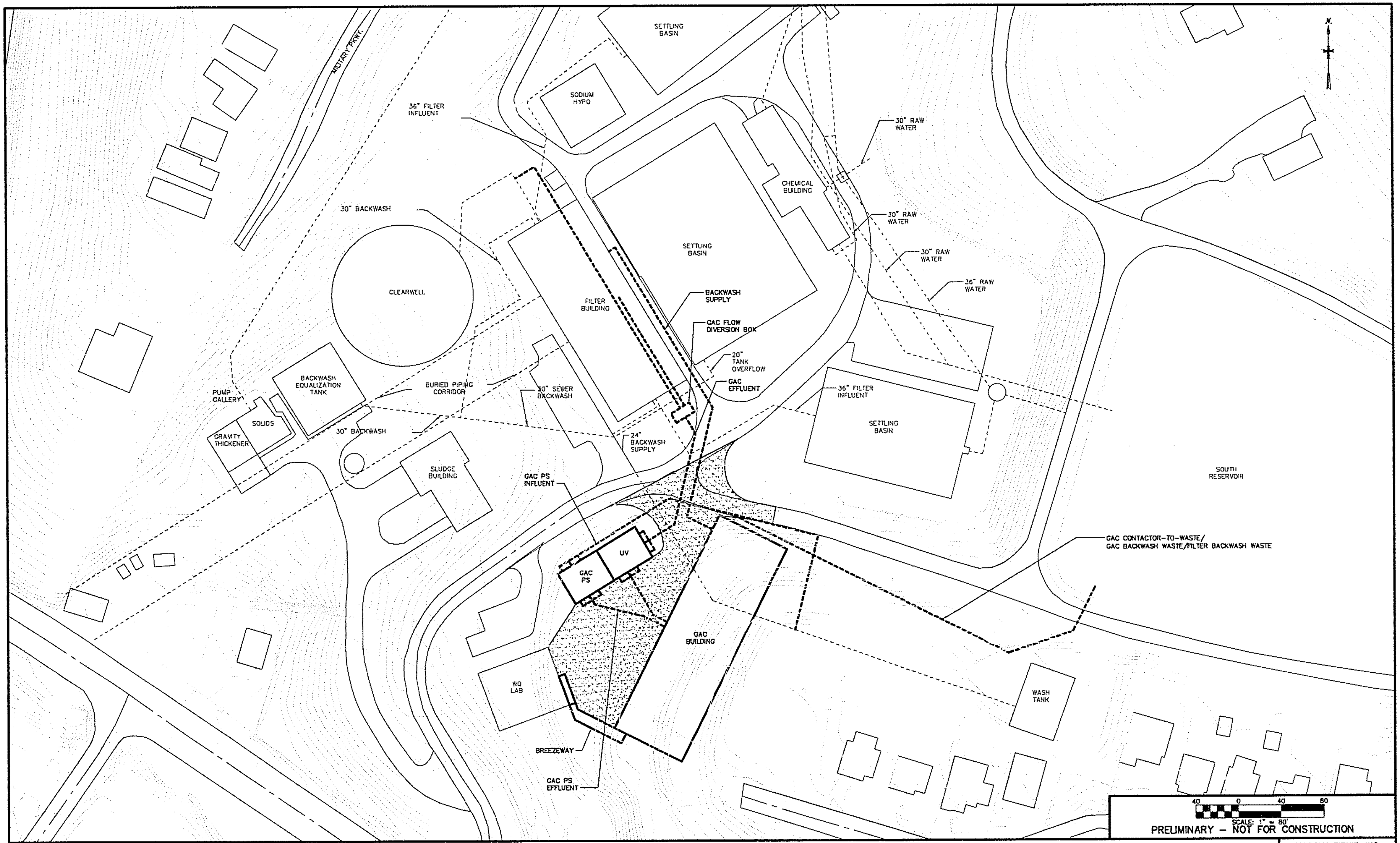
FIGURE 4–11

User:HORLANDER Spec:PIRNIE STANDARD File:\4775010\15-CADD\FT THOMAS\GEN\FIGURE 4-11.DWG Scale:1:1 Date:03/04/2008 Time:10:13 Layout:FIG 4-11

4.5.3. Option 3 – Adjacent to Lab Building

Option 3, shown in Figure 4-12, consists of constructing the GAC building in the vacant space located near the Lab building. The filter effluent would be intercepted at the south end of the filter gallery and re-routed to the GAC feed pump station. The station is located north of the Lab building between the existing roadway and the proposed GAC building. To connect to both clearwells, a 42-inch contactor effluent line will be routed to a splitter box located south of the filter building. From the splitter box, two 36-inch pipes will be routed through the clearwell beneath the filter building. The first will terminate in the middle of Clearwell No. 1 as shown in Figure 4-12. The second will be connected to the existing 36-inch filter effluent line located north of the filter building to convey water to Clearwell No. 2. Also, a breezeway is proposed to connect the GAC building to the Lab building and to help blend the building into the surrounding area, a green roof is proposed for this option.

This is a viable option to consider since the location offers room for GAC expansion, limited disruption to residents, and limited disruption to plant operability since the location is near the plant entrance. Due to the steep elevation changes from the front of the GAC building to the back, the side and back walls will be constructed as a retaining wall. Also, during piping and foundation excavation in this area, significant amounts of weathered and unweathered bedrock are expected. The benefits of this option outweigh these additional costs. For these reasons, this option was chosen as the final recommendation for the GAC facility.



PRELIMINARY – NOT FOR CONSTRUCTION

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NORTHERN KENTUCKY WATER DISTRICT PRELIMINARY DESIGN OF GAC SYSTEMS
FORT THOMAS WATER TREATMENT PLANT

OPTION 3 GAC LAYOUT

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FIGURE 4–12

User:Wete Spec:PIRNIE STANDARD File:\4775010\15-CADD\FT THOMAS\GEN\FIGURE 4-12.DWG Scale:1:1 Date:03/03/2008 Time:13:27 Layout:FIG 4-12

4.5.4. Option 4 – East of South Reservoir

Option 4 consists of constructing the GAC building east of the South Reservoir. This is a viable option to consider since this location will not affect plant expansion, and is expected to have less excavation and shoring costs than the other options. The drawbacks to this option include significant costs associated with contactor influent and effluent piping connections, poor accessibility, relocation of large diameter sewer pipe required, and proximity to neighbors. For these reasons, this location was not recommended as the final site location.

4.5.5. Option 5 – East of Filter Building in Settling Basin Footprint

Option 5 consists of constructing the GAC building in one of the existing settling basins east of the filter building. This option would require elimination of the two centrally located settling basins. The lost capacity would be replaced with a high-rate treatment process such as Actiflo® to free up the space requirement for the GAC process. This would result in two separate flocculation/sedimentation processes. Also, due to the unknown foundation conditions, it is expected that the truss support system would need to be replaced. Furthermore routing of contactor piping and foundation support would be costly given this location. It is estimated that this is the highest cost alternative. For these reasons, this option was not recommended as the final site location.

4.5.6. Cost Considerations

4.5.6.1. High Level Costs

Once an initial comparison of each GAC site location alternative was complete, a high level cost opinion was determined for each alternative. The cost opinion is considered a Class 4 estimate in accordance with the Association for the Advancement of Cost Engineering (AACE) and has a predicted accuracy of -30% to +50%. The cost analysis included additional costs of each option, associated with building excavation, influent/effluent piping connections, influent/effluent pumping, and pipe relocations. Additional costs were added to the costs generated by the AWWARF cost model based on a 20-minute EBCT to derive total costs.

Table 4-3.
GAC Site Location Alternatives High Level Cost Comparison

Site Location Alternative	Additional Cost Range Associated with Option ($ Millions)	Total Cost Range ($ Millions)
Option 1	$3.25-$6.50	$32.3 – $35.5
Option 2	$0.85-$1.70	$29.9 - $30.7
Option 3	$1.83-$3.65	$30.8 – $32.7
Option 4	$4.20-$8.40	$33.2 – $37.4
Option 5	$9.10-$18.20	$38.1 – $47.2

4.5.6.2. Detailed Costs

Based on the advantages of each alternative, discussed above, and the high level costs, NKWD chose to evaluate Options 2 and 3 in further detail. Option 2 would be a desirable alternative only if the cost was significantly lower than that of Option 3 due to the possible disturbance to residents and to the plant traffic flow. The remaining alternatives were discarded and not investigated further. A detailed cost analysis was completed for both Options 2 and 3 and is discussed in the following Section.

As aforementioned, Options 2 and 3 were evaluated in more detail with an additional cost comparison based on each alternative's advantages and high level cost. The cost opinion is still considered a Class 4 estimate in accordance AACE and has a predicted accuracy of -25% to +40%.The detailed cost comparison, shown in Table 4-4, does not include the UV disinfection facility. The details of the cost opinion are included in Appendix C.

Table 4-4.
GAC Site Location Alternatives Detailed Cost Comparison

Site Location Alternative	Escalation to Midpoint Construction Costs (2010, $ Millions)
Option 2 – Adjacent to Sodium Hypochlorite Building	$40.8
Option 3 – Adjacent to Lab Building	$42.4

4.5.7. Final GAC Site Location Recommendation

As shown in Table 4-4, the difference in the high-level cost between Options 2 and 3 are not great. Since Option 2's cost was not significantly lower than Option 3 and its benefits did not outweigh those of Option 3, NKWD selected Option 3, the location near the Lab building. This option allows for future GAC and plant expansion as well as ease of accessibility by carbon tanker trucks. By comparison, Option 3 is a more favorable location due to the minimal plant disruption during both construction and carbon change-out.

4.6. Design Criteria and Basic Assumptions

The following assumptions for capacity and redundancy were made in developing the basis of design for the GAC facilities:

- The GAC facility will include 8 GAC contactors.
- Normal operation will provide at least a 20-minute EBCT with all contactors in-service at a maximum production rate of 44 MGD.
- Duty and standby pumps are provided for each of the pumping systems required for these facilities.
- Provisions to enable incorporation of UV disinfection at the current treatment capacity of 44 MGD.

A GAC supplier will provide virgin carbon to the site and truck the spent GAC off-site.

4.7. Design Approach

4.7.1. General Layout

Figure 4-12 presents a site plan of the proposed GAC preliminary design improvements for the FTTP. Water will be diverted from the existing filter building by shutting the existing sluice gate to Clearwell No. 1 (located under the filter building) and by constructing a duplicate water bypass in the filter building channel. The outlet to Clearwell No. 2 will be closed but left remaining in the event that the GAC process needs to be bypassed. A new 42-inch filter effluent line will be constructed to connect the filter building to the GAC feed pump station. From the pump station, the GAC feed pumps will convey water to the contactors located in the GAC building.

Water will flow through the GAC contactors to a new 42-inch contacted water pipeline to deliver the water to the finished water clearwells. To connect to both clearwells, a 42-inch contactor effluent line will be routed to a splitter box located south of the filter building. From the splitter box, two 36-inch pipes will be routed through the clearwell beneath the filter building. The first will terminate in the middle of Clearwell No. 1 as shown in Figure 4-12. The second will be connected to the existing 36-inch filter effluent line located north of the filter building to convey water to Clearwell No. 2.

Provisions to add a UV disinfection process between the GAC contactors and the clearwells have been included. The UV process would be constructed either adjacent to or contiguous with the GAC feed pump station between the existing roadway and the proposed GAC building. The GAC effluent would be rerouted to enter the south side of the UV building prior to entering the flow splitter box located south of the filter building. Considerations for bypassing all or a portion of the flow between the GAC pump station and UV process should be examined further as part of detailed design. The proposed facility location will require relocation of site piping.

To mitigate drawdown concerns, it is recommended that the backwash pumps either take suction from the clearwell or the GAC feed pump station wet well. The final selection will be determined during final design. For either option, backwash waste will flow by gravity from the backwash troughs to the GAC backwash equalization basin located directly beneath the GAC pipe gallery.

The contactor facility will be equipped with a contactor-to-waste function. Effluent shut off valves will be utilized to convey contactor-to-waste flow by gravity through piping connected to the GAC backwash equalization basin. Equalization volume will be provided for the volume of one GAC contactor backwash event and one contactor-to-waste event, as well as filter backwash waste. Basin sizing considerations included with the reservoir recycle pumps were running. Reservoir recycle pumps located at the GAC backwash equalization basin will convey the backwash waste to the existing South Reservoir. The ultimate sizing of the pumps will be determined during detailed design.

Two additional electrical rooms will be needed on the site. One will be located in the GAC feed pump station/UV building and house all of the electrical gear and equipment for the GAC feed pump station and UV process. A second electrical room will be located in the GAC building and will house the electrical gear and equipment for the building. NKWD anticipates providing a new standby generator for the GAC facilities as part of the detailed design.

GAC facility truck access will be from the main plant entrance. GAC change-out activities will occur in the front of the GAC building where a drive and parking area will exist. Trucks may be required to back into the GAC building drive from the main plant access route. Leaving the plant, the GAC trucks will be required to exit through the main plant entrance. There will be significant traffic during change-out events.

4.7.2. GAC Operation Strategy

The GAC contactors will be operated in parallel. Once the finished water TOC set point is approached, a GAC change-out will be required. The preferred method of GAC facility operation is to establish a staggered contactor operating strategy, taking advantage of effluent blending, where the GAC is replaced in one contactor at a time. Similar to series operation of GAC contactors, this approach is taken to utilize the GAC to the maximum extent possible. Section 2 discusses the blending of GAC-contacted water. During the GAC change-out event, one contactor will be out of service. Spent GAC will be removed from the contactor with the GAC media that has been in service the longest. Following removal of the spent GAC, virgin GAC will be installed in the same contactor and placed into service. Once the contactor is placed into service, the blended effluent TOC concentration will decrease. When the GAC-contacted water again approaches the TOC criterion, the GAC change-out process will be repeated. This strategy will be perpetuated throughout the life of the facility.

4.8. GAC Feed Pump Station

The GAC feed pump station, shown in Figure 4-12, is the source water location for the GAC contactors and supporting facilities. The GAC feed pump station includes the items noted below.

- GAC Feed Pumps: The GAC feed pumps will take suction from a wet well. Submersible pumps were considered for the preliminary design, but vertical pumps could be used as well. The pumps lift the filtered water to the top of the GAC contactors. Provisions should be included in the detailed design to bypass all or some of the flow through UV.
- GAC Transfer/Service Water Pumps: The GAC transfer/service water pumps are anticipated to be located in the GAC feed pump station. The pumps deliver filtered water through a hydropneumatic tank to the GAC building.
- Hydropneumatic Tank: The hydropneumatic tank receives water from the GAC transfer/service water pumps and provides a means to stabilize pressure in the service water line during low system demands and reduces service water pump cycling.

4.8.1. GAC Feed Pumps

The GAC feed pumps will convey water from the GAC feed pump station to the Contactor Inlet Conduit. It is anticipated that an individual discharge line will be provided for each pump. The GAC feed pumps are either submersible or vertical style pumps and will take suction from a wet well. The pump station will be provided with three GAC feed pumps, two duty and one standby. Table 4-5 presents the design parameters for the GAC feed pumps.

Table 4-5.
GAC Feed Pump Design Criteria

Parameter	Value
No. of Pumps	3 (2 Duty, 1 standby)
Design Point Pump Flow	22 MGD (one pump, full speed)
Design Point Pump TDH	45 ft (one pump, full speed, low wet well condition) to be verified during detailed design
Pump Control	VFD

Table 4-6 summarizes the VFD set points required based on full plant conditions.

Table 4-6.
GAC VFD Set Point Summary

VFD Set Point Description	VFD Set Point Flow Rate (MGD)
Minimum	12.0
Average	21.7
Maximum	44.0

4.9. GAC Contactors

All eight GAC contactors will have the same type of equipment and operational mode as shown in Table 4-7.

Table 4-7.
Design Criteria for GAC Contactors

Parameter	Value
No. of Contactors	8
Contactor Length (feet)	44
Contactor Width (feet)	20
Surface Area per Contactor (sf)	880
GAC Media Depth (inches to top of underdrain)	144
Design Flow per Contactor at Design Capacity (MGD)	5.5
Surface Loading Rate at Design Capacity (gpm/sf)	4.3

The GAC contactors shall be designed with the following features:

- A 20-minute EBCT at design flows with all contactors in service.
- A dedicated GAC truck transfer station for each contactor equipped with quick-connect fittings, service water supply, GAC transfer air (GAC TA) supply, and a truck waste pipe to drain water from the trucks.
- A dedicated eductor and service water piping and valves in the piping gallery for each contactor to remove spent GAC.
- A wash-down water system with spray nozzles in the contactors to facilitate removal of GAC and flushing out the contactors during spent GAC removal.
- Three feet of freeboard above the normal operating water level to provide excess storage capacity in the process, maintaining operational flexibility.
- Contactor-to-waste capability to recycle GAC contacted water to the head of the plant immediately after a backwash event via the GAC equalization basin, preventing fines from being washed into the finished water piping and reservoirs (and possibly into potential future UV reactors, where the fines may inhibit inactivation of Cryptosporidium).
- Turbidity monitors at the discharge end of each contactor.
- Pressure differential transmitters at each contactor to measure headloss through the GAC.
- A sampling station with TOC, UV absorbance at 254 nanometers (UV254), and particle counting analyzers. The sampling station will receive a sample line from each individual contactor and one combined sample line for analysis.
- Low level point probes within each contactor.

Operating design criteria for the GAC contactors are summarized in Table 4-8.

Table 4-8.
GAC Contactor Operating Parameters

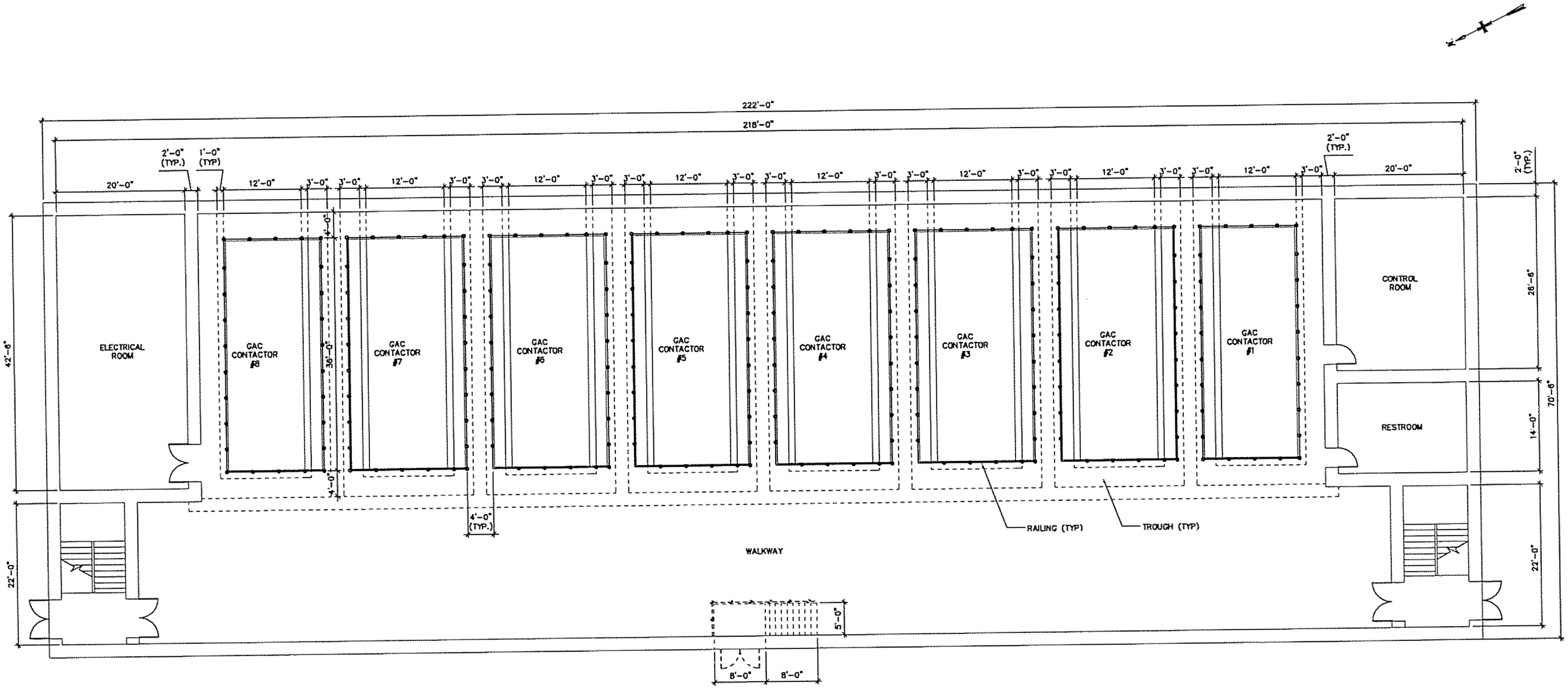
Parameter	Normal Operation	Operation During GAC Change-out
Number of Contactors in Service At WTP Capacity (44 MGD)	8	7
Flow Rate per Contactor (MGD) At GAC Design Flow (44 MGD) At 2012 Projected Average Flow (35 MGD)	5.5 4.4	6.3 5.0
Surface Loading Rate (gpm/sf) At GAC Design Flow (44 MGD) At 2012 Projected Average Flow (35 MGD)	4.3 3.5	5.0 4.0
Empty Bed Contact Time (minutes) At GAC Design Flow (44 MGD) At 2012 Projected Average Flow (35 MGD)	20.7 26.0	18.1 22.8
Design Backwash Duration (minutes)	30	
Design Backwash Rate (gpm/sf)	15	
Design Contactor-to-Waste Duration (minutes)	30	
Design Contactor-to-Waste Rate (gpm/sf)	4.3	

Notes:
Normal operation = No contactors out of service
GAC change-out operation = One equipped contactor out of service

The surface loading rates during GAC change-out, when one contactor is out of service, are higher than the design loading rates for similar size plants, but are lower than those for Greater Cincinnati Water Works' Richard Miller WTP, which has a maximum loading rate of 5.67 gpm/sf. A detailed comparison of design criteria and operating parameters for GAC contactors at the NKWD's facilities and the GCWW facility is included in Appendix D.

Figure 4-13 shows locations of walkways, entrances, stairs, and control rooms located on the GAC Building operating floor level. A typical section through a GAC contactor is shown in Figure 4-14. The sections illustrate the following details:

- The GAC-contacted water/backwash supply pipe is located within the contactor. Flanged pipe spools will connect the underdrains to the pipe.
- Open space has been left along the full length of the pipe gallery to allow for maintenance access. The GAC transfer piping is overhead and out of the way to facilitate access.
- Critical elevations are shown.



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SCALE: 1/16" = 1'-0"
PRELIMINARY – NOT FOR CONSTRUCTION

MALCOLM PIRNIE

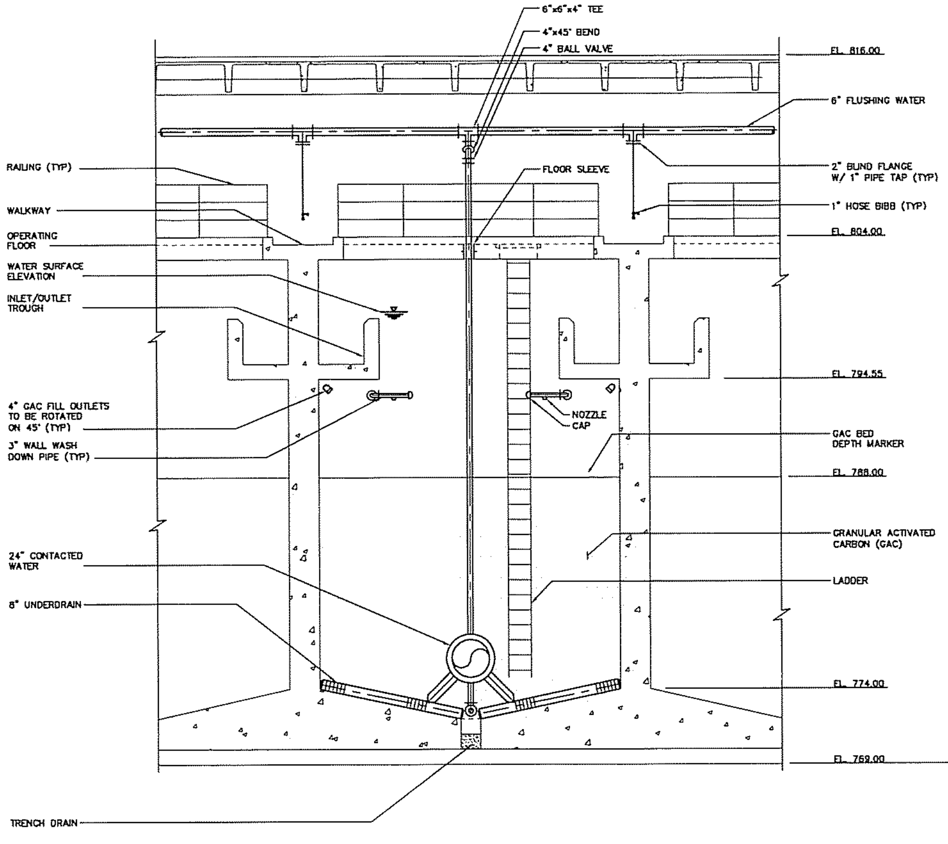
NORTHERN KENTUCKY WATER DISTRICT PRELIMINARY DESIGN OF GAC SYSTEMS
FORT THOMAS WATER TREATMENT PLANT

GAC BUILDING PLAN - OPERATING LEVEL EL. 804.00

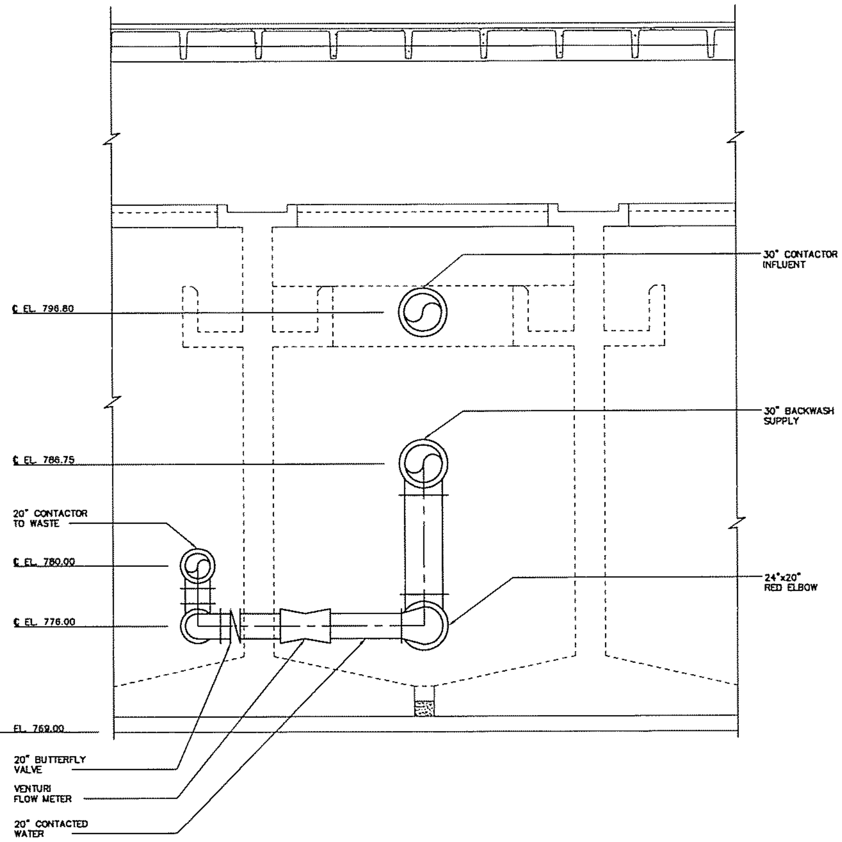
MALCOLM PIRNIE, INC.

FIGURE 4–13

User:Wells Spec:PIRNIE STANDARD File:I:\4775010\15-CADD\FT THOMAS\MECH\FIGURE 4-13.DWG Scale:1:1 Date:03/03/2008 Time:15:08 Layout:FIG 4-13



TYPICAL CONTACTOR SECTION



TYPICAL CONTACTOR SECTION

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PRELIMINARY – NOT FOR CONSTRUCTION

MALCOLM PIRNIE

NORTHERN KENTUCKY WATER DISTRICT PRELIMINARY DESIGN OF GAC SYSTEMS
FORT THOMAS WATER TREATMENT PLANT

GAC CONTACTOR SECTIONS

MALCOLM PIRNIE, INC.

FIGURE 4–14

4.9.1. Equipping of GAC Contactors

As discussed previously, each contactor will be filled with GAC to a nominal bed depth of 12.0 feet. During normal operations, water will flow by gravity through the contactor and be collected via the underdrain system. Effluent flow control will be utilized to maintain a constant rate of flow through the contactors. Several styles of underdrains are available for consideration. The preliminary design is based on a wedge-wire style stainless steel underdrain. A-frame style underdrains have also been used successfully for GAC contactors/vessels. The final underdrain selection and piping configuration will be determined during final design.

4.9.2. GAC Loading/Unloading Facilities

The contactors will be filled with GAC from manufacturers' delivery trucks. Delivery trucks will carry 20,000 to 40,000 pounds of dry GAC to the site. Filling one contactor will require fifteen 20,000-pound deliveries or eight 40,000-pound deliveries. The GAC transfer station at each contactor will be equipped with the following:

- A service water line with a quick connect fitting to provide water to fluidize the virgin GAC. The GAC manufacturers have stated they require approximately 4,000 to 6,000 gallons of water per 20,000-pound shipment. Water must be provided to the tanker truck at a rate of at least 100-200 gpm (to maintain a minimal filling time for the tanker).
- A GAC fill line with quick connect fitting and knife gate valve.
- A spent GAC line with quick connect fitting and knife gate valve to deliver spent GAC to empty tanker trucks.
- Compressed air with a quick connect fitting will provide air pressure to the tanker trucks for GAC transfer. GAC transfer air requirements are approximately 200 standard cubic feet per minute (SCFM) at 15 psig (per GAC suppliers).
- A GAC truck waste line with knife gate valve and quick connect fitting. After delivery of spent GAC to the delivery truck, the transfer water can be drained out of the truck through this line and into the backwash waste line that drains to the GAC Backwash Equalization Basin.

The spent GAC line will deliver fluidized GAC to an empty tanker truck from each contactor using a jet water eductor. The eductors will be sized to fill a tanker truck with 20,000 pounds of wet carbon (drained weight) in approximately 4 hours. GAC removal from the contactors will be assisted by a sidewall wash-down system consisting of spray nozzles mounted below the backwash troughs.

The time required to place one truckload of carbon into a contactor was estimated as 4 hours. This number includes the following:

- One hour to fill the GAC delivery truck with 6,000 gallons of service water or drain water from the spent GAC.
- Two hours to transfer the GAC
- One hour cushion

The time to completely change-out one contactor (i.e. remove carbon and replace with new carbon), is estimated to take 6 to 7 days.

4.10. Backwash System

4.10.1. Backwash Supply Pumps

To mitigate drawdown concerns, it is recommended that the backwash pumps either take suction from the clearwell or the GAC feed pump station wet well. The final selection will be determined during final design. The proposed clearwell supply location is the abandoned storage rooms in the filter building located to the southeast of the Clearwell No. 1 hydraulic sluice gate, as shown in Figure 4-15. Either vertical pumps or submersible centrifugal pumps would take suction directly from Clearwell No. 1. The backwash supply line would be routed through the clearwell or the trench between the clearwell and the settling basins, exiting through the south end to connect to the contactor underdrain system for upward fluidization of the GAC bed.

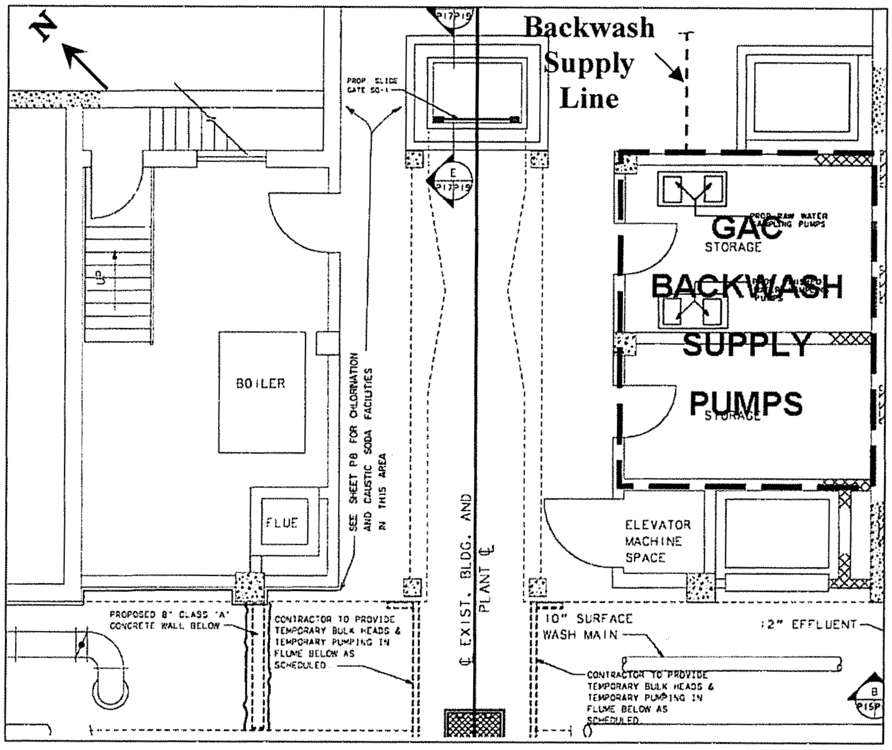

Figure 4-15: Backwash Supply Location

Table 4-9 presents the design parameters for the GAC backwash supply pumps.

Table 4-9.
GAC Backwash Supply Pump Design Criteria

Parameter	Value
No. of Pumps	1 duty, 1 standby
Design Point Pump Flow	19 MGD (one pump, full speed)
Design Point Pump TDH	55 ft (one pump, full speed, low wet well condition) to be finalized during detailed design

The design flow capacity for the backwash supply pumps noted in Table 4-9 (19 MGD) corresponds to a backwash rate of 15 gpm/sf. The GAC suppliers suggest a backwash rate of 11.8 gpm/sf (15 MGD) is adequate to achieve the recommended 30 percent bed expansion. The backwash equalization storage is based on the 19 MGD backwash rate for a duration of 30 minutes. The backwash supply pumps will be sized to accommodate for varying temperatures of the supply water. The effect of water temperature on the backwashing rate is shown in Appendix E.

4.10.2. GAC Backwash Equalization

4.10.2.1. General

GAC contactor backwashes are not expected to generate a significant mass of solids. Calgon Carbon Corporation (Calgon) and Norit Americas Inc. (Norit) were contacted to obtain any available estimates of fines production and recommended parameters for backwashing (*e.g.*, loading rate and duration of backwash). Calgon did not have any fines production information. Norit provided the following information:

- The amount of fines can vary widely, depending on how much rough handling the GAC receives.
- Fines are usually less than 1 percent of the total weight of the shipment.
- Fines are always less than 5 percent of the total weight of the shipment.

Assuming a scenario of 2 percent solids washed out in fines, the solids loading from backwashing a single contactor would be as follows:

2% of (880 sf x 12.0 ft) x 27.5 pounds /cubic foot = 5,808 pounds

All backwash waste will be sent directly to the South reservoir via the GAC Backwash Equalization Basin. Therefore, no additional loading will occur at the Solids Handling Facility.

4.10.2.2. Sizing the GAC Backwash Equalization Basin

The GAC backwash equalization basin provides a means to equalize flow to the reservoir when a GAC contactor is backwashed. The backwash water flows by gravity from the backwash troughs in the GAC contactors to the GAC backwash equalization basin. Two submersible, non-clog centrifugal pumps will be located in the basin to pump the backwash water to the existing South Reservoir.

The GAC backwash equalization basin was sized to accept the volume of one contactor backwash. Assuming the design backwash rate (15 gpm/sf) and duration (30 minutes), approximately 400,000 gallons of backwash waste are generated and sent to the backwash equalization basin. The contactor-to-waste will also be transferred to the GAC backwash equalization basin. Assuming a contactor-to-waste rate (4.3 gpm/sf) and duration (30 minutes), approximately 115,000 gallons of waste volume is generated. Therefore, a 515,000 gallon GAC backwash equalization basin is required. NKWD desires to send filter to waste water to this basin as well. The final selection of the reservoir recycle pumps and final basin sizing will be determined during final design. The GAC backwash equalization basin is proposed to be located beneath the GAC building.

4.11. Contactor-To-Waste

After a GAC contactor is backwashed, flow through the contactor will be reinitiated in contactor-to-waste mode. In this mode, the flow through the contactor will be recycled back to the reservoirs by gravity flow via the GAC backwash equalization basin, located underneath the GAC building. The purpose of recycling the flow is to prevent GAC fines from being washed through the contactor to the finished water piping and reservoirs. However, the amount of fines expected to pass through the contactor underdrains after backwashing is minimal. Therefore, flow will be returned to the reservoirs to avoid the need for substantial additional volume in the Solids Handling Facility and to prevent dilution of thickened solids.

4.12. UV Disinfection Facility

Accommodations are being made for potential inclusion of a UV disinfection process after GAC treatment. The location and conceptual building footprint for this facility are shown on the site plan Figure 4-7. Developing design criteria for a UV disinfection facility was not part of the scope of this project. However, a conceptual layout was required to allocate space on the site for its possible inclusion in the treatment process. A conceptual footprint for the UV disinfection facility was developed using the following information:

- The UV disinfection facility footprint was determined using a layout similar to that used for TMTP.
- Medium pressure (MP) UV lamp reactors were assumed based on a UV dosage of 40 MJ/cm^3. Low pressure high output (LPHO) reactors are also available. Benefits of MP reactors for planning purposes at the FTTP include the following:
- MP reactors have a much smaller footprint than LPHO reactors due to the fewer number of lamps required to achieve inactivation of target organisms.
- Of the major UV reactor manufacturers, only one markets LPHO reactors. Therefore, eliminating LPHO does not significantly limit equipment procurement options.
- O&M is less labor-intensive because of the lower number of lamps required.
- Reactors were preliminarily sized for capacity of 20 MGD each.

Although LPHO UV reactors were not used to develop the process footprint, NKWD may consider LPHO as a candidate UV technology if it is considered for future use. LPHO reactors have their own benefits including the following:

- Lower energy consumption than MP reactors. LPHO reactors emit UV radiation at a wavelength of 254 nanometers, whereas MP reactors emit radiation along the entire UV spectrum.
- Replacement lamps for LPHO reactors are less expensive.

If NKWD decides to implement UV disinfection at FTTP, a more comprehensive evaluation of the process and facility needs will be required. It is anticipated that the UV process can be located with the GAC feed pump station.

4.13. Opinion of Probable Costs

As the preliminary design progressed, a final opinion of probable costs was developed. The cost opinion is considered a Class 3 estimate in accordance AACE and has a predicted accuracy of -20% to +30%.The detailed cost opinion is shown in Table 4-10, and includes the UV disinfection facility.

Table 4-10.
Opinion of Probable Project Costs

Item	Capital Cost ($ Million)
GAC Facilities (Contactor building, site work, GAC PS, EQ Basin)	$33.5
UV Facility	$2.8
Contingency	$7.3
Engineering (Legal, administration)	$5.4
Total	**$49.0**

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[1] Owen, D.M., Z.M. Chowdhury, R.S. Summers, S.M. Hooper, G. Solarik, and K. Grey. 1997. Removal of DBP Precursors by GAC Adsorption. AWWARF.

[2] Malcolm Pirnie, Inc. (MPI). 2007. *Information Collection and Data Review Technical Memorandum.*

[3] Black & Veatch. May 2004. *Asset Management Program Final Report.*

5. MPTP GAC Preliminary Design

As mentioned in Section 1, NKWD will be installing post-filter carbon contactors at the MPTP to comply with the Stage 2 DBP rule. This study investigates the possibilities for installing a GAC facility at the MPTP, paying close attention to plant accessibility and future plant expansion.

5.1. General Information Review

The sizing of the GAC contactors and ultimately the GAC facilities begins with the selection of the appropriate TOC target, and corresponding EBCT to achieve a reasonable carbon change-out frequency. Decisions concerning the MPTP (and the FTTP) were based on existing data for the Ohio River. The data were derived from various sources, including NKWD operating records, a bench-scale GAC performance study that was conducted for the FTTP, an American Water Works Association Research Foundation (AwwaRF) report on removing DBP precursors using GAC, and various reports/records concerning the post-filter contactors at the Richard Miller Water Treatment Plant (Greater Cincinnati Water Works). A detailed analysis of the above information is presented in the *Information Collection and Data Review Technical Memorandum*[1] found in Appendix B.

The MPTP has a design capacity of 10 MGD. Based on a review of the Monthly Operating Reports (MORs) for 2004 through 2006, the current average daily demand is 3.3 MGD and maximum daily demand is 8.1 MGD. Figure 5-1 presents a summary of the information review.

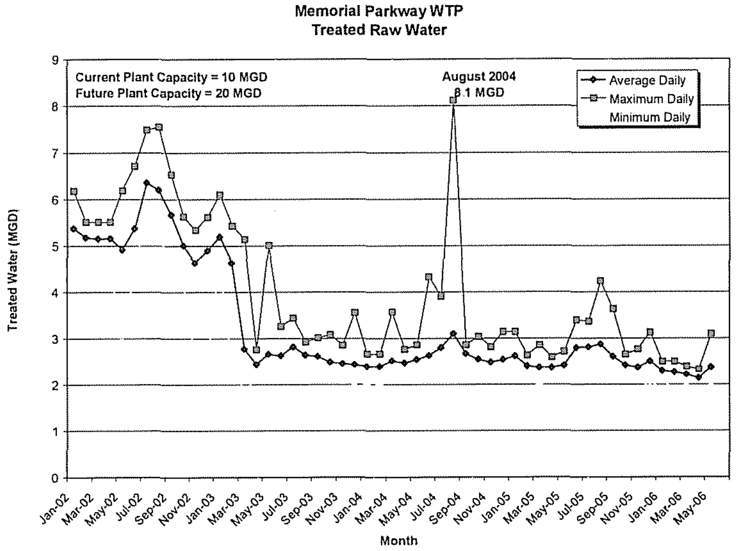


Figure 5-1: MPTP Treated Raw Water (2004 - 2006)

5.2. EBCT Selection

In selecting an EBCT for a GAC system it is important to consider that: a) longer EBCTs generally improve GAC performance, but require greater capital investment (to build larger adsorbers/contactors), and b) shorter EBCTs result in lower capital costs, but increase the GAC change-out frequency. The impacts of EBCT on GAC performance (change-out frequency) can be determined using breakthrough curves for the contaminant of interest. Breakthrough curves show the contaminant concentration in the GAC effluent over time. Various breakthrough curves showing TOC removal from Ohio River water were utilized in selecting an EBCT for the MPTP, along with NKWD's goal to explore a minimum, moderate and aggressive approach to compliance.

Figure 5-2 shows TOC breakthrough profiles for full- and bench-scale contactors with an EBCT (real or simulated) of 15 minutes and that were processed with Ohio River water. The influent TOC concentration for these tests was about 2 mg/L, which is similar to the average TOC level in the finished water at the MPTP during June – November. Figure 5-2 also includes estimated breakthrough profiles for 20- and 25-minute EBCTs. Importantly, the profiles indicate that for a 15-minute EBCT, the effluent TOC concentration reaches 1.0 mg/L after about 100 days of full-scale operation. The time to reach 1.0 mg/L TOC increases to 165 days for a 20-minute EBCT and to 190 days for a 25-minute EBCT. These performance levels would rule out yearly GAC change-outs for a 15-minute EBCT; although it would be possible for 20- and 25-minute EBCTs. Table 5-1 includes the estimated change-out frequencies associated with each EBCT if six contactors are operated in a staggered mode. As discussed in Section 1.5, the GAC change-out cycles for multiple post-filter contactors are commonly staggered so as to maximize the time between change-outs.

Table 5-1.
Estimated Change-out Frequencies Associated with Various EBCTs

EBCT (min)	Yearly change-out possible?	Staggered change-out frequency
15	No	1-2 contactors every 27 days
20	Yes	1-2 contactors every 36-40 days
25	Yes	1-2 contactors every 44-48 days

Notes: Initial assessment assumed a six contactor design with a TOC target of 1.0 mg/L.

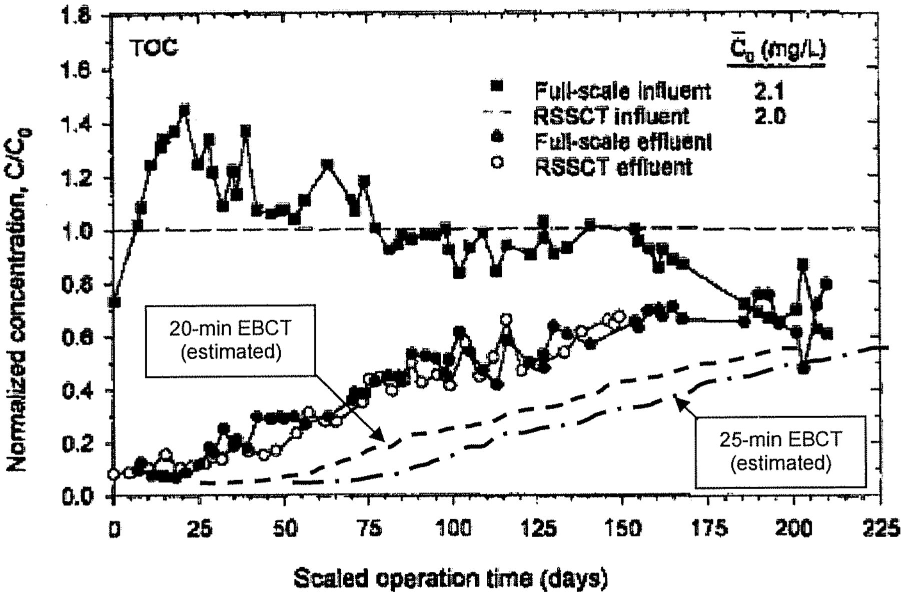


Figure 5-2: TOC Breakthrough Profiles for Bench-scale (RSSCT) Contactors - Ohio River Water

5.3. Minimum/Moderate/Aggressive Approach to Compliance

As discussed in Section 1.3, NKWD adopted the strategy of analyzing treatment objectives based on a Minimum/Moderate/Aggressive approach to sizing the GAC contactors. To aid in determining the appropriate approach to follow at the MPTP, a TOC target, EBCT, and replacement frequency were obtained for each approach using the RSSCT data discussed in Section 3.2 and is summarized in Table 5-1. The EBCT selection for each approach was based on a monthly change-out frequency. Since the GAC design includes six contactors, only change-out frequencies greater than 150 days were considered. This criterion resulted in only one EBCT for each approach as shown in Table 5-2.

Table 5-2.
GAC Treatment Strategies

Approach	Minimum	Moderate	Aggressive
Percent of MCL Permitted for LRAA	100%	80%	60%
Target Maximum TTHM Value on LRAA Basis (mg/L)	80	64	48
Target Maximum HAA5 Value on LRAA Basis (mg/L)	60	48	36
EBCT (min)	15	20	25
TOC Target (mg/L)	1.4	1.25	1.0
Replacement Frequency (days)	230	240-260	250-270

To further aid in the approach selection, high level costs were developed by utilizing cost curves for GAC facilities from a 1997 AWWARF report[2] and escalated to 2009 dollars using current ENR interest projections. The costing tool includes the following:

- Contactor feed pump station
- GAC contactors
- Backwash pump station
- Carbon storage
- 25% contingency

An equalization (EQ) basin is not included in the high level cost assumptions, but would increase relative to the contactor size.

Figures 5-3 and 5-4 depict the results of the cost tool with the various treatment strategies.

Based on the high level costing and the preferences of NKWD to maintain cost effective production and delivery of high quality drinking water, the moderate treatment approach was selected. This resulted in a 20-minute EBCT selection with a TOC target of 1.25 mg/L.

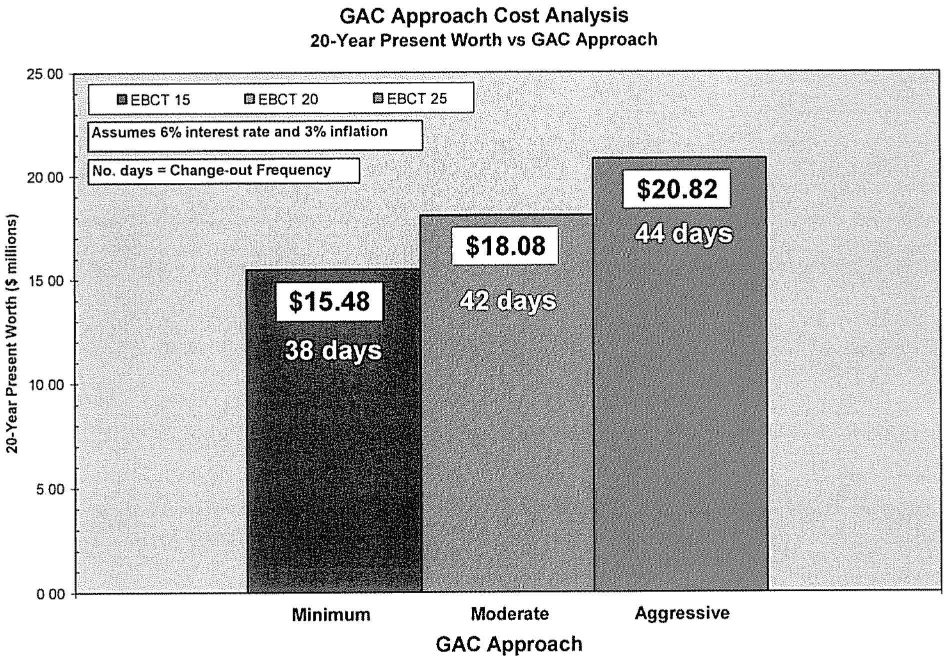


Figure 5-3: GAC Approach Cost Analysis - 20-Year Present Worth

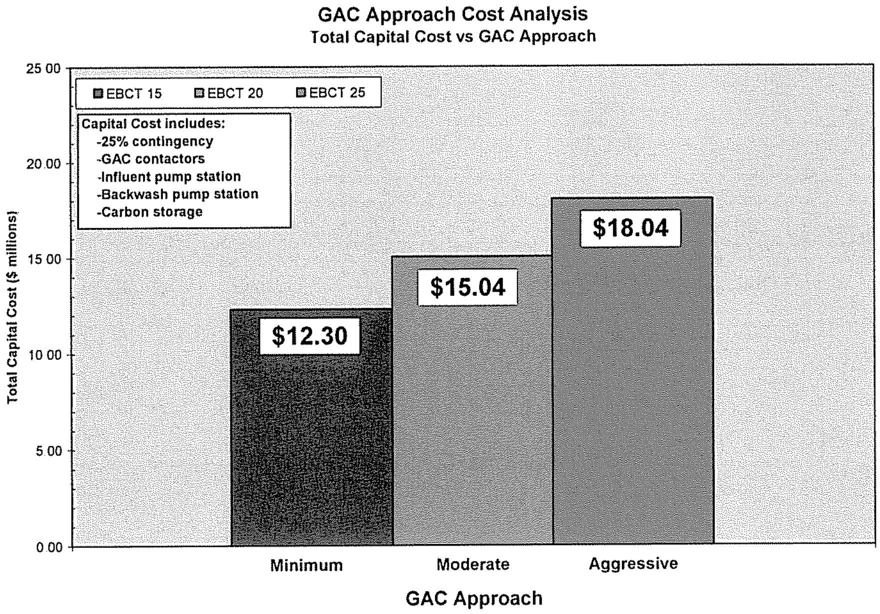


Figure 5-4: GAC Approach Cost Analysis - Total Capital Cost

5.4. General Considerations

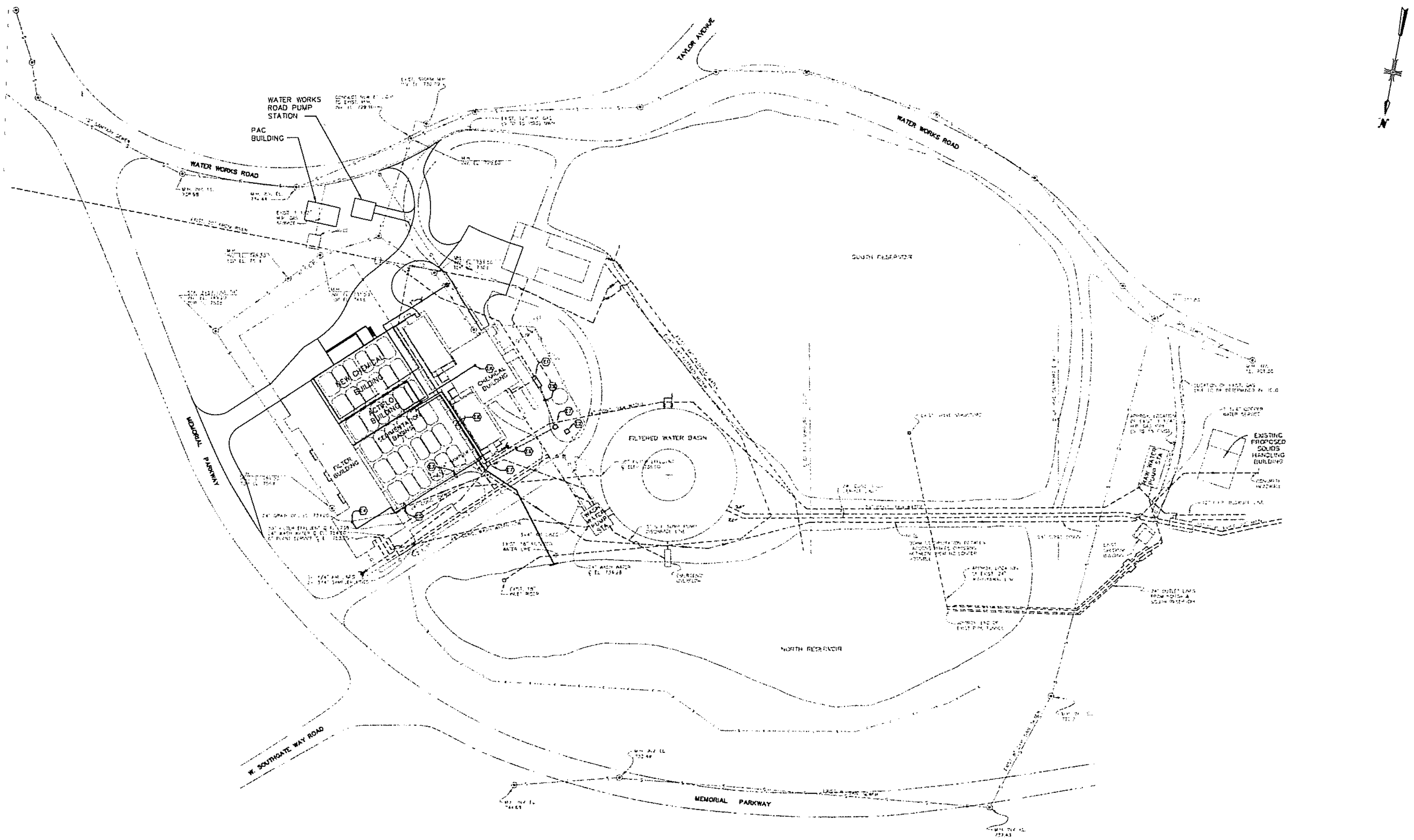
A site plan is shown in Figure 5-5 and the current treatment plant schematic[1] is shown in Figure 5-6. Raw water is conveyed from the Ohio River Pump Station No. 2 to two raw water reservoirs located at the MPTP. Flow from the reservoirs is fed through the Actiflo® process, and then to gravity filtration. After filtration, flow from the six filters is conveyed to a 3.0 MG clearwell.

The new facilities will include the following new structures and subprocesses:

- Tie-in to the Filter Effluent lines
- GAC feed pump station
- Contactors
- Contactor effluent tie-in to clearwell
- Backwash supply pumps
- Contactor-to-waste piping
- Ultraviolet (UV) disinfection facility

The current treatment hydraulic profile[3] for the MPTP is shown in Figure 5-7. Given the hydraulic profile and plant site, only two GAC facility location options were investigated for the GAC facility. Each GAC layout is based on 20-minute EBCT and includes a GAC building housing six contactors, GAC pump station(s), connection to the filter line and to the clearwell, and a UV disinfection facility. The layouts were analyzed based on the following criteria:

- Impact on plant operability during construction
- Provisions for future expansion of plant
- Impact on daily plant operability



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SCALE: 1" = 120'

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MALCOLM PIRNIE

NORTHERN KENTUCKY WATER DISTRICT PRELIMINARY DESIGN OF GAC SYSTEMS
MEMORIAL PARKWAY WATER TREATMENT PLANT

SITE PLAN

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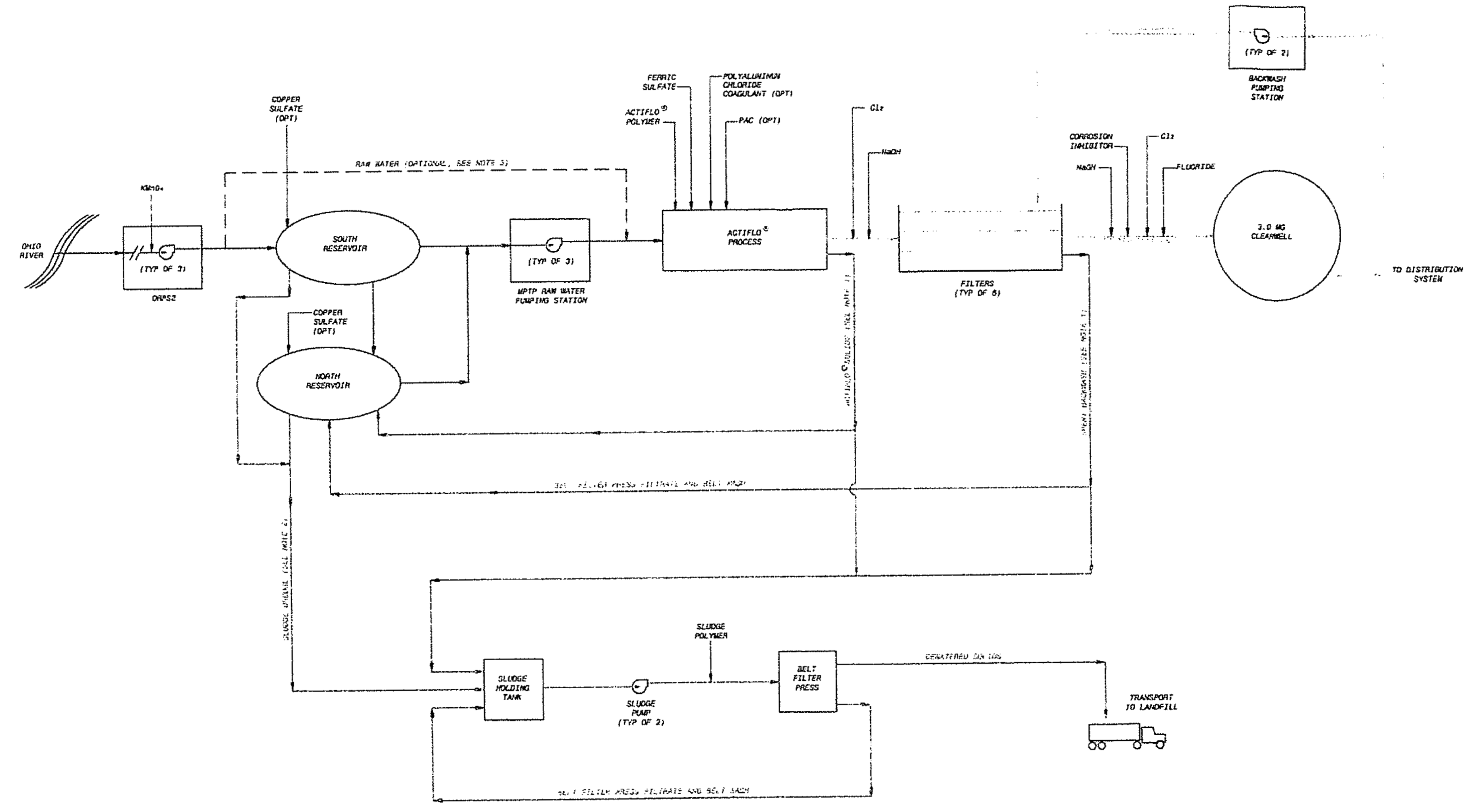
FIGURE 5–5

User:Wells Spec:PIRNIE STANDARD File:I:\4775010\15-CADD\MEMORIAL PKWY\GEN\FIGURE 5-5.DWG Scale:1:1 Date:03/03/2008 Time:12:10 Layout:FIG 5-5



NOTE: SCHEMATIC OBTAINED FROM ASSET MANAGEMENT PROGRAM REPORT, BLACK & VEATCH, MAY 2004.

NOT TO SCALE

PRELIMINARY – NOT FOR CONSTRUCTION

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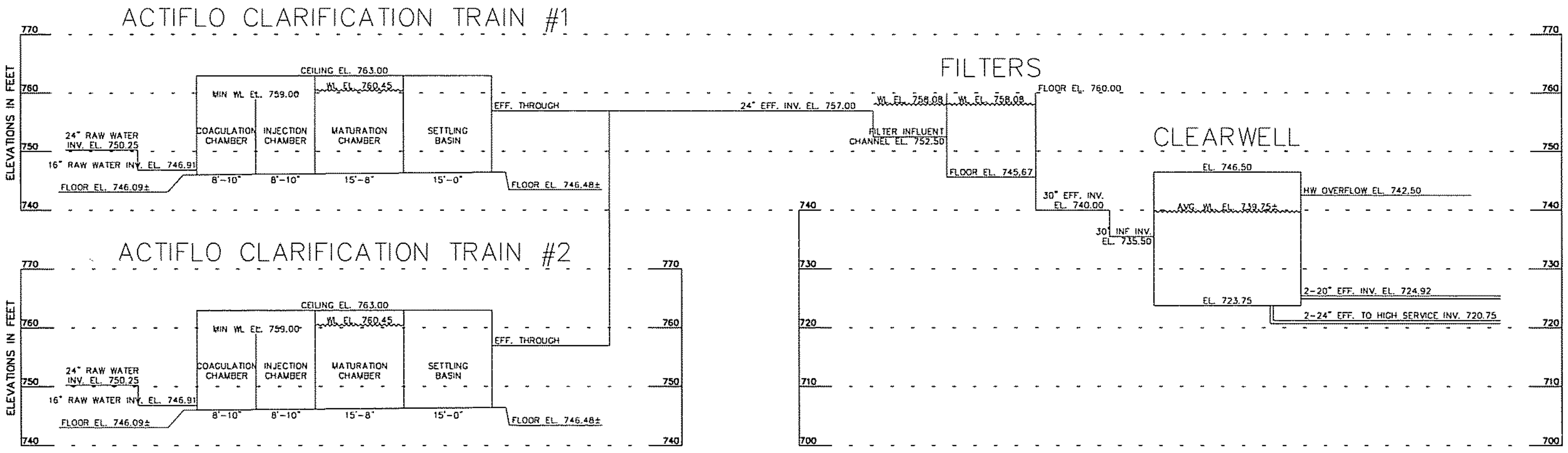
MEMORIAL PARKWAY WATER TREATMENT PLANT

CURRENT TREATMENT SCHEMATIC

MALCOLM PIRNIE, INC.

FIGURE 5–6



HORIZONTAL: NOT TO SCALE
VERTICAL SCALE: ½" = 10'-0"

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NORTHERN KENTUCKY WATER DISTRICT PRELIMINARY DESIGN OF GAC SYSTEMS
MEMORIAL PARKWAY WATER TREATMENT PLANT

CURRENT TREATMENT HYDRAULIC PROFILE

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FIGURE 5-7

5.5. GAC Site Location Alternatives

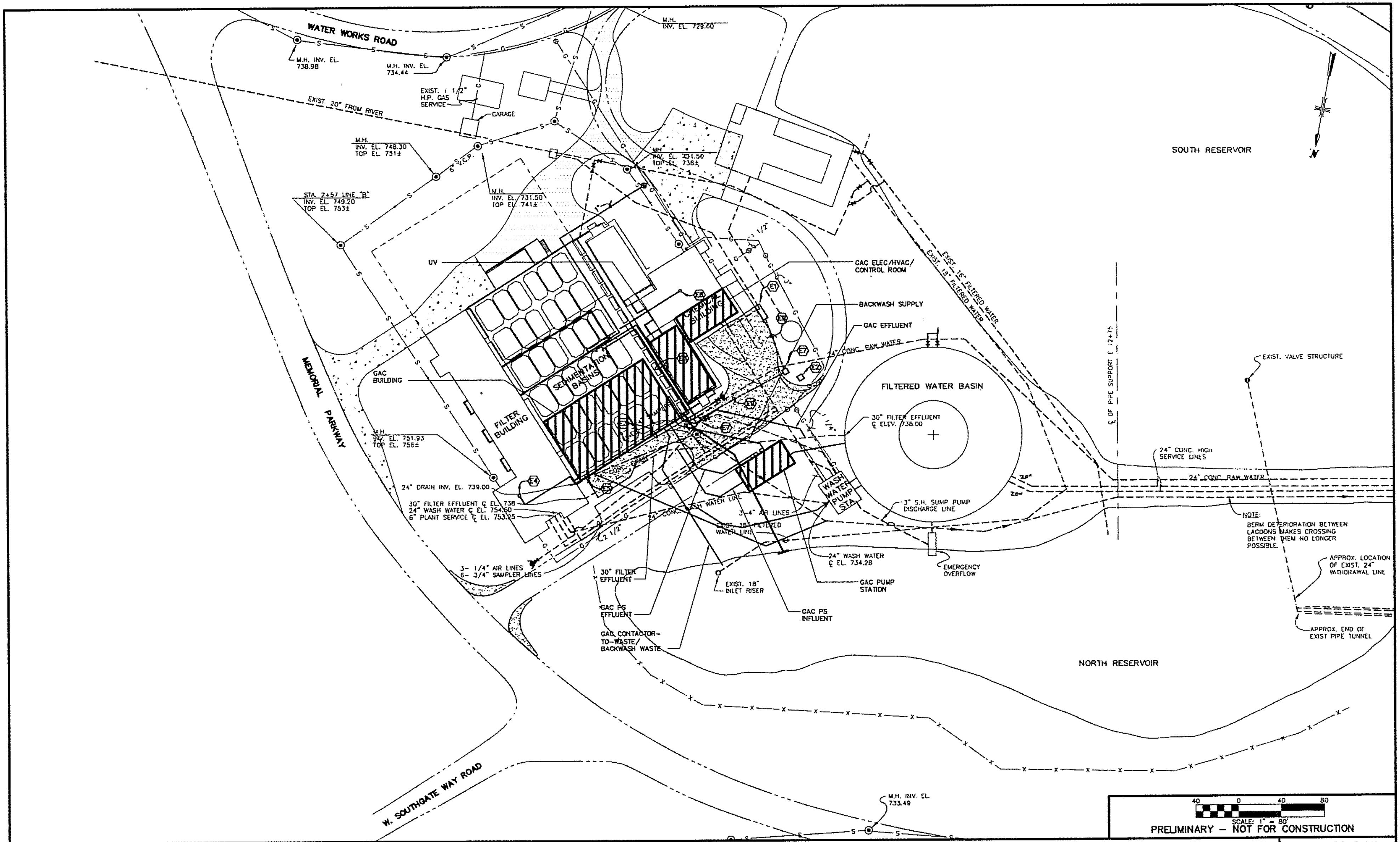
5.5.1. Option 1 – Between Memorial Parkway and Water Works Road

Option 1 consists of constructing the GAC building southeast of the new chemical building between Memorial Parkway and Water Works Road. The filter effluent would be intercepted at the south end of the filter gallery and re-routed to the GAC influent pump station. This option requires no demolition of existing facilities and would have limited plant interruption during carbon change-outs. However, NKWD would like to reserve this location for aesthetics and green space preservation at the site. Another drawback to this option is that it requires large runs of pipe for post filter and clearwell connections. Given these disadvantages, this option was not recommended as the final location for the GAC facility.

5.5.2. Option 2 – Footprint of Sedimentation Basins No. 5 and No. 6

Option 2, shown in Figure 5-8, consists of constructing the GAC building within the footprint of Sedimentation Basins No. 5 and No. 6 (leaving Sedimentation Basin No. 4 for future Actiflo® expansion). For purposes of the preliminary design, the assumption was made that the basins would be completely demolished prior to construction of the GAC facility. During detailed design, the option of reusing all or a portion of the existing basins should be investigated taking into account the structural integrity of the existing walls. These basins were taken out of service in 1997 when the conventional treatment process was replaced with the Actiflo® process. The area available is approximately 7,000 square feet. Within this space, various GAC contactor configurations were considered and are discussed in Section 4.4. The filter effluent would be intercepted at the north end of the filter gallery and re-routed to the GAC influent pump station, which is located east of the clearwell and southeast of the wash water pump station. To the west of Sedimentation Basins No. 5 and No. 6, the out of service flocculation basin was selected as the site for the future UV facility. The existing basin is approximately 65 feet by 30 feet with a 14 foot sidewall depth. Another possible location for the facility would be to co-locate the UV and GAC pump station. Additional space near this basin may be required to house electrical, HVAC, and control facilities for the GAC process. Additional space is also available in the abandoned chemical rooms, located east of the future UV facility. There will be no equalization basin included in the design, as NKWD would like to convey all backwash waste and contactor-to-waste flow directly to the reservoirs.

This is a viable option to consider due to relatively short pipe connections from the filter building and to the clearwell. Also, this option revitalizes out of service locations on site and allows for limited plant interruption during carbon change-outs. For these reasons, this option was chosen as the final recommendation for the GAC facility.



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MEMORIAL PARKWAY WATER TREATMENT PLANT

OPTION 2 GAC LAYOUT

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FIGURE 5–8

5.5.3. Cost Considerations

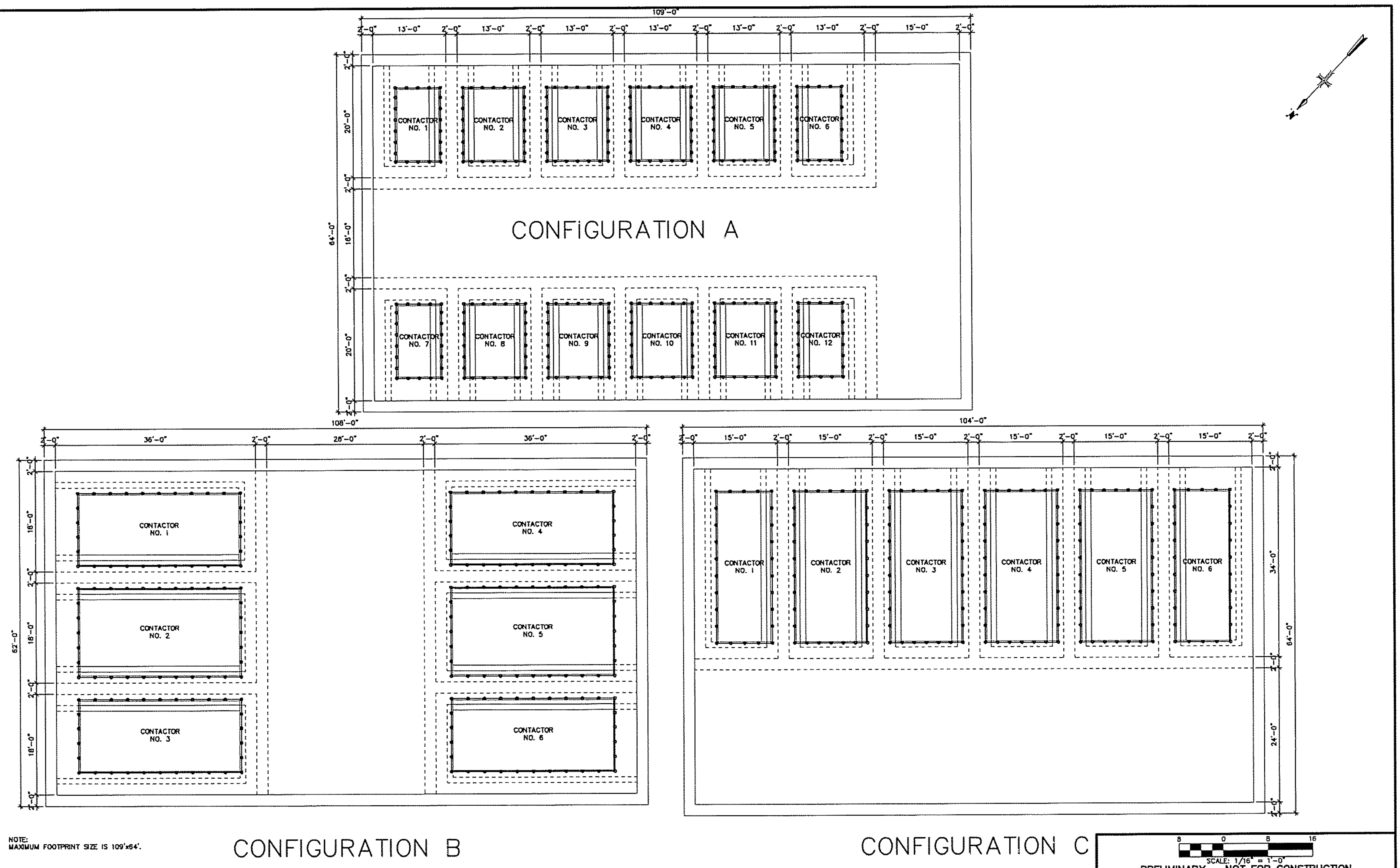
Based on the advantages of each alternative discussed above, NKWD chose to evaluate only Option 2 in further detail. The cost opinion is considered a Class 4 estimate in accordance with the Association for the Advancement of Cost Engineering (AACE) and has a predicted accuracy of -30% to +50%. The detailed cost comparison does not include the UV disinfection facility and is estimated to be approximately $22.1 Million. The details of the cost opinion are included in Appendix C.

5.5.4. Final GAC Site Location Recommendation

After comparing the two options, NKWD selected Option 2, the location which will be constructed within the footprint of Sedimentation Basins No. 5 and No. 6. This option allows ease of accessibility by carbon trucks as well as provides simple connections to both the filter building and clearwell.

5.6. GAC Contactor Configuration Alternatives

Once Option 2 was selected as the location for the GAC facility, three GAC contactor configurations were investigated and are shown in Figure 5-9. Each configuration was designed based on an EBCT of 20 minutes at the future design capacity of 20 MGD and the available footprint of approximately 65 feet by 109 feet.



NOTE:
MAXIMUM FOOTPRINT SIZE IS 109'x64'.

8 0 8 16
SCALE: 1/16" = 1'-0"
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MEMORIAL PARKWAY WATER TREATMENT PLANT

GAC CONTACTOR CONFIGURATION OPTIONS

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FIGURE 5–9

5.6.1. Configuration A

Configuration A, as shown in Figure 5-9, consists of twelve contactors constructed on the north and south sides of the available footprint. The design criteria for Configuration A are shown in Table 5-3.

Table 5-3.
GAC Contactors Design Criteria – Configuration A

Parameter	Value
No. of Contactors	12
Contactor Length (feet)	20
Contactor Width (feet)	13
Surface Area per Contactor (sf)	260
GAC Media Depth (inches to top of underdrain)	144
Design Flow per Contactor at Current Design Capacity (MGD)	1.7
Surface Loading Rate at Current Design Capacity (gpm/sf)	4.5

As stated above, all twelve contactors must be in operation under the future design capacity of 20 MGD in order to obtain a 20 minute EBCT. Under the current design capacity of 10 MGD, Configuration A allows NKWD the flexibility to operate the GAC facility with as little as six contactors to obtain the 20 minute EBCT. This flexibility makes Configuration A a viable option to consider. However, the drawbacks include: option requires difficult piping for carbon transfers, increased maintenance difficulty with location of piping gallery, and increased maintenance expected due to number of contactors. Since other options allow for flexibility during current design capacity, this option was not chosen as the final contactor configuration.

5.6.2. Configuration B

Configuration B, as shown in Figure 5-9, consists of six contactors constructed on the east and west sides of the available footprint. The design criteria for Configuration B are shown in Table 5-4.

Table 5-4.
GAC Contactors Design Criteria - Configuration B

Parameter	Value
No. of Contactors	6
Contactor Length (feet)	36
Contactor Width (feet)	18
Surface Area per Contactor (sf)	648
GAC Media Depth (inches to top of underdrain)	144
Design Flow per Contactor at Current Design Capacity (MGD)	3.3
Surface Loading Rate at Current Design Capacity (gpm/sf)	3.6

For Configuration B, five contactors must be in operation under the future design capacity of 20 MGD in order to obtain a 20 minute EBCT. Running all six contactors will obtain a 25 minute EBCT. The sixth contactor is included in order to obtain a symmetrical layout. Under the current design capacity of 10 MGD, Configuration B allows NKWD the flexibility to operate the GAC facility with as little as three contactors to obtain the 20 minute EBCT. This flexibility makes Configuration B a viable option to consider. However, the drawbacks include: option requires difficult piping for carbon transfers, increased maintenance difficulty with location of piping gallery, and the surface loading rate at the current design capacity is lower than the recommended minimum (3.96 gpm/sf). Since another configuration allows for flexibility during current design capacity, meets the minimum surface loading rate recommendations and does not have added maintenance difficulties, Configuration B was not chosen as the final contactor configuration.

5.6.3. Configuration C

Configuration C, as shown in Figure 5-9, consists of six contactors constructed on the south side of the available footprint. The design criteria for Configuration C are shown in Table 5-5.

Table 5-5.
GAC Contactors Design Criteria - Configuration C

Parameter	Value
No. of Contactors	6
Contactor Length (feet)	34
Contactor Width (feet)	15
Surface Area per Contactor (sf)	510
GAC Media Depth (inches to top of underdrain)	144
Design Flow per Contactor at Current Design Capacity (MGD)	3.3
Surface Loading Rate at Current Design Capacity (gpm/sf)	4.5

For Configuration C, six contactors must be in operation under the future design capacity of 20 MGD in order to obtain a 20 minute EBCT. Under the current design capacity of 10 MGD, Configuration C allows NKWD the flexibility to operate the GAC facility with as little as three contactors to obtain the 20 minute EBCT. This flexibility makes Configuration C a viable option to consider. Also, the configuration for Configuration C allows for the piping gallery to be completed on the north side of the available footprint. This allows for easier maintenance access than the other options. This configuration also allows for straight piping for carbon transfers. Since Configuration C allows for flexibility during current design capacity, does not have added maintenance difficulties, and allows for easier carbon transfers, this option was chosen as the final contactor configuration.

5.6.4. Final GAC Contactor Configuration Recommendation

After comparing the three contactor configuration options, NKWD selected Configuration C, this option allows for easier maintenance, straight piping for carbon transfers, and allows for flexible operation at the current design capacity of 10 MGD.

5.7. Design Criteria and Basic Assumptions

The following assumptions for capacity and redundancy were made in developing the basis of design for the GAC facilities:

- The GAC facility will include 6 GAC contactors.
- Normal operation will provide at least a 20-minute EBCT with all contactors in-service at a maximum production rate of 20 MGD.
- Duty and standby pumps are provided for each of the pumping systems required for these facilities.
- Provisions to enable incorporation of UV disinfection at the future treatment capacity of 20 MGD.

A GAC supplier will provide virgin carbon to the site and truck the spent GAC off-site.

5.8. Design Approach

5.8.1. General Layout

Figure 5-8 presents a site plan of the proposed GAC preliminary design improvements for the MPTP. Filter effluent will be intercepted near the GAC influent pump station. From the pump station, the GAC feed pumps will convey water to the contactors located in the GAC building.

Water will flow through the GAC contactors to a new 30-inch contacted water pipeline to deliver the water to the finished water clearwell.

Provisions to add a UV disinfection process between the GAC contactors and the clearwell at a later date have been included. The UV process would be constructed in the abandoned flocculation basin located west of the GAC facility. The GAC effluent would be rerouted to enter the east side of the UV building prior to entering the clearwell. These provisions will require limited pipe demolition. Another option that could be evaluated during detailed design, is to co-locate the GAC influent pump station and UV facility.

Backwash supply pumps would be located in the GAC feed pump station and draw water from the wetwell. The backwash supply line would be routed to the GAC building following the GAC influent line. Waste backwash water will flow by gravity from the backwash troughs to the North Reservoir.

The contactor facility will be equipped with a contactor-to-waste function. Effluent shut off valves will be utilized to convey contactor-to-waste flow by gravity through piping to the North Reservoir.

GAC facility truck access will be from either the main plant entrance on Memorial Parkway, the secondary plant entrance on Memorial Parkway or the plant entrance from Water Works Road. Trucks entering from the main plant entrance will back into the loading area and then leave by the Water Works Road entrance. Trucks entering from the secondary Memorial Parkway entrance or the Water Works Road entrance will pull into the loading area and back out and leave by the main plant entrance. The loading area will be directly in front of the contactors and will be graded to be flat. Modifications may be required for the existing loading area at the basement of the filter building. The standby generator is anticipated to be replaced in an alternate location as part of the detailed design project.

During detailed design, the final decision will be made whether or not to provide the equipment for all six contactors, or only the three required for the current plant design flow.

5.8.2. GAC Operation Strategy

The GAC contactors will be operated in parallel. Once the finished water TOC set point is approached, a GAC change-out will be required. The preferred method of GAC facility operation is to establish a staggered contactor operating strategy, taking advantage of effluent blending, where the GAC is replaced in one contactor at a time. Similar to series operation of GAC contactors, this approach is taken to utilize the GAC to the maximum extent possible. Section 1 discusses the blending of GAC-contacted water.

Under conditions in which the plant is running at current design capacity (10 MGD), NKWD will have the flexibility to decide how many contactors to have in-service. At least three contactors will have to be in-service to obtain an EBCT of 20 minutes. In this case and the case of four or five contactors in-service, the GAC operation strategy will be as follows. During the GAC changeout event, at least one contactor will be out of service and ready to receive virgin carbon. Spent GAC will be removed from the contactor with the GAC media that has been in-service the longest, while virgin GAC is simultaneously installed in one of the contactors that has been empty and out of service. Once the contactor with virgin GAC is placed into service, the blended effluent TOC concentration will be lower. When the GAC-contacted water again approaches the TOC criterion, the GAC changeout process will be repeated. This strategy will be perpetuated throughout the life of the facility.

Under conditions in which the plant is running at future design capacity (20 MGD), all six contactors will be utilized to obtain an EBCT of 20 minutes. During the GAC change-out event, one contactor will be taken out of service. Spent GAC will be removed from the contactor with the GAC media that has been in service the longest. Following removal of the spent GAC, virgin GAC will be installed in the same contactor and placed into service. Once the contactor is placed into service, the blended effluent TOC concentration will decrease. When the GAC-contacted water again approaches the TOC criterion, the GAC change-out process will be repeated. This strategy will be perpetuated throughout the life of the facility.

5.9. GAC Feed Pump Station

The GAC feed pump station, shown in Figure 5-8, is the source water location for the GAC contactors and supporting facilities. The GAC feed pump station includes the items noted below.

- GAC Feed Pumps: The GAC feed pumps will take suction from a wetwell. Submersible pumps were considered for the preliminary design, but vertical pumps could be used as well. The pumps lift the filtered water to the top of the GAC contactors. Provisions should be included in the detailed design to bypass all or some of the flow through UV.
- GAC Transfer/Service Water Pumps: The GAC transfer/service water pumps are anticipated to be co-located in the GAC feed pump station. The pumps deliver filtered water through a hydropneumatic tank to the GAC building.
- Hydropneumatic Tank: The hydropneumatic tank receives water from the GAC transfer/service water pumps and provides a means to stabilize pressure in the service water line during low system demands and reduces service water pump cycling.

5.9.1. GAC Feed Pumps

The GAC feed pumps will convey water from the GAC feed pump station to the Contactor Inlet Conduit. It is anticipated that an individual discharge line will be provided for each pump. The GAC feed pumps are either submersible or vertical style pumps and will take suction from a wetwell. Each 5 MGD pump will be replaced with a 10 MGD pump as the plant conditions approach the future design capacity of 20 MGD. Table 5-6 presents the design parameters for current conditions (10 MGD) for the GAC feed pumps. Table 5-7 presents the design parameters for the ultimate future design capacity of 20 MGD.

Table 5-6.
GAC Feed Pump Design Criteria – Current Conditions (10 MGD)

Parameter	Value
No. of Pumps	3 (two duty, one standby)
Design Point Pump Flow	5 MGD (two duty) 10 MGD (one standby)
Design Point Pump TDH	40 ft (5 MGD pump, full speed) 42 ft (10 MGD pump, full speed) to be verified during detailed design
Pump Control	VFD

Table 5-7.
GAC Feed Pump Design Criteria - Future Conditions (20 MGD)

Parameter	Value
No. of Pumps	3 (two duty, one standby)
Design Point Pump Flow	10 MGD (two duty, one standby
Design Point Pump TDH	42 ft (10 MGD pump, full speed) to be verified during detailed design
Pump Control	VFD

Table 5-8 summarizes the VFD set points required based on current plant conditions.

Table 5-8.
GAC VFD Set Point Summary

VFD Set Point Description	VFD Set Point Flow Rate (MGD)
Minimum	1.8 (to be verified during detailed design based on final pump selection)
Average	3.2
Maximum	5.0

5.10. GAC Contactors

All six GAC contactors will have the same type of equipment and operational mode as shown in Table 5-9.

Table 5-9.
Design Criteria for GAC Contactors

Parameter	Value
No. of Contactors	6
Contactor Length (feet)	34
Contactor Width (feet)	15
Surface Area per Contactor (sf)	510
GAC Media Depth (inches to top of underdrain)	144
Design Flow per Contactor at Current Design Capacity (MGD)	3.3
Surface Loading Rate at Current Design Capacity (gpm/sf)	4.5

The GAC contactors shall be designed with the following features:

- A 20-minute EBCT at future design capacity with all contactors in-service.
- A dedicated GAC truck transfer station for each contactor equipped with quick-connect fittings, service water supply, GAC transfer air (GAC TA) supply, and a truck waste pipe to drain water from the trucks.
- A dedicated eductor and service water piping and valves in the piping gallery for each contactor to remove spent GAC.
- A wash-down water system with spray nozzles in the contactors to facilitate removal of GAC and flushing out the contactors during spent GAC removal.
- Three feet of freeboard above the normal operating water level to provide excess storage capacity in the process, maintaining operational flexibility.
- Contactor-to-waste capability to recycle GAC contacted water to the head of the plant immediately after a backwash event, preventing fines from being washed into the finished water piping and reservoirs (and possibly into potential future UV reactors, where the fines may inhibit inactivation of Cryptosporidium).
- Turbidity monitors at the discharge end of each contactor.
- Pressure differential transmitters at each contactor to measure headloss through the GAC.
- A sampling station with TOC, UV absorbance at 254 nanometers (UV254), and particle counting analyzers. The sampling station will receive a sample line from each individual contactor and one combined sample line for analysis.
- Low level point probes within each contactor.
- Operating design criteria for the GAC contactors are summarized in Table 5-10.

Table 5-10.
GAC Contactor Operating Parameters

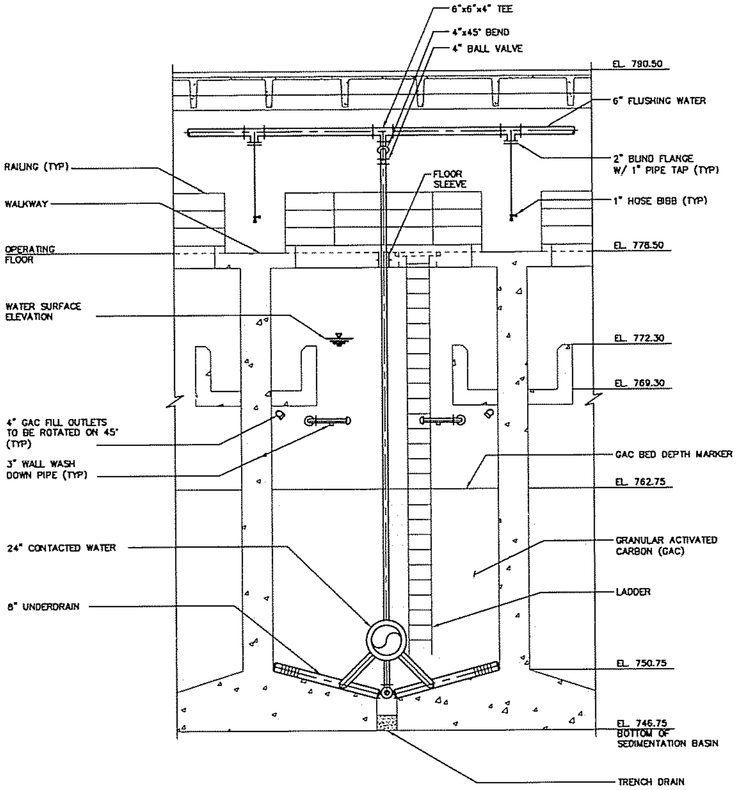
Parameter	Normal Operation	Operation During GAC Change-out
Number of Contactors in Service (20 minute EBCT)		
At WTP Current Capacity (10 MGD)	3	3
At WTP Future Capacity (20 MGD)	6	5
Flow Rate per Contactor (MGD)		
At WTP Current Capacity (10 MGD)	3.3	3.3
At WTP Future Capacity (20 MGD)	3.3	4.0
Surface Loading Rate (gpm/sf)		
At WTP Current Capacity (10 MGD)	4.5	4.5
At WTP Future Capacity (20 MGD)	4.5	5.5
Empty Bed Contact Time (minutes)		
At WTP Current Capacity (10 MGD)	19.8	19.8
At WTP Future Capacity (20 MGD)	19.8	16.5
Design Backwash Duration (minutes)	30	
Design Backwash Rate (gpm/sf)	15	
Design Contactor-to-Waste Duration (minutes)	30	
Design Contactor-to-Waste Rate (gpm/sf)	4.5	

Notes:
Normal operation = No contactors out of service
GAC change-out operation = One equipped contactor out of service

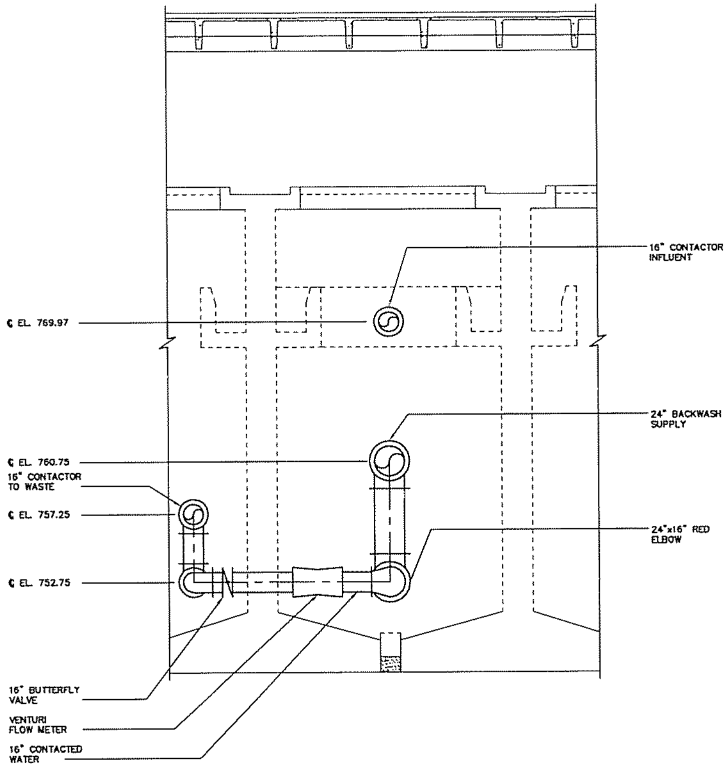
Figure 5-9, Configuration C shows locations of the walkways located on the GAC Building operating floor level. A typical section through a GAC contactor is shown in Figure 5-10. The sections illustrate the following details:

- The GAC-contacted water/backwash supply pipe is located within the contactor.
- Open space has been left along the full length of the pipe gallery to allow for maintenance access. The GAC transfer piping is overhead and out of the way to facilitate access.
- Critical elevations are shown.

User:Nata Spec:PIRNIE STANDARD File:I:\4775010\15-CADD\MEMORIAL PKWY\MECH\FIGURE 5-10.DWG Scale:1:1 Date:03/03/2008 Time:15:13 Layout:FIG 5-10



TYPICAL CONTACTOR SECTION



TYPICAL CONTACTOR PIPING SECTION

NOTE:
GAC CONTACTOR SECTIONS ARE BASED ON THE RECOMMENDED CONTACTOR CONFIGURATION C.

4 0 4 8
SCALE: 1/8" = 1'-0"
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MALCOLM PIRNIE

NORTHERN KENTUCKY WATER DISTRICT PRELIMINARY DESIGN OF GAC SYSTEMS
MEMORIAL PARKWAY WATER TREATMENT PLANT

GAC CONTACTOR SECTIONS

MALCOLM PIRNIE, INC.

FIGURE 5–10

5.10.1. Equipping of GAC Contactors

As discussed previously, each contactor will be filled with GAC to a nominal bed depth of 12.0 feet. During normal operations, water will flow by gravity through the contactor and be collected via the underdrain system. Effluent flow control will be utilized to maintain a constant rate of flow through the contactors. Several styles of underdrains are available for consideration. The preliminary design is based on a wedge-wire style stainless steel underdrain. A-frame style underdrains have also been used successfully for GAC contactors/adsorbers. The final underdrain selection and piping configuration will be determined during final design.

5.10.2. GAC Loading/Unloading Facilities

The contactors will be filled with GAC from manufacturers' delivery trucks. Delivery trucks will carry 20,000 to 40,000 pounds of dry GAC to the site. Filling one contactor will require nine 20,000-pound deliveries or five 40,000-pound deliveries. The GAC transfer station at each contactor will be equipped with the following:

- A service water line with a quick connect fitting to provide water to fluidize the virgin GAC. The GAC manufacturers have stated they require approximately 4,000 to 6,000 gallons of water per 20,000-pound shipment. Water must be provided to the tanker truck at a rate of at least 100-200 gpm (to maintain a minimal filling time for the tanker).
- A GAC fill line with quick connect fitting and knife gate valve.
- A spent GAC line with quick connect fitting and knife gate valve to deliver spent GAC to empty tanker trucks.
- Compressed air with a quick connect fitting will provide air pressure to the tanker trucks for GAC transfer. GAC transfer air requirements are approximately 200 standard cubic feet per minute (SCFM) at 15 psig (per GAC suppliers).
- A GAC truck waste line with knife gate valve and quick connect fitting. After delivery of spent GAC to the delivery truck, the transfer water can be drained out of the truck through this line and into the backwash waste line that drains to the North Reservoir.

The spent GAC line will deliver fluidized GAC to an empty tanker truck from each contactor using a jet water eductor. The eductors will be sized to fill a tanker truck with 20,000 pounds of wet carbon (drained weight) in approximately 4 hours. GAC removal from the contactors will be assisted by a sidewall wash-down system consisting of spray nozzles mounted below the backwash troughs.

The time required to place one truckload of carbon into a contactor was estimated as 4 hours. This number includes the following:

- One hour to fill the GAC delivery truck with 6,000 gallons of service water or drain water from the spent GAC.
- Two hours to transfer the GAC
- One hour cushion

The time to completely change-out one contactor (i.e. remove carbon and replace with new carbon), is estimated to take 3 to 4 days.

5.11. Backwash System

5.11.1. Backwash Supply Pumps

To mitigate drawdown concerns, it is recommended that the backwash pumps either take suction from the clearwell or the GAC pump station wetwell. The final selection will be determined during final design. The backwash supply line would be routed to connect to the contactor underdrain system for upward fluidization of the GAC bed. Table 5-11 presents the design parameters for the GAC backwash supply pumps.

Table 5-11.

GAC Backwash Supply Pump Design Criteria

Parameter	Value
No. of Pumps	1 duty, 1 standby
Design Point Pump Flow	11 MGD (one pump, full speed)
Design Point Pump TDH	45 ft (one pump, full speed, low clearwell condition) to be finalized during detailed design

The design flow capacity for the backwash supply pumps noted in Table 5-11 (11 MGD) corresponds to a backwash rate of 15 gpm/sf. The GAC suppliers suggest a backwash rate of 11.8 gpm/sf (8.6 MGD) is adequate to achieve the recommended 30 percent bed expansion. The backwash supply is based on the higher backwash rate as recommended by the GAC suppliers for a duration of 30 minutes. The backwash supply pumps will be sized to accommodate for varying temperatures of the supply water. The effect of water temperature on the backwashing rate is shown in Appendix E.

5.11.2. Backwash Waste

GAC contactor backwashes are not expected to generate a significant mass of solids. Calgon and Norit were contacted to obtain any available estimates of fines production and recommended parameters for backwashing (*e.g.*, loading rate and duration of backwash). Calgon did not have any fines production information, but Norit provided the following information:

- The amount of fines can vary widely, depending on how much rough handling the GAC receives.
- Fines are usually less than 1 percent of the total weight of the shipment.
- Fines are always less than 5 percent of the total weight of the shipment.

Assuming a scenario of 2 percent solids washed out in fines, the solids loading from backwashing a single contactor would be as follows:

2% of (510 sf x 12.0 ft) x 27.5 pounds /cubic foot = 3,366 pounds

All backwash waste will be sent directly to the North Reservoir.

5.12. Contactor-To-Waste

After a GAC contactor is backwashed, flow through the contactor will be reinitiated in contactor-to-waste mode. In this mode, the flow through the contactor will be recycled to the North Reservoir by gravity flow. The purpose of recycling the flow is to prevent GAC fines from being washed through the contactor to the finished water piping and reservoirs. However, the amount of fines expected to pass through the contactor underdrains after backwashing is minimal.

5.13. UV Disinfection Facility

Accommodations are being made for potential future inclusion of a UV disinfection process after GAC treatment. The location and conceptual building footprint for this facility are shown on the site plan Figure 5-9. Developing design criteria for a UV disinfection facility was not part of the scope of this project. However, a conceptual layout was required to allocate space on the site for its future inclusion in the treatment process. A conceptual footprint for the UV disinfection facility was developed using the following information:

- The UV facility footprint was determined using a layout similar to that used for TMTP.
- Medium pressure (MP) UV lamp reactors were assumed. Low pressure high output (LPHO) reactors are also available. Benefits of MP reactors for planning purposes at the MPTP include the following:
  - MP reactors have a much smaller footprint than LPHO reactors due to the fewer number of lamps required to achieve inactivation of target organisms.
  - Of the major UV reactor manufacturers, only one markets LPHO reactors. Therefore, eliminating LPHO does not significantly limit equipment procurement options.
  - O&M is less labor-intensive because of the lower number of lamps required.
- Reactors were preliminarily sized for capacity of 20 MGD each.

Although LPHO UV reactors were not used to develop the process footprint, NKWD may consider LPHO as a candidate UV technology if it is considered for future use. LPHO reactors have their own benefits including the following:

- Lower energy consumption than MP reactors. LPHO reactors emit UV radiation at a wavelength of 254 nanometers, whereas MP reactors emit radiation along the entire UV spectrum.
- Replacement lamps for LPHO reactors are less expensive.

Additional yard piping and valves will be required if UV is added in the future. Spool pieces are shown in the locations where valves would be required in piping runs being installed with the GAC facilities: These valves will facilitate bypassing of GAC or UV if the need arises.

If NKWD decides to implement UV disinfection at MPTP, a more comprehensive evaluation of the process and facility needs will be required.

5.14. Opinion of Probable Costs

As the preliminary design progressed, a final opinion of probable costs was developed. The cost opinion is considered a Class 3 estimate in accordance AACE and has a predicted accuracy of -20% to +30%.The detailed cost opinion is shown in Table 5-12, and includes the UV disinfection facility.

Table 5-12.
Opinion of Probable Project Costs

Item	**Capital Cost ($ Million)**
GAC Facilities (Contactor building, site work, GAC PS, EQ Basin)	$18.5
UV Facility	$2.3
Contingency	$4.1
Engineering (Legal, administration)	$3.1
Total	**$28.0**

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[1] Malcolm Pirnie, Inc. (MPI). 2007. *Information Collection and Data Review Technical Memorandum.*

[2] Owen, D.M., Z.M. Chowdhury, R.S. Summers, S.M. Hooper, G. Solarik, and K. Grey. 1997. Removal of DBP Precursors by GAC Adsorption. AWWARF.

[3] Black & Veatch. May 2004. *Asset Management Program Final Report.*

6. TMTP GAC Preliminary Design

As mentioned in Section 1, NKWD will be installing post-filter carbon contactors at the TMTP to comply with the Stage 2 D/DBP rule. This study investigates the possibilities for installing a GAC facility at the TMTP paying close attention to plant accessibility.

6.1. General Information Review

The sizing of the GAC contactors and ultimately the GAC facilities begins with the selection of the appropriate TOC target, and corresponding EBCT to achieve a reasonable carbon change-out frequency. To develop this relationship for the TMTP, which uses the Licking River as its source water, data were derived through RSSCT and SDS testing. Since no previous data were available for the Licking River as was for the Ohio River, NKWD performed the testing. In order to capture both the low TOC months (spring/winter) and the high TOC months (summer/fall), two phases of the testing were conducted.

The TMTP has a design capacity of 10 MGD. Based on a review of the Monthly Operating Reports (MORs) for 2004 through 2006, the current average daily demand is 5.3 MGD. The typical minimum daily flow is between 6 and 8 MGD, however, minimum daily flows can be less than 2 MGD on days where the plant does not operate for a full day. Figure 6-1 presents a summary of the information review.

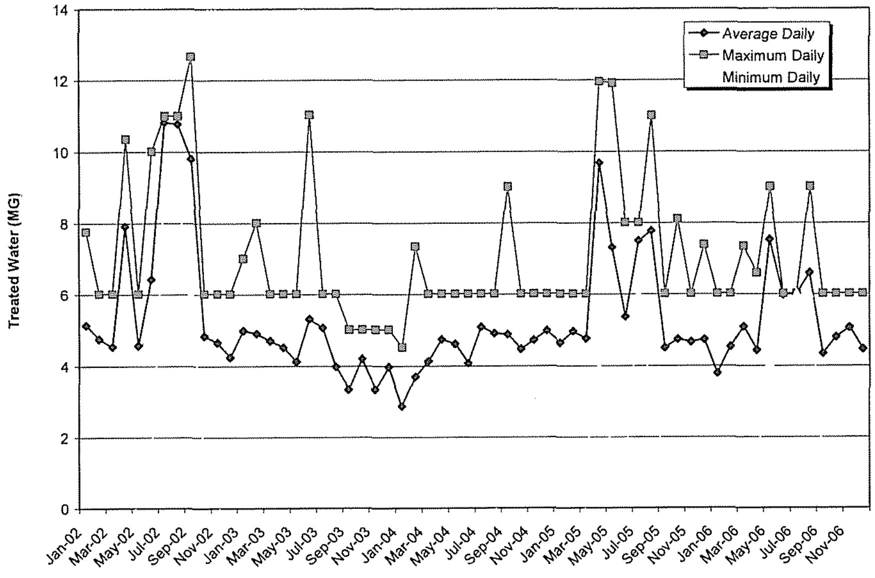


Figure 6-1: TMTP Treated Raw Water (2004 - 2006)

6.2. EBCT Selection

In selecting an EBCT for a GAC system it is important to consider that: a) longer EBCTs generally improve GAC performance, but require greater capital investment (to build larger adsorbers/contactors), and b) shorter EBCTs result in lower capital costs, but increase the GAC change-out frequency. The impacts of EBCT on GAC performance (change-out frequency) can be determined using breakthrough curves for the contaminant of interest. Breakthrough curves show the contaminant concentration in the GAC effluent over time. Various breakthrough curves showing TOC removal from Licking River water were utilized in selecting an EBCT for the TMTP, along with NKWD's goal to explore a minimum, moderate and aggressive approach to compliance.

Figure 6-2 shows TOC breakthrough profiles for Licking River water that were generated during the Phase 2 bench-scale GAC evaluation for the TMTP. The profiles were developed using miniature GAC contactors according to the "rapid small-scale column test" (RSSCT) protocol. RSSCTs are commonly used to simulate full-scale breakthrough performance and various studies have confirmed that RSSCT data are highly reliable.

The data points in Figure 6-2 demonstrate the performance associated with 15- and 20-minute EBCTs. The results depict the GAC performance that could be expected (at TMTP) during the warmer months, with a TOC of 3.0 mg/L. The data in the figure and the corresponding change-out frequencies are based on complete carbon replacement.

As discussed in Section 3, the GAC change-out cycles for multiple post-filter contactors are commonly staggered so as to maximize the time between change-outs. Figure 6-3 shows the 20-minute breakthrough data from Figure 6-2, as well as "multi-contactor" TOC profiles that indicate the optimal change-out frequencies if six or more contactors are operating in staggered mode. A summary of the estimated change-out frequencies associated with 15-, 20-, and 25-minute EBCTs for staggered replacement is provided in Table 6-1.

Table 6-1.
Estimated Change-out Frequencies Associated with Various EBCTs

EBCT (min)	Staggered Change-out Frequency
15	17
20	23
25	28

Notes: Initial assessment assumed a six contactor design with a TOC target of 1.1 mg/L.

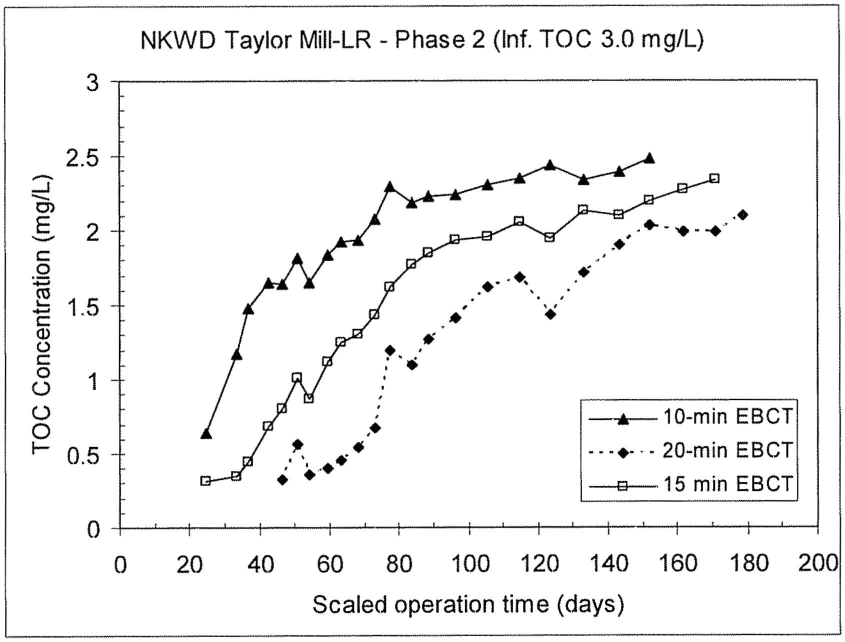


Figure 6-2: TOC Breakthrough as Scaled Operation Times - Phase 2

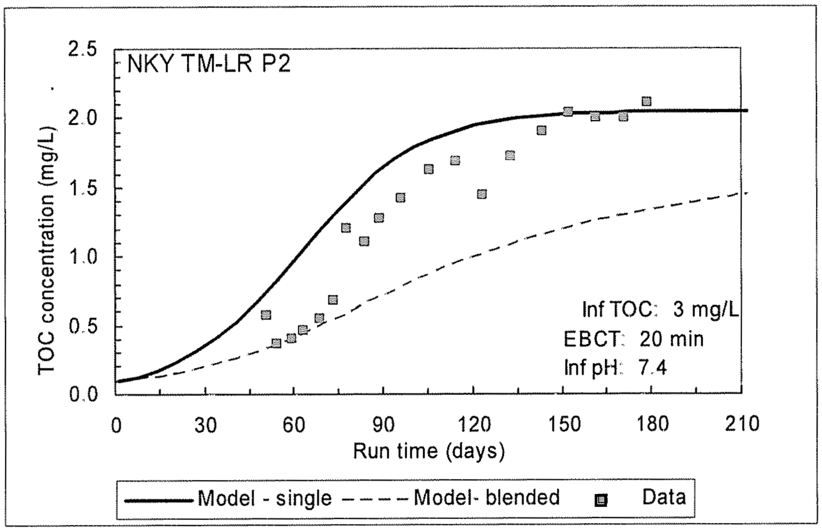


Figure 6-3: TOC Breakthrough as Scaled Operation Time with Staggered Operation Prediction (20- min EBCT) - Phase 2

6.3. Minimum/Moderate/Aggressive Approach to Compliance

As discussed in Section 1.3, NKWD adopted the strategy of analyzing treatment objectives based on a Minimum/Moderate/Aggressive approach to sizing the GAC contactors. To aid in determining the appropriate approach to follow at the TMTP, a TOC target, EBCT, and replacement frequency were obtained for each approach using the RSSCT data and is summarized in Table 6-2. The EBCT selection for each approach was based on a monthly change-out frequency.

Table 6-2.
GAC Treatment Approaches

Approach	Minimum	Moderate	Aggressive
Percent of MCL Permitted for LRAA	100%	80%	60%
Target Maximum TTHM Value on LRAA Basis (mg/L)	80	64	48
Target Maximum HAA5 Value on LRAA Basis (mg/L)	60	48	36
EBCT (min)	15	20	25
TOC Target (mg/L)	1.4	1.1	0.9
Replacement Frequency (days)	150	135	130

To further aid in the approach selection, high level costs were developed by utilizing cost curves for GAC facilities from a 1997 AWWARF report[1] and escalated to 2009 dollars using current ENR interest projections. The costing tool includes the following:

- Contactor feed pump station
- GAC contactors
- Backwash pump station
- Carbon storage
- 25% contingency

An equalization (EQ) basin is not included in the high level cost assumptions, but would increase relative to the contactor size.

Figures 6-4 and 6-5 depict the results of the cost tool with the various treatment strategies.

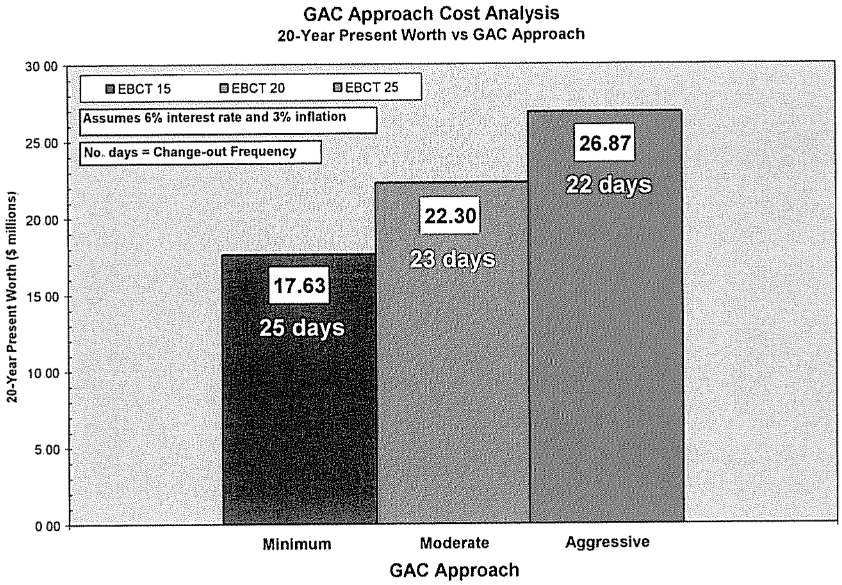


Figure 6-4: GAC Approach Cost Analysis - 20-Year Present Worth

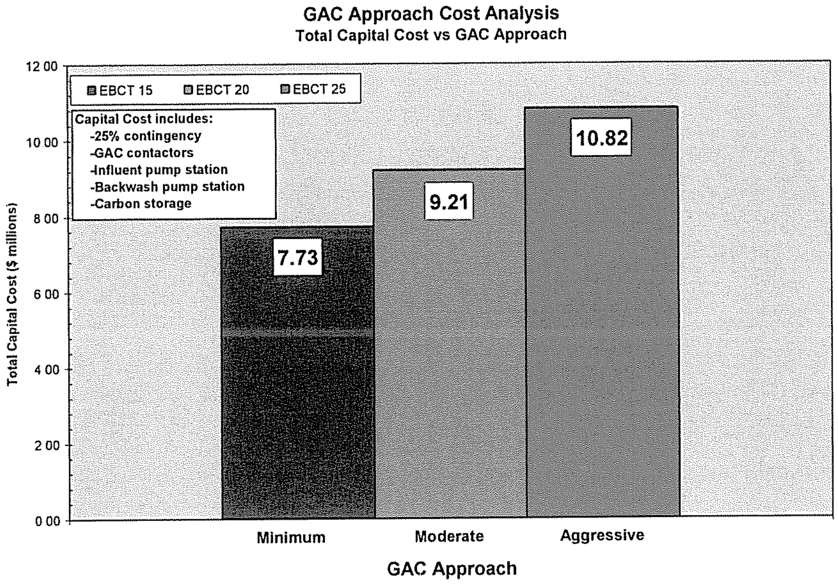


Figure 6-5: GAC Approach Cost Analysis - Total Capital Cost

Based on the high level costing and the preferences of NKWD to maintain cost effective production and delivery of high quality drinking water, the moderate treatment approach was selected. This resulted in a 20-minute EBCT selection with a TOC target of 1.1 mg/L.

6.4. General Considerations

A site plan is shown in Figure 6-6 and the current treatment plant schematic[1] is shown in Figure 6-7. The existing site has open and available land to the west of the current plant layout. Improvements to the sedimentation and flocculation basins have been proposed and include the addition of plate settler basins and new flocculation basins. The recommended improvements are detailed in Appendix F of this report. These improvements will affect the layout of the GAC facility and are important to note as facility locations are analyzed. The recent addition of UV reactors in the Filter Building also needs to be considered when the tie-in locations are being determined.

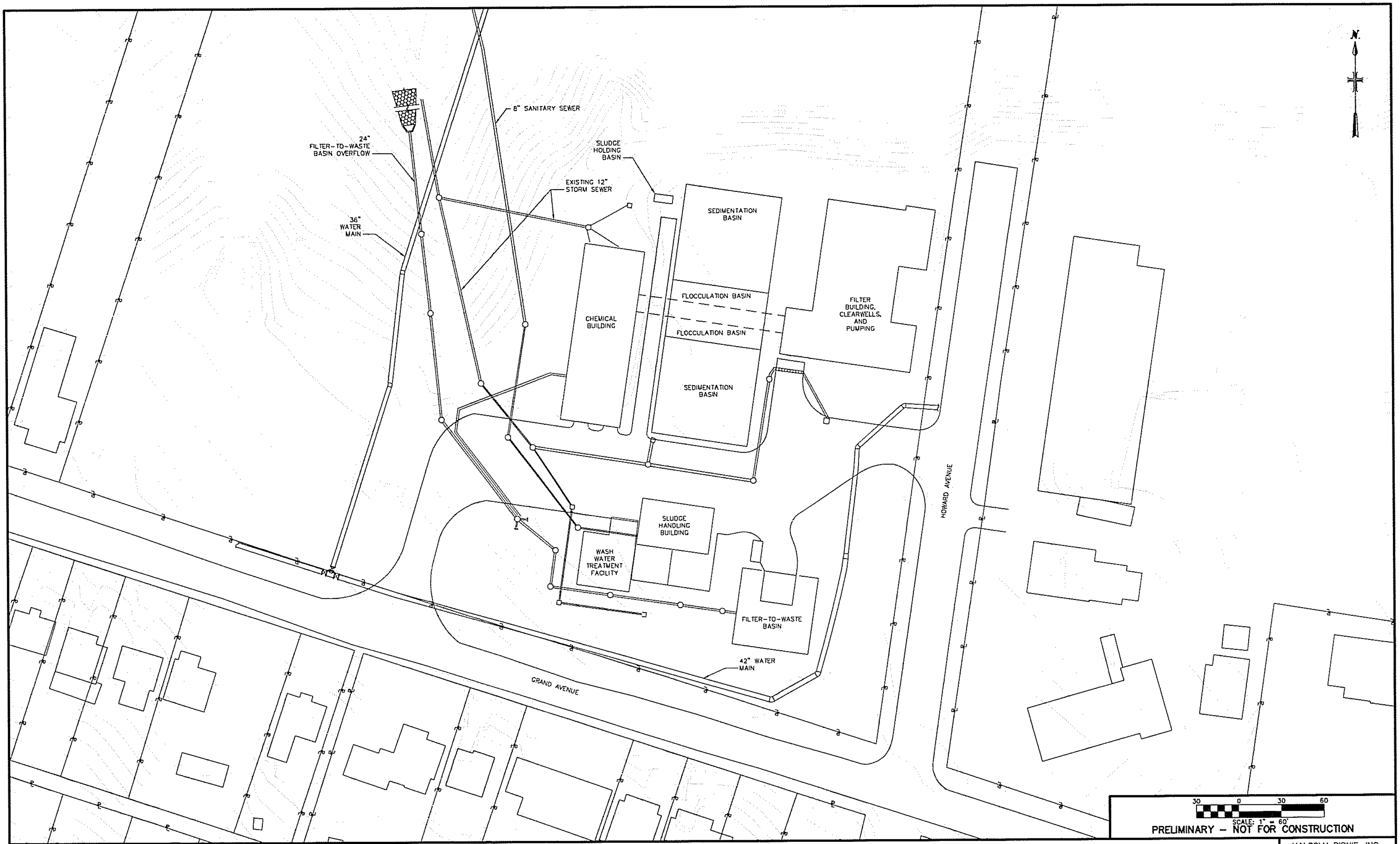
Raw water is conveyed from the Licking River pump station to the TMTP and is fed to a rapid mix basin. Flow from the rapid mix basin is fed to the flocculation/sedimentation process, and then to gravity filtration. After filtration, flow from Filters 1-8 is conveyed to the 1.0 MG Clearwell. The current treatment hydraulic profile[2] for the TMTP is shown in Figure 6-8.

The new facilities will include the following new structures and subprocesses:

- Tie-in to the Filter Effluent lines
- GAC feed pump station
- Contactors
- Contactor effluent tie-in to UV and clearwells
- Backwash supply pumps
- Backwash equalization facility, equipped with reservoir feed pumps
- Contactor-to-waste piping

Given the hydraulic profile, plant site constraints and new facilities required, two GAC alternatives were presented to NKWD. Each GAC design is based on 20-minute EBCT. Each layout includes a GAC building, GAC feed pump station(s), backwash basin, backwash pumping and connections from the filter building and to the clearwell (with connections to the UV reactors). The layouts were analyzed based on the following criteria:

- Impact on nearby residents (both during construction and daily operations)
- Impact on daily plant operability
- Time associated with carbon transfers



PRELIMINARY – NOT FOR CONSTRUCTION

MALCOLM PIRNIE

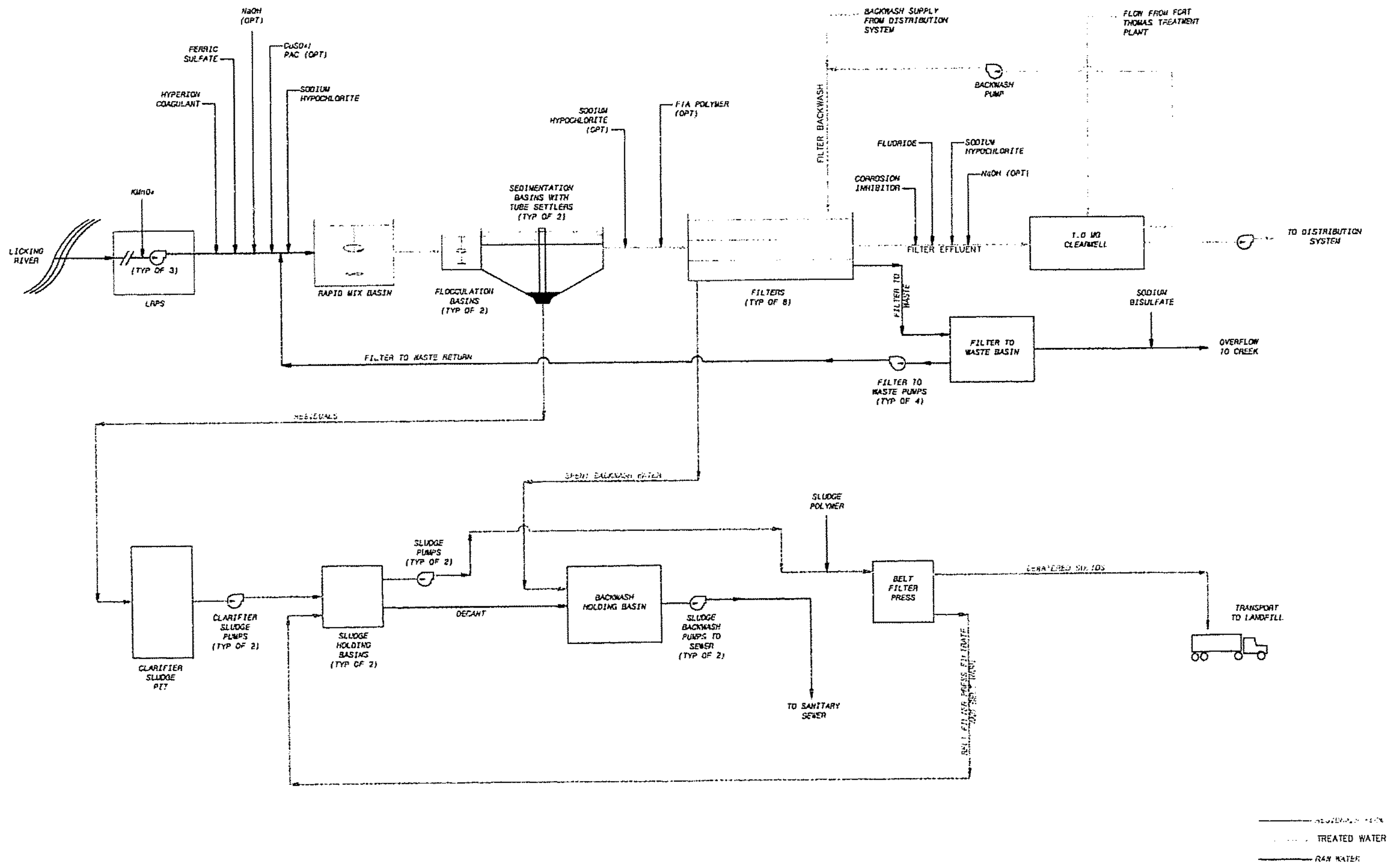
NORTHERN KENTUCKY WATER DISTRICT PRELIMINARY DESIGN OF GAC SYSTEMS
TAYLOR MILL WATER TREATMENT PLANT

SITE PLAN

MALCOLM PIRNIE, INC.

FIGURE 6–6

User:HORLANDER Spec:PIRNIE STANDARD File:\4775010\15-CADD\TAYLOR MILL\GEN\(FIG 6-6) TM-GAC EXISTING SITE PLAN.DWG Scale:1:1 Date:03/04/2008 Time:08:20 Layout:FIG 6-6



NOTE: SCHEMATIC OBTAINED FROM ASSET MANAGEMENT PROGRAM REPORT, BLACK & VEATCH, MAY 2004.

NOT TO SCALE

PRELIMINARY – NOT FOR CONSTRUCTION

MALCOLM PIRNIE

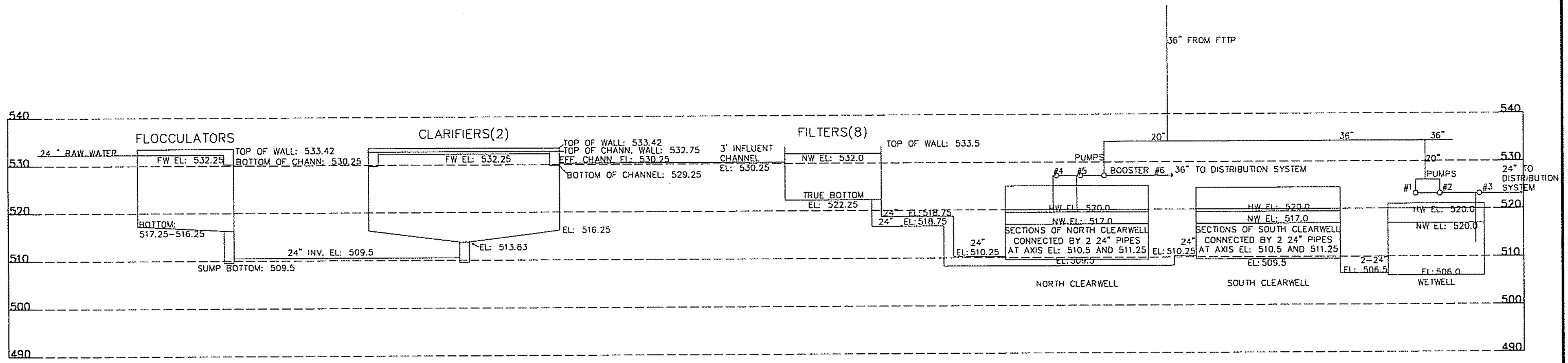
NORTHERN KENTUCKY WATER DISTRICT PRELIMINARY DESIGN OF GAC SYSTEMS
TAYLOR MILL WATER TREATMENT PLANT

CURRENT TREATMENT SCHEMATIC

MALCOLM PIRNIE, INC.

FIGURE 6–7

User:Wells Spec:PIRNIE STANDARD File:I:\4775010\15-CADD\TAYLOR MILL\CEN\(FIG 6-7) TM-SCHEMATIC.DWG Scale:1:1 Date:03/03/2008 Time:12:29 Layout:FIG 6-7



NOTE:
HW EL = HIGH WATER ELEVATION
NW EL = NORMAL WATER ELEVATION
FW EL = FREE WATER ELEVATION

HORIZONTAL: NOT TO SCALE
VERTICAL SCALE: ½" = 10'-0"
PRELIMINARY – NOT FOR CONSTRUCTION

MALCOLM PIRNIE

NORTHERN KENTUCKY WATER DISTRICT PRELIMINARY DESIGN OF GAC SYSTEMS
TAYLOR MILL WATER TREATMENT PLANT

CURRENT TREATMENT HYDRAULIC PROFILE

MALCOLM PIRNIE, INC.

FIGURE 6–8

6.5. GAC Alternatives

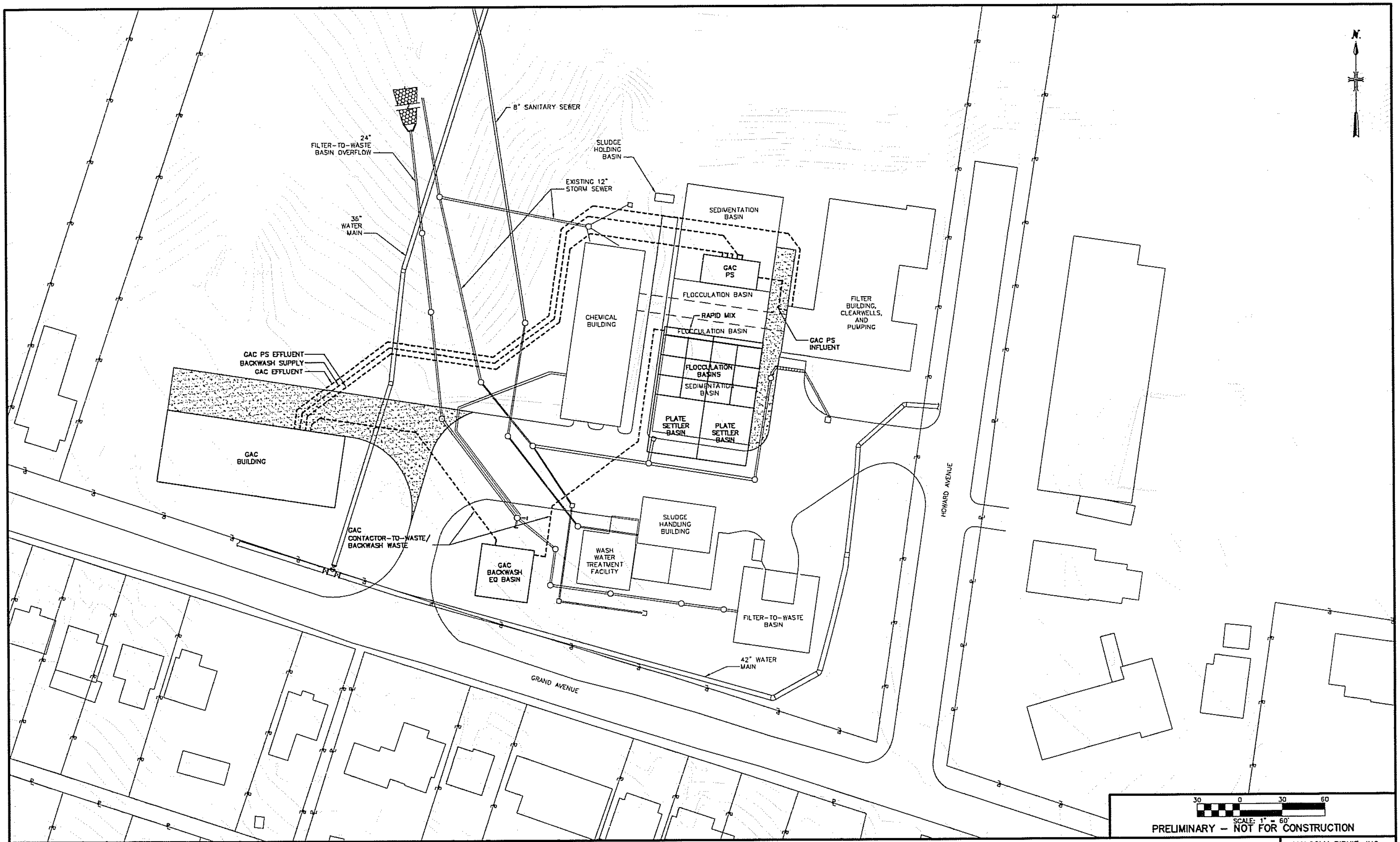
Based on the amount of space available and the relatively small capacity of the plant, both gravity concrete basin-style GAC contactors (as designed for both the FTTP and the MPTP) and vessel-style GAC contactors were investigated. Each layout was designed in the same location (west of the current treatment facilities) and is described in more detail below.

6.5.1. Option 1 – Basin-Style Contactors

Option 1, shown in Figure 6-9, consists of constructing the GAC building to the west of the current treatment facilities. This GAC building would house six basin-style contactors similar to those designed for the FTTP and the MPTP. The filter effluent would be intercepted in the filter building before entering the UV reactors and then would be re-routed to the GAC feed pump station. The station is located adjacent to the proposed flocculation basin improvement. This option allows for easy access by carbon tanker trucks and has a slightly smaller footprint than the vessel-style contactors. It is estimated that contactor unloading/loading will take approximately two to three days. However, the hydraulic profile limits the depth of the building, resulting in a relatively tall structure. Due to geotechnical considerations and slope stability in the area, the structure would require a pile-supported foundation. It is assumed that the building will be of brick construction to match the existing facilities.

6.5.2. Option 2 – Vessel-Style Contactors

Option 2, shown in Figure 6-10, also consists of constructing the GAC building to the west of the current treatment facilities. This GAC building would house 28 pressurized carbon steel contactors designed specifically for post-filtration GAC adsorption facilities. The filter effluent would be intercepted in the filter building before entering the UV reactors and then would be re-routed to the GAC feed pump station. The station is located adjacent to the proposed flocculation basin improvement. This option allows for easy access by carbon tanker trucks, allows for a shorter carbon transfer time due to the pressurized contactors, and provides cover for the loading/unloading procedure. It is anticipated that the carbon tanker trucks will pull into the building to load/unload carbon. A single truck is required per vessel. The unloading/loading procedure is estimated to take one to two hours per vessel for this arrangement. The overall building height is less for this option as the vessels are pressurized. Also, with the exception of piping, this option does not require extensive excavation. However, the building would require piles for structural support. It is assumed that the building will be of brick construction to match the existing facilities. The greater number of valves and actuators for this option (vs. Option 1) is a disadvantage. Another disadvantage associated with this option is that it is a different concept than FTTP and MPTP.



PRELIMINARY – NOT FOR CONSTRUCTION

MALCOLM PIRNIE

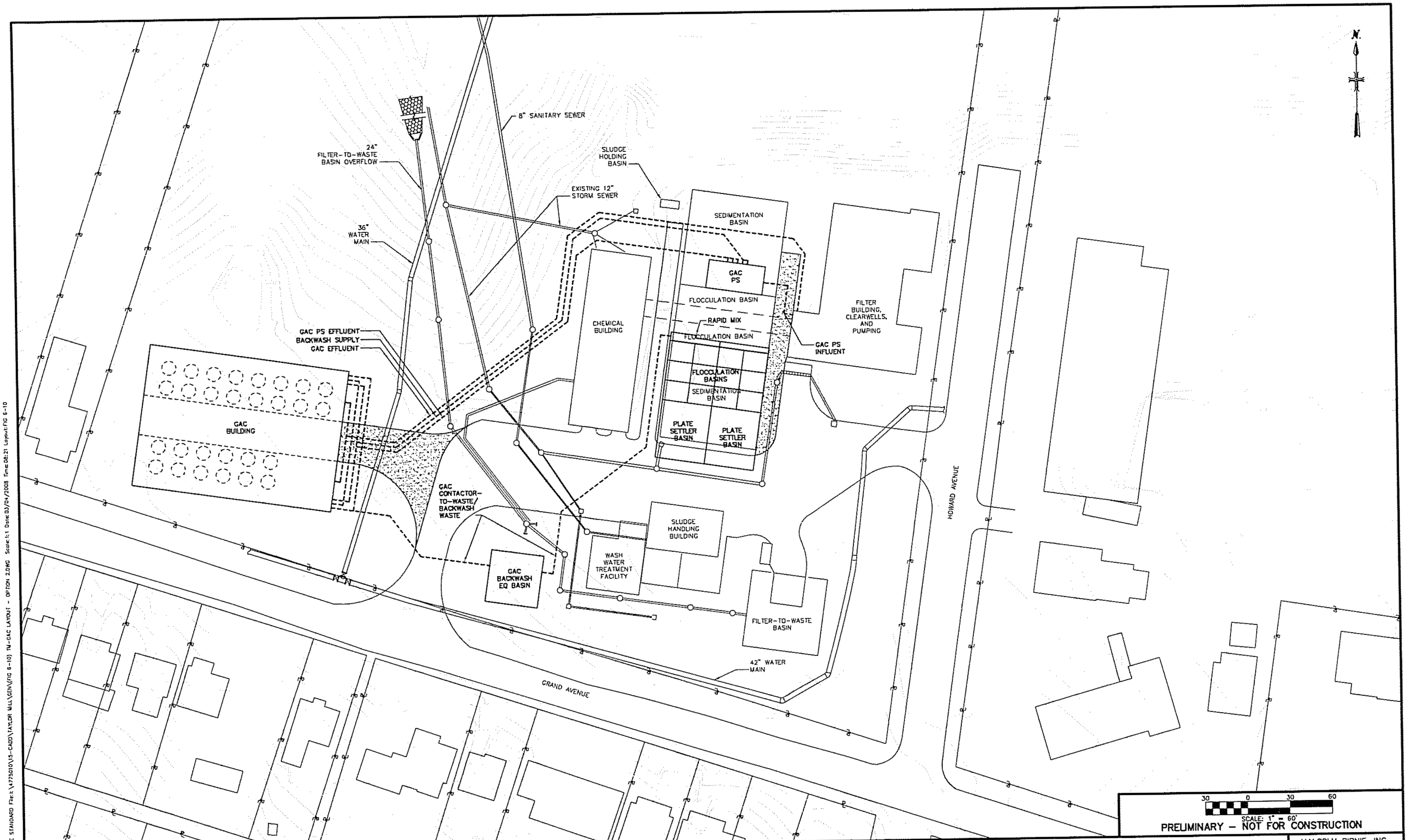
NORTHERN KENTUCKY WATER DISTRICT PRELIMINARY DESIGN OF GAC SYSTEMS
TAYLOR MILL WATER TREATMENT PLANT

OPTION 1 GAC LAYOUT

MALCOLM PIRNIE, INC.

FIGURE 6–9

User:HORLANDER Spec:PIRNIE STANDARD File:I:\4775010\15-CADD\TAYLOR MILL\DEN\(FIG 6-9) TM-GAC LAYOUT – OPTION 1 DWG Scale:1:1 Date:03/04/2008 Time:09:51 Layout:FIG 6-9



PRELIMINARY – NOT FOR CONSTRUCTION

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MALCOLM PIRNIE

NORTHERN KENTUCKY WATER DISTRICT PRELIMINARY DESIGN OF GAC SYSTEMS
TAYLOR MILL WATER TREATMENT PLANT

OPTION 2 GAC LAYOUT

FIGURE 6–10

User:HORLANDER Spec:PIRNIE STANDARD File:I:\4775010\15-CADD\TAYLOR MILL\GEN\(FIG 6-10) TM-GAC LAYOUT - OPTION 2.DWG Scale:1:1 Date:03/04/2008 Time:08:21 Layout:FIG 6-10

6.5.3. Cost Considerations

6.5.3.1. Detailed Costs

A detailed cost analysis was completed for both options. The detailed cost comparison does not include modifications to the UV disinfection facility and is shown in Table 6-3. The details of the cost opinion are included in Appendix C. Option 1, the basin-style contactors, costs more than Option 2, the vessel-style contactors, due to a slightly larger EQ basin, additional piping associated with the basin layout, and additional structural concerns associated with the basin-style contactors.

Table 6-3.
GAC Site Location Alternatives Detailed Cost Comparison

Site Location Alternative	Escalation to Midpoint Construction Costs (2010, $ Millions)
Option 1 – Basin-style Contactors	$20.4
Option 2 – Vessel-style Contactors	$18.4

6.5.4. Final GAC Site Location Recommendation

As shown in Table 6-3, Option 2 (Vessel-style contactors) costs less than Option 1 (Basin-style contactors). The advantages and disadvantages of both options were discussed with NKWD stakeholders. Due to the cost benefit, ease of carbon transfers, and little excavation, NKWD selected Option 2 for the GAC facility layout.

6.6. Design Criteria and Basic Assumptions

Vessel-style contactors are available from both Calgon and Norit. Typical vessel sizes are based on 20,000 pounds of carbon and come in standard 10-foot or 12-foot diameters. Based on our selected EBCT of 20 minutes, approximately 28 vessels are required.

The following assumptions for capacity and redundancy were made in developing the basis of design for the GAC facilities:

- The GAC facility will include 28 GAC pressurized vessels.
- Normal operation will provide at least a 20-minute EBCT with all contactors in-service at a maximum production rate of 10 MGD.
- Duty and standby pumps are provided for each of the pumping systems required for these facilities.

A GAC supplier will provide virgin carbon to the site and truck the spent GAC off-site.

6.7. Design Approach

6.7.1. General Layout

Figure 6-10 presents a site plan of the proposed GAC preliminary design improvements for the TMTP. Filter effluent will be diverted prior to entering the UV reactors and will be sent to the GAC feed pump station. From the pump station, the GAC feed pumps (vertical or submersible style) will convey water to the pressurized contactors located in the GAC building.

Water will flow through the GAC contactors to a new 20-inch contacted water pipeline to the clearwell. UV reactors are currently being installed downstream of the filters. It is logical to consider relocation of the UV reactors between the GAC and clearwell, but not necessary. The effluent from the GAC reactors will have more UV transmissivity and as such, would allow for a smaller UV dose. Since the reactors are currently sized for the post-filter water quality characteristics, leaving the reactors in their proposed location is a valid option as well. One drawback to leaving the reactors between the filtration and GAC process is that UV will not be the final barrier prior to distribution. Detailed design will need to investigate if the UV disinfection process needs to be relocated in order to allow for post-GAC connection.

Either vertical style or submersible style backwash supply pumps would be located in the GAC feed pump station. The backwash supply line would be routed to the GAC building following the GAC influent line. Waste backwash water will flow by gravity to the GAC backwash equalization basin.

The contactor facility will be equipped with a contactor-to-waste function and a backwash equalization/contactor to waste basin. It is anticipated that carbon change-out will occur for four vessels per change out event. As such, equalization volume will be provided for the volume of four GAC contactor backwash events and four contactor-to-waste events. Submersible pumps located at the GAC backwash equalization basin will convey the backwash waste/contactor-to-waste flow to the rapid mix process.

During GAC change-outs, the carbon tanker trucks will either pull into or back into a driveway located in the center of the GAC building by way of either plant entrance. In the future, it is recommended that NKWD consider purchasing the adjacent property to continue the truck drive and create another entrance/exit onto Grand Avenue.

6.7.2. GAC Operation Strategy

The GAC contactors will be operated in parallel. Once the finished water TOC set point is approached, a GAC change-out will be required. The preferred method of GAC facility operation is to establish a staggered contactor operating strategy, taking advantage of effluent blending, where the GAC is replaced four adsorbers at a time. Similar to series operation of GAC contactors, this approach is taken to utilize the GAC to the maximum extent possible. Section 3 discusses the blending of GAC-contacted water. During the GAC change-out event, one contactor will be out of service. Spent GAC will be removed from the contactor with the GAC media that has been in service the longest. Following removal of the spent GAC, virgin, or regenerated GAC will be installed in the same contactor and placed into service. This will be repeated for a total of four contactors. Once the contactors are placed back into service, the blended effluent TOC concentration will decrease. When the GAC-contacted water again approaches the TOC criterion, the GAC change-out process will be repeated. This strategy will be perpetuated throughout the life of the facility.

6.8. GAC Feed Pump Station

The GAC feed pump station, shown in Figure 6-10, is the source water location for the GAC contactors and supporting facilities. The GAC feed pump station includes the items noted below:

- GAC Feed Pumps: The GAC feed pumps will be either vertical or submersible pumps. It is anticipated that the pumps will draw from a wet well with up to 70,000 gallons of capacity. The pumps will transfer filter effluent through the GAC contactors and into the clearwell.
- Hose bibs will be located throughout the GAC facility to allow for loading/unloading of carbon. A service water system may be required and will be determined during detailed design. It may be appropriate to locate any additional pumps in the GAC feed pump station.

The location is ideal from the standpoint of intercepting and re-routing filtered water. Also, access can be incorporated for pump access. The issue associated with locating a major structure in this area is the long term stability of the hillside. It is our understanding that the hillside is experiencing long term slippage and at some point, an earth retention modification may be required. The assumption was made that the foundation of the pump station would be pile-supported. The ultimate foundation design should consider the geotechnical issues more thoroughly. It has also been assumed that the tunnel between the filter building and the chemical building is to remain. The structural integrity of this tunnel is unknown and it is recommended that further investigation be conducted as part of detailed design.

6.8.1. GAC Feed Pumps

The GAC feed pumps will convey water from the GAC feed pump station to the contactors. It is anticipated that either vertical or submersible pumps will be utilized. The pump station will be provided with three GAC feed pumps, two duty and one standby. It is anticipated that a strategy will be established to allow portions of the flow to bypass the GAC process and be pumped directly to UV.

Table 6-4 presents the design parameters for the GAC feed pumps.

Table 6-4.
GAC Feed Pump Design Criteria

Parameter	Value
No. of Pumps	3 (2 Duty, 1 standby)
Design Point Pump Flow	6 MGD (one pump, full speed)
Design Point Pump TDH	Approximately 45 ft (one pump, full speed, low wet well condition) to be finalized during detailed design
Pump Control	VFD

Table 6-5 summarizes the VFD set points required based on plant conditions.

Table 6-5.
GAC VFD Set Point Summary

VFD Set Point Description	VFD Set Point Flow Rate (MGD)
Average	5.3
Maximum	12

6.9. GAC Contactors

Twenty-eight pressurized contactors will be provided. It is anticipated that the contactors will have the following characteristics as shown in Table 6-6.

Table 6-6.
Design Criteria for GAC Contactors

Parameter	Value
No. of Contactors	28
Contactor diameter (feet)	10
Approximate Contactor height (feet)	22
Design Flow per Contactor at Design Capacity (MGD)	0.42

The GAC contactors shall be designed with the following features:

- A 20-minute EBCT at design flows with all contactors in service.
- Electric actuators.
- A dedicated carbon truck transfer station for each contactor skid (one per pair of contactors), equipped with quick-connect fittings.
- Contactor-to-waste capability to recycle GAC-contacted water to the equalization basin.
- Turbidity monitors at the discharge end of each contactor.
- A sampling station with TOC, UV absorbance at 254 nanometers (UV254), and particle counting analyzers. The sampling station will receive a sample line from each pair of contactors and one combined sample line for analysis.

Operating design criteria for the GAC contactors are summarized in Table 6-7.

Table 6-7.
GAC Contactor Operating Parameters

Parameter	Normal Operation	Operation During GAC Change-out
Number of Contactors in Service At WTP Capacity (10 MGD)	28	26
Flow Rate per Contactor (MGD) At GAC Design Flow (10 MGD)	0.36	0.38
Approximate Empty Bed Contact Time (minutes) At GAC Design Flow (10 MGD)	22	20
Design Backwash Duration (minutes)	30	
Design Backwash Rate (gpm)	1,100	
Design Contactor-to-Waste Duration (minutes)	30	
Design Contactor-to-Waste Rate (gpm)	290	

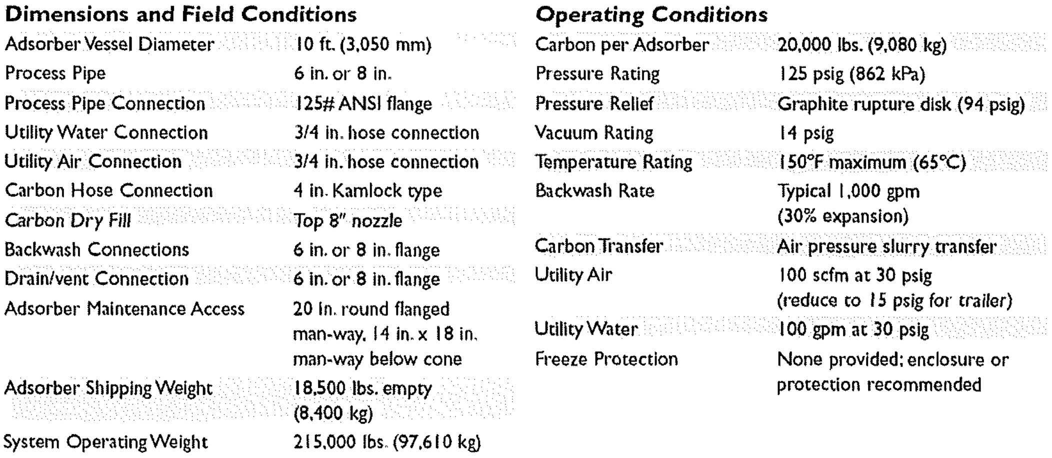
Notes:
Normal operation = No contactors out of service
GAC change-out operation = Two equipped contactors out of service

6.9.1. Equipping of GAC Contactors

Basic dimensions, field conditions and operating conditions[3] of the proposed Calgon contactors are shown in Figure 6-11

Contactors will come skid mounted in pairs of two, with interconnected piping and valving. Figure 6-12 shows a typical arrangement[3] available from Calgon.

Typical specifications[3] for Calgon vessel style contactors are provided in Figure 6-13.



Dimensions and Field Conditions	
Adsorber Vessel Diameter	10 ft. (3,050 mm)
Process Pipe	6 in. or 8 in.
Process Pipe Connection	125# ANSI flange
Utility Water Connection	3/4 in. hose connection
Utility Air Connection	3/4 in. hose connection
Carbon Hose Connection	4 in. Kamlock type
Carbon Dry Fill	*Top 8" nozzle*
Backwash Connections	6 in. or 8 in. flange
Drain/vent Connection	6 in. or 8 in. flange
Adsorber Maintenance Access	20 in. round flanged man-way, 14 in. x 18 in. man-way below cone
Adsorber Shipping Weight	18,500 lbs. empty (8,400 kg)
System Operating Weight	215,000 lbs. (97,610 kg)

Operating Conditions	
Carbon per Adsorber	20,000 lbs. (9,080 kg)
Pressure Rating	125 psig (862 kPa)
Pressure Relief	Graphite rupture disk (94 psig)
Vacuum Rating	14 psig
Temperature Rating	150°F maximum (65°C)
Backwash Rate	Typical 1,000 gpm (30% expansion)
Carbon Transfer	Air pressure slurry transfer
Utility Air	100 scfm at 30 psig (reduce to 15 psig for *trailer)*
Utility Water	100 gpm at 30 psig
Freeze Protection	None provided; enclosure or protection recommended

Figure 6-11: Dimensions and Field Conditions for Calgon Vessel-style Contactors

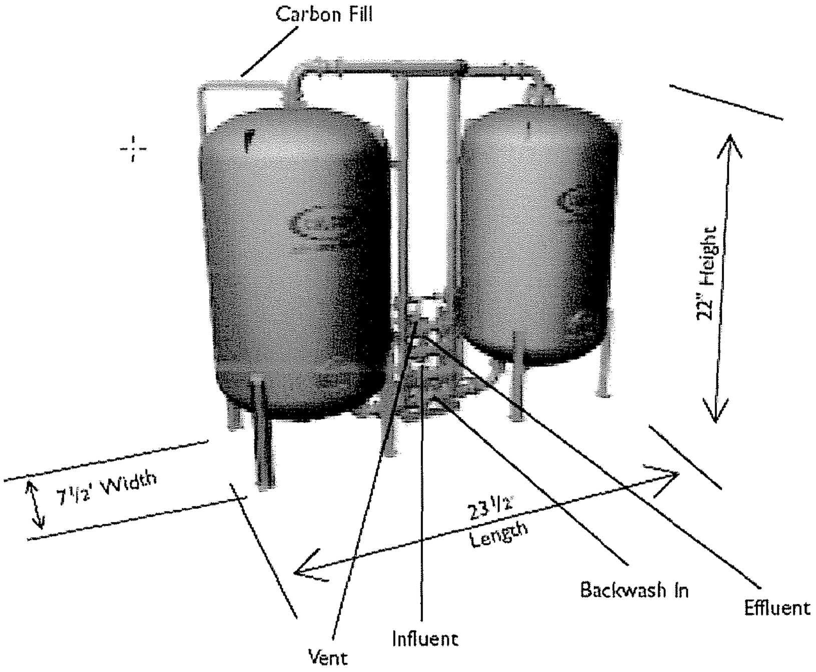
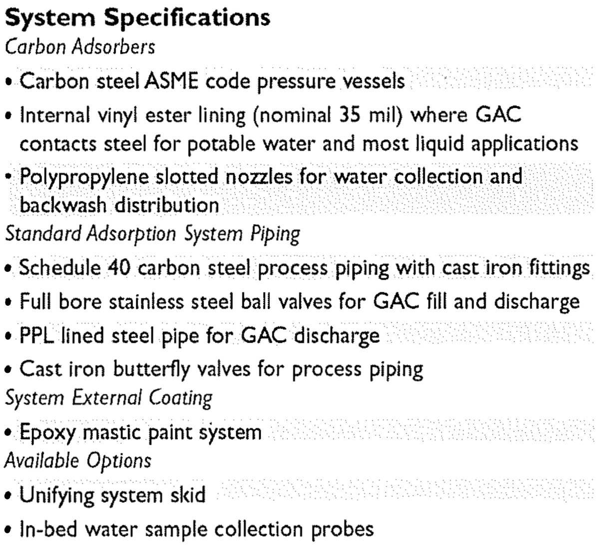


Figure 6-12: Calgon Typical Vessel-style Contactor Arrangement



System Specifications

Carbon Adsorbers

- Carbon steel ASME code pressure vessels
- Internal vinyl ester lining (nominal 35 mil) where GAC contacts steel for potable water and most liquid applications
- Polypropylene slotted nozzles for water collection and backwash distribution

Standard Adsorption System Piping

- Schedule 40 carbon steel process piping with cast iron fittings
- Full bore stainless steel ball valves for GAC fill and discharge
- PPL lined steel pipe for GAC discharge
- Cast iron butterfly valves for process piping

System External Coating

- Epoxy mastic paint system

Available Options

- Unifying system skid
- In-bed water sample collection probes

Figure 6-13: Calgon Vessel-style Contactors System Specifications

6.9.2. GAC Loading/Unloading Facilities

The contactors will be filled with GAC from manufacturers' delivery trucks. Delivery trucks will carry 20,000 pounds of dry GAC to the site. The contents of the contactor will be unloaded into the spent carbon compartment of the delivery truck. The new carbon will be unloaded from the new carbon storage compartment of the same delivery truck. It is estimated for the change-out to take approximately 2 hours per vessel.

The GAC transfer station at each contactor will be equipped with the following:

- A service water line with a quick connect fitting to provide 100-200 gpm (to maintain a minimal filling time for the tanker).
- A GAC loading/unloading line with quick connect fitting.
- A GAC truck waste line with knife gate valve and quick connect fitting. After delivery of spent GAC to the delivery truck, the transfer water can be drained out of the truck through this line and into the backwash waste line that drains to the GAC Backwash Equalization Basin.

6.10. Backwash System

6.10.1. Backwash Supply Pumps

Either vertical or submersible backwash supply pumps would be located in the GAC feed pump station. The backwash supply line would be routed to the GAC building following the GAC influent line. Table 6-8 presents the design parameters for the GAC backwash supply pumps.

Table 6-8.
GAC Backwash Supply Pump Design Criteria

Parameter	**Value**
No. of Pumps	1 duty, 1 standby
Design Point Pump Flow	1,100 gpm (one pump, full speed)
Design Point Pump TDH	55 ft (one pump, full speed, low wet well condition) to be verified during detailed design

The design flow capacity for the backwash supply pumps noted in Table 6-8 (1,100 gpm) corresponds to 10% more than the flow required for a 30% bed expansion as provided by the vessel manufacturer.

6.11. GAC Backwash Equalization

6.11.1. General

GAC contactor backwashes are not expected to generate a significant mass of solids. Calgon and Norit were contacted to obtain any available estimates of fines production and recommended parameters for backwashing (*e.g.*, loading rate and duration of backwash). Calgon did not have any fines production information. Norit provided the following information:

- The amount of fines can vary widely, depending on how much rough handling the GAC receives.
- Fines are usually less than 1 percent of the total weight of the shipment.
- Fines are always less than 5 percent of the total weight of the shipment.

Assuming a scenario of 2 percent solids washed out in fines, the solids loading from backwashing would be as follows:

2% of 20,000 pounds = 400 pounds (single adsorber)

2% of 20,000 pounds x 4 adsorbers= 1,600 pounds (four adsorbers)

All backwash waste will be sent directly to the rapid mix process via the GAC Backwash Equalization Basin.

6.11.2. Sizing the GAC Backwash Equalization Basin

The GAC backwash equalization basin provides a means to equalize flow when a GAC contactor is backwashed. The backwash water flows by gravity from the adsorbers to the GAC backwash equalization basin. Two submersible, non-clog centrifugal pumps will be located in the basin to pump the backwash water to the Rapid Mix Basin. The GAC backwash equalization basin was sized to accept the volume of four adsorber backwashes. Assuming the design backwash rate (1,000 gpm) and duration (30 minutes), approximately 120,000 gallons of backwash waste are generated and sent to the backwash equalization basin. The contactor-to-waste will also be transferred to the GAC backwash equalization basin. Assuming a contactor-to-waste rate (0.42 MGD/adsorber) and duration (30 minutes), approximately 35,000 gallons of waste volume is generated. Therefore, a 155,000 gallon GAC backwash equalization basin is required. The GAC backwash equalization basin is shown in plan view in Figure 6-10, located adjacent to the existing wash water treatment facility. This basin will include an overflow line.

6.12. Contactor-To-Waste

After a GAC adsorber is backwashed, flow through the contactor will be reinitiated in contactor-to-waste mode. In this mode, the flow through the contactor will be recycled back to the Rapid Mix Basin by gravity flow via the GAC backwash equalization basin. The purpose of recycling the flow is to prevent GAC fines from being washed through the contactor to the finished water piping and reservoirs. However, the amount of fines expected to pass through the contactor underdrains after backwashing is minimal.

6.13. Opinion of Probable Costs

As the preliminary design progressed, a final opinion of probable costs was developed. The cost opinion is considered a Class 3 estimate in accordance AACE and has a predicted accuracy of -20% to +30%.The detailed cost opinion, which includes the UV disinfection facility, is shown in Table 6-9.

Table 6-9.
Opinion of Probable Project Costs

Item	**Capital Cost ($ Million)**
GAC Facilities (Contactor building, site work, GAC PS, EQ Basin)	$15.3
Contingency	$3.1
Engineering (Legal, administration)	$2.3
Total	**$20.7**

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[1] Owen, D.M., Z.M. Chowdhury, R.S. Summers, S.M. Hooper, G. Solarik, and K. Grey. 1997. Removal of DBP Precursors by GAC Adsorption. AWWARF.

[2] Black & Veatch. May 2004. *Asset Management Program Final Report.*

[3] *Making Water and Air Safer and Cleaner, Model 10, Modular Carbon Adsorption System.* 2004. ES-EB1025-0604. Pittsburgh, P.A.: Calgon Carbon Corporation.

Northern Kentucky Water District

Northern Kentucky Water District
Preliminary Design of GAC Systems

Appendix A: RSSCT/SDS Results

4775-010 / CIN

GRW, Inc.

MALCOLM PIRNIE

MPI -NKWD updated 6/19/07
8/29/07
RSSCT and DBP Formation Testing Conditions

Task number	Task	Drum* or Sample #	Testing Conditions		
			pH	Temperature^{C} (°F)	Chlorine Residual (mg/L)**
1	RSSCT – 15 and 20 min EBCT w/ F400 27 TOC (3 inf & 12 eff each EBCT)	Drum	7.6	55-60	2.0-2.5
2	RSSCT – 15 min EBCT w/ NORIT 1240 15 TOC (3 inf & 12 eff)	Drum	7.6	55-60	2.0-2.5
3	RSSCT– 15 EBCT w/ HD 4000 15 TOC (3 inf & 12 eff)	Drum	7.6	55-60	2.0-2.5
4	SDS-TTHM and SDS-HAA5 at 7 and 14 days for GAC influent	Drum	7.6	55-60	2.0-2.5
5	SDS-TTHM and SDS-HAA5 at 7 and 14 days for GAC effluent of task 1 at TOC = 0.55, 0.82, and 0.94 mg/L	Effluent of Task 1	7.6	55-60	2.0-2.5
6	SDS-TTHM and SDS-HAA5, at 7 and 14 days for three blends (66% TM, 25% TM) of Taylor Mill GAC influent(Drum) and R. Miller (GCWW) GAC effluent (#1)	Drum + #1	7.6	55-60	2.0-2.5
7a	SDS-TTHM and SDS-HAA5, at 7 and 14 days for MIEX treated water – TM Plant settled sample	#2	7.6	55-60	2.0-2.5
7b	SDS-TTHM and SDS-HAA5, at 7 and 14 days for MIEX treated water – MIEX 20 min/1000 BV	#4	7.6	55-60	0.0***
7c	SDS-TTHM and SDS-HAA5, at 7 and 14 days for MIEX treated water – MIEX 20 min/1000 BV with coagulation****	#3	7.6	55-60	2.0-2.5

*All samples taken from drum, #2, #3, and #4 should be filtered prior to testing.

^{C} T= 13 to 16 C

**Add amount of chlorine needed to reach this chlorine residual at startup (t = 2 hr).

***5 mg/L chlorine was accidentally added to sample. No more chlorine will be added.

****3/4 full scale coagulant used (lowest turbidity jar result).

Description of Samples:

Drum: Taylor Mill Treatment Plant, settled, pre-filter, pre-chlorination

1) GCWW – Richard Miller Treatment Plant: finished, pre-chlorination
2) Taylor Mill Treatment Plant: settled
3) Taylor Mill Treatment Plant: 20 minute/1000 BV, MIEX, coagulated, unfiltered
4) Taylor Mill Treatment Plant: 20 minute/1000 BV, MIEX, unfiltered, 5 mg/L chlorine was accidentally added

MPI –NKWD RESULTS 8/30/07
DBP Formation Testing Results
T* = 11 to 15 C, average 13 C

SDS Task Number	Drum or Sample # Used	Time (days)	pH	Chlorine Residual (mg/L)	THM (µg/L)	HAA5 (µg/L)
4 (TOC=1.4)	Drum TM GAC inf	2 hr	7.5	2.6	13.7	21.4
		7	7.9	1.25	51.2	44.2
		14	7.8	1.46	65.0	47.1
5 (TOC=0.55)	Effluent of Task 1	2 hr	6.7	2.3	3.6	14.8
		7	7.3	1.7	21.0	26.9
		14	7.1	1.5	28.3	28.2
5 (TOC=0.82)	Effluent of Task 1	2 hr	7.0	2.59	4.5	15.9
		7	7.5	1.76	26.5	26.7
		14	7.3	1.6	36.2	32.5
5 (TOC=0.94)	Effluent of Task 1	2 hr	7.3	2.6	7.1	17.2
		7	7.8	1.7	25.0	36.7
		14	7.7	1.61	42.1	44.4
6 (66% TM)	Drum + #1	2 hr	7.8	2.78	10.2	26.1
		7	8.1	1.5	47.3	47.9
		14	7.9	1.4	57.2	65.1
6 (37% TM)	Drum + #1	2 hr	7.9	2.76	10.5	21.3
		7	8.1	1.8	44.8	37.1
		14	8.0	1.1	54.3	42.0
7a	#2	2 hr	7.6	2.61	11.4	24.0
		7	7.7	1.6	39.9	37.5
		14	7.8	1.8	46.4	51.7
7b	#4					
		7	?	1.97	113	91.7
		14	?	1.27	135	104
7c	#3	2 hr	7.9	2.79	8.2	19.4
		7	8.0	1.85	36.1	29.7
		14	**7.8**	1.3	51.0	33.9

* All samples were incubated at the same time. The average temperature over the 2 week period was 13 C and the range was 11 to 15 C.

NKWD-MPI - Project update 8/10/07

RSSCT Results

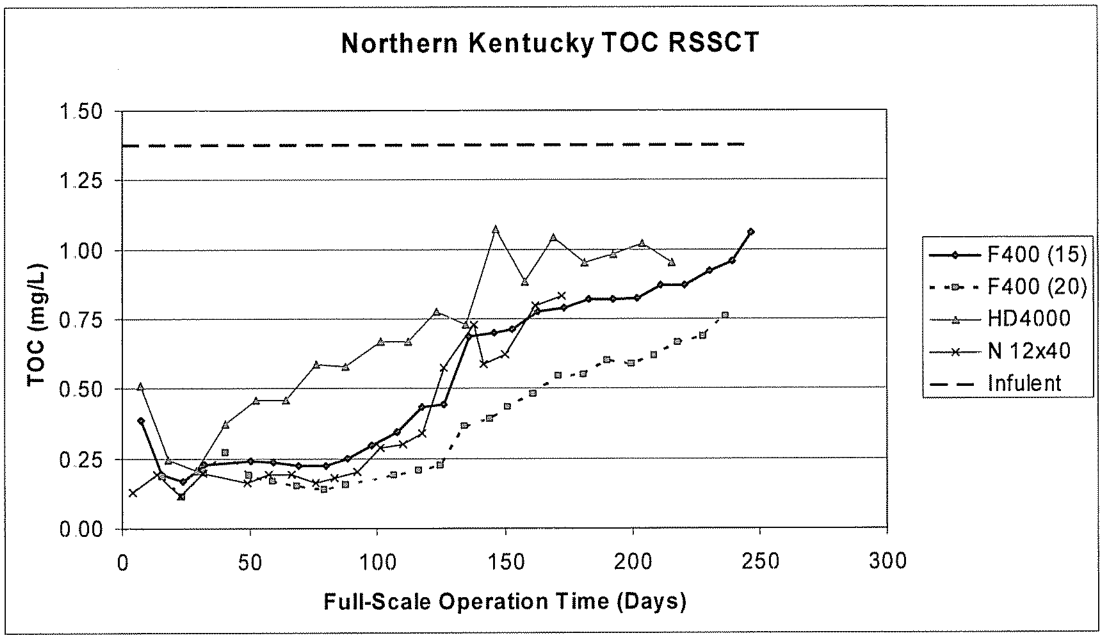


Figure 1. RSSCT results – TOC breakthrough as scaled operation time.

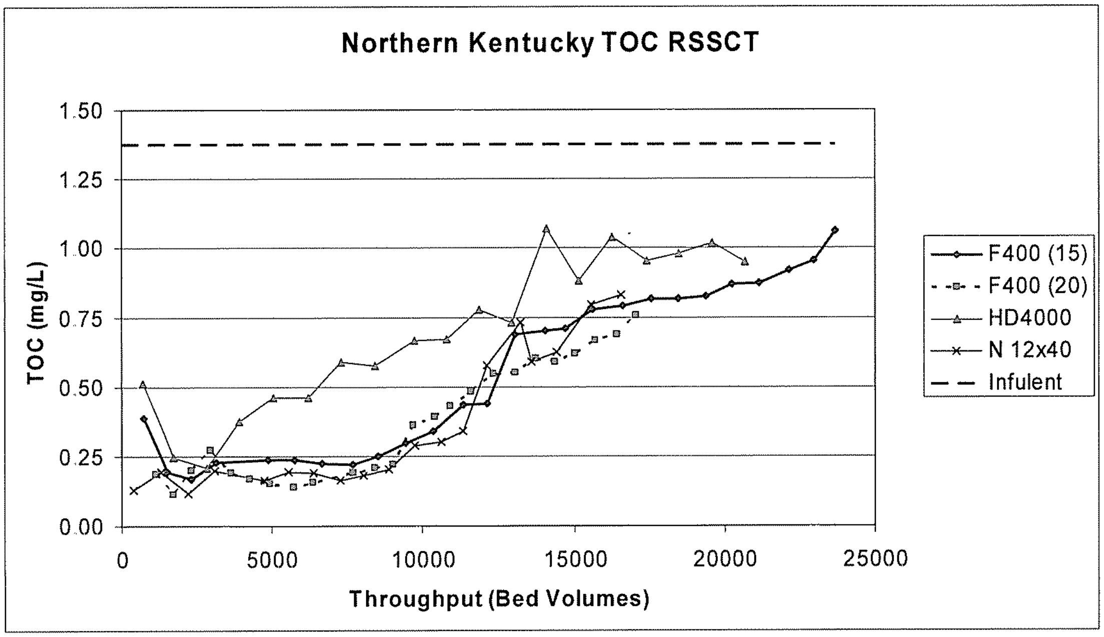


Figure 2. RSSCT results – TOC breakthrough as throughput (bed volumes).

Table 1. DBP results

SDS Task Number	Drum or Sample # Used	Time (days)	Chlorine Residual (mg/L)	THM (µg/L)	HAA5 (µg/L)
4 (TOC=1.4)	Drum TM GAC inf	2 hr	2.6	13.7	21.4
		7	1.25	51.2	44.2
		14	1.46	65.0	47.1
5 (TOC=0.55)	Effluent of Task 1	2 hr	2.3	3.6	14.8
		7	1.7	21.0	26.9
		14	1.5	28.3	28.2
5 (TOC=0.82)	Effluent of Task 1	2 hr	2.59	4.5	15.9
		7	1.76	26.5	26.7
		14	1.6	36.2	32.5
5 (TOC=0.94)	Effluent of Task 1	2 hr	2.6	7.1	17.2
		7	1.7	25.0	36.7
		14	1.61	42.1	44.4
6 (66% TM)	Drum + #1	2 hr	2.78	10.2	26.1
		7	1.5	47.3	47.9
		14	1.4	57.2	65.1
6 (37% TM)	Drum + #1	2 hr	2.76	10.5	21.3
		7	1.8	44.8	37.1
		14	1.1	54.3	42.0
7a	#2	2 hr	2.61	11.4	24.0
		7	1.6	39.9	37.5
		14	1.8	46.4	51.7
7b	#4				
7c	#3	2 hr	2.79	8.2	19.4
		7	1.85	36.1	29.7
		14	1.3	51.0	33.9

DBP-TOC relationship from RSSCT

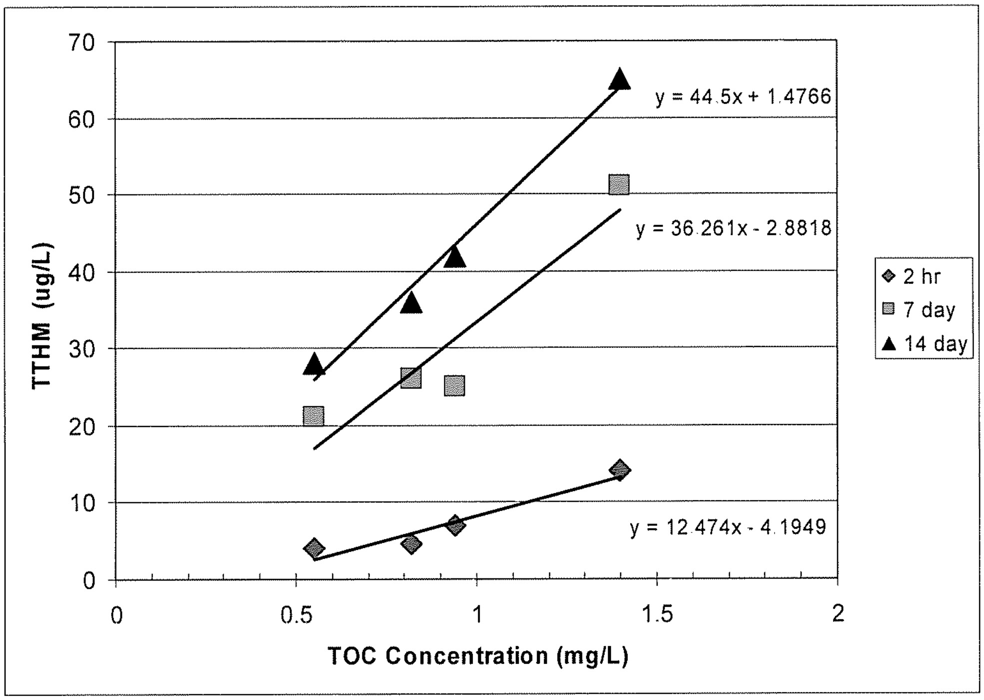


Figure 3. TTHM-TOC relationship at different reaction times

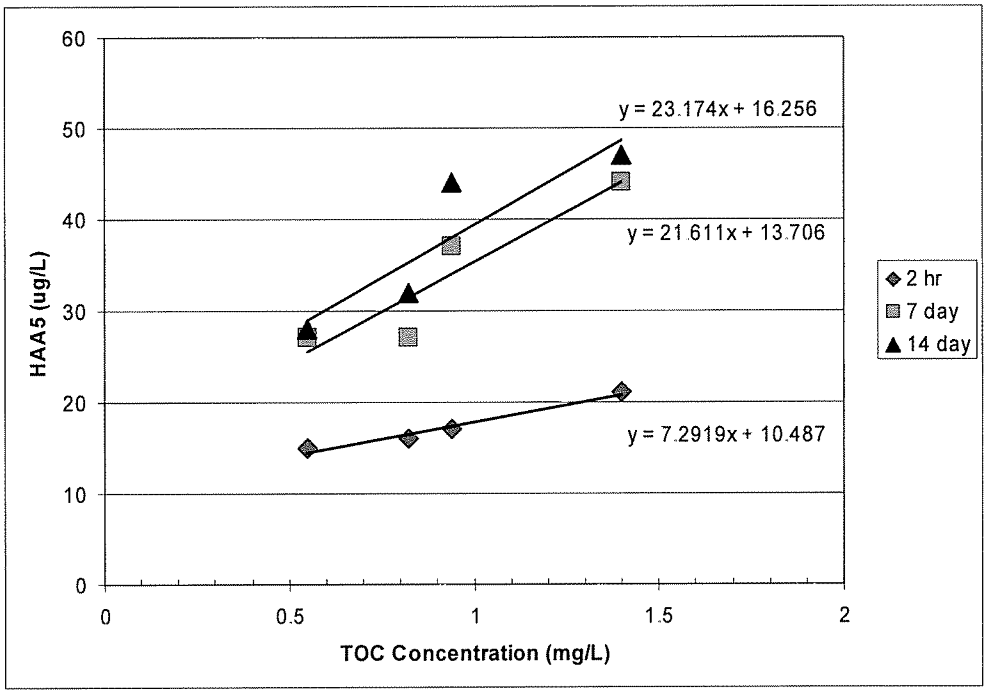
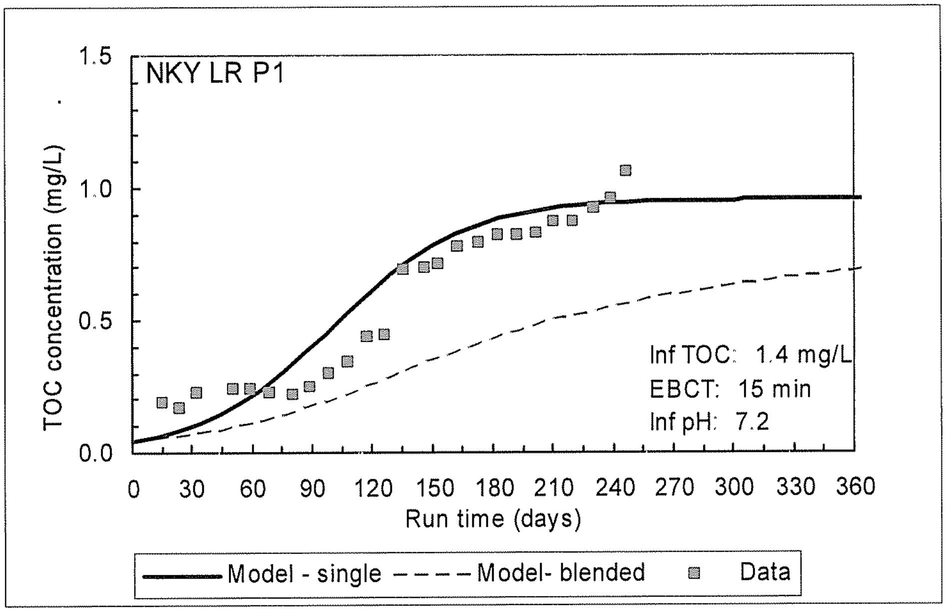


Figure 4. HAA5-TOC relationship at different reaction times

RSSCT Modeling



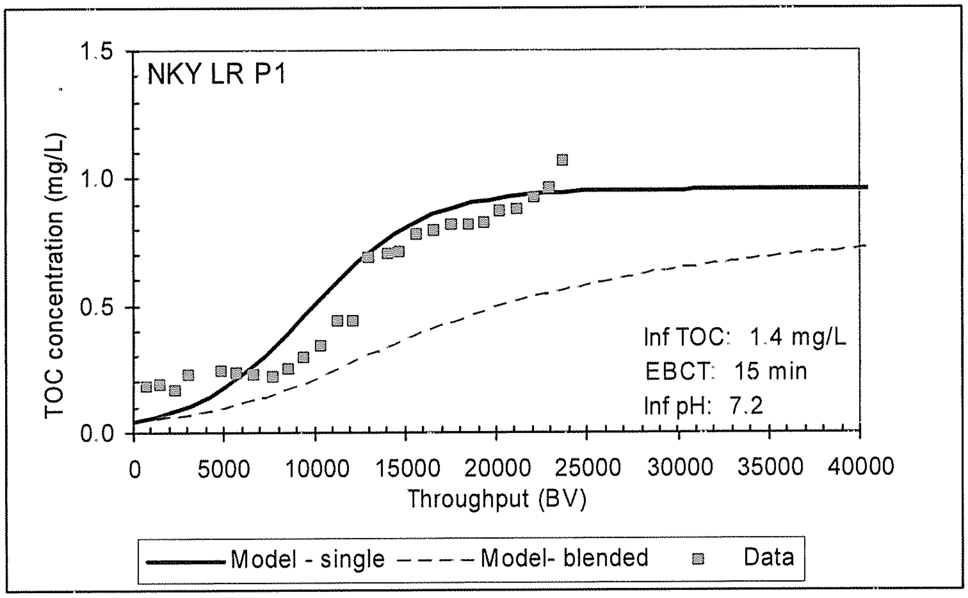
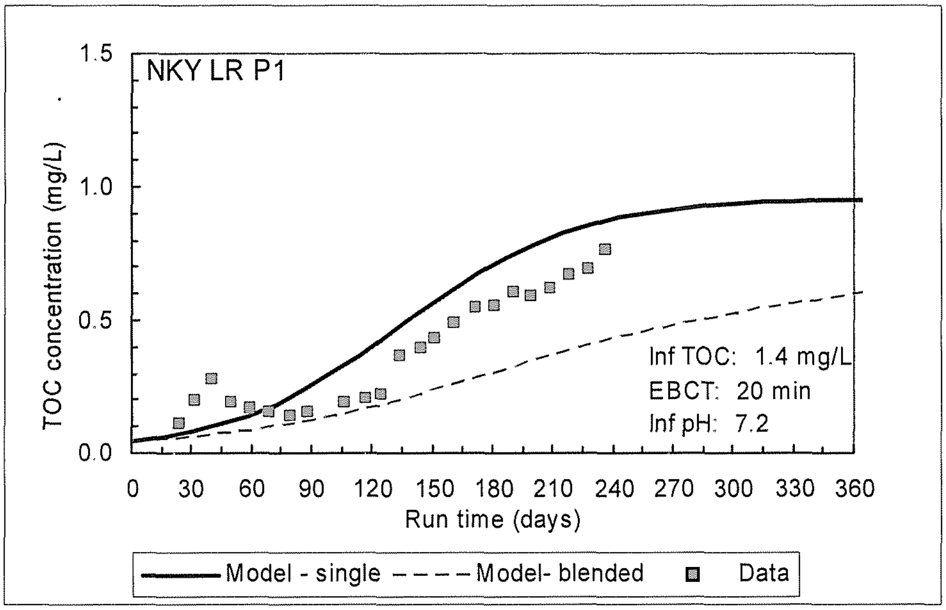


Figure 5. RSSCT modeling results – 15 min EBCT and TOC_{inf} = 1.4 mg/L.



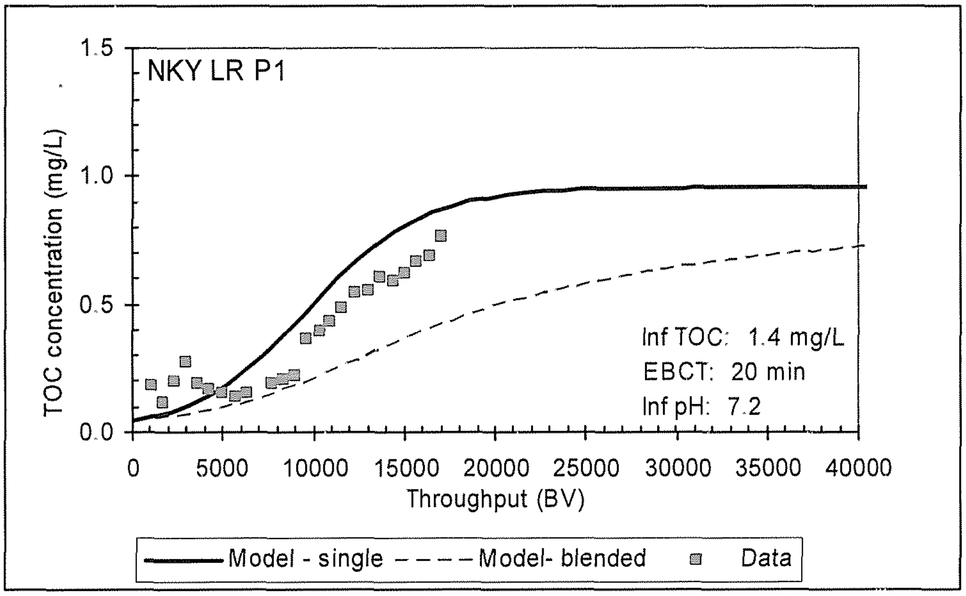
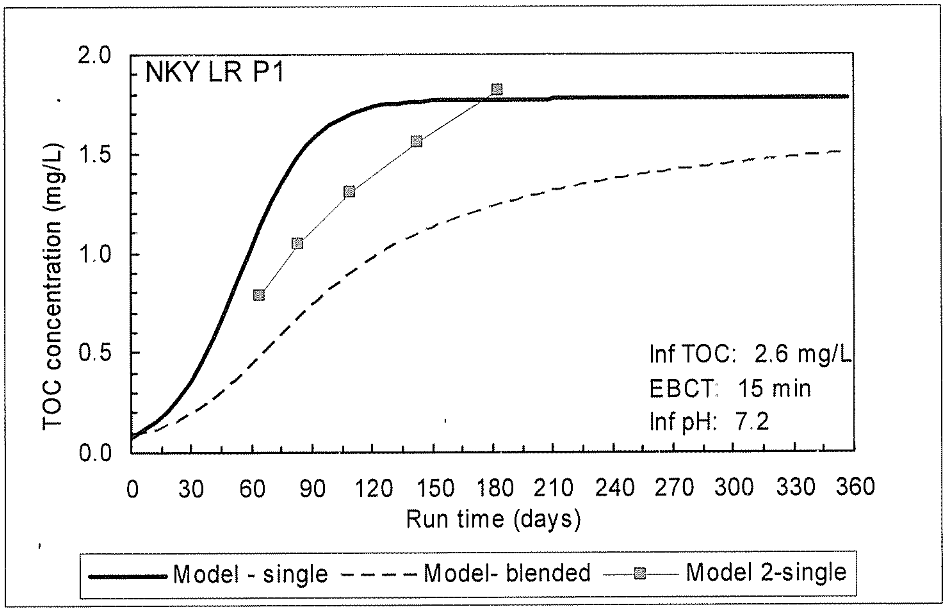


Figure 6. RSSCT modeling results – 20 min EBCT and TOC_{inf} = 1.4 mg/L.



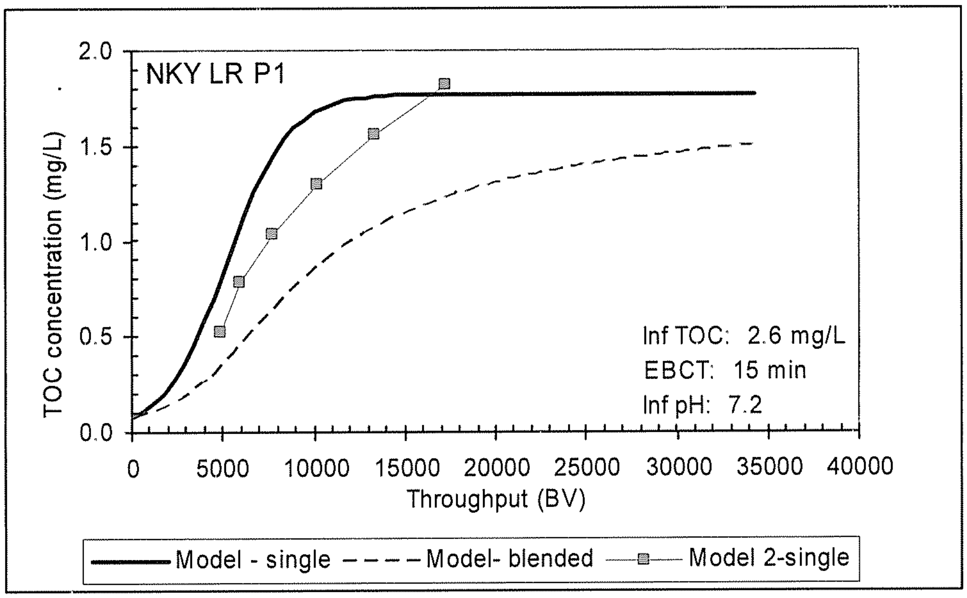
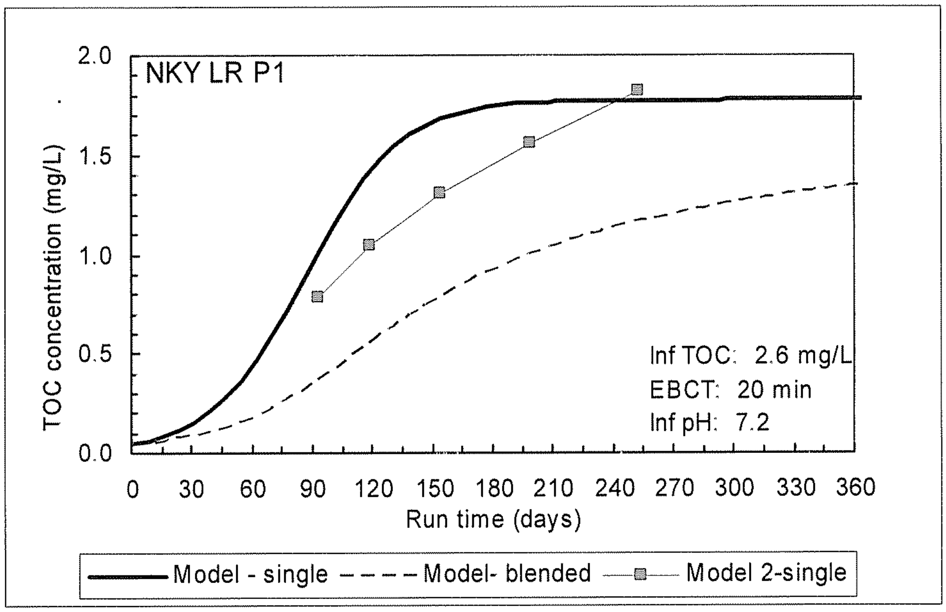


Figure 7. RSSCT modeling results – 15 min EBCT and $TOC_{inf} = 2.6$ mg/L.



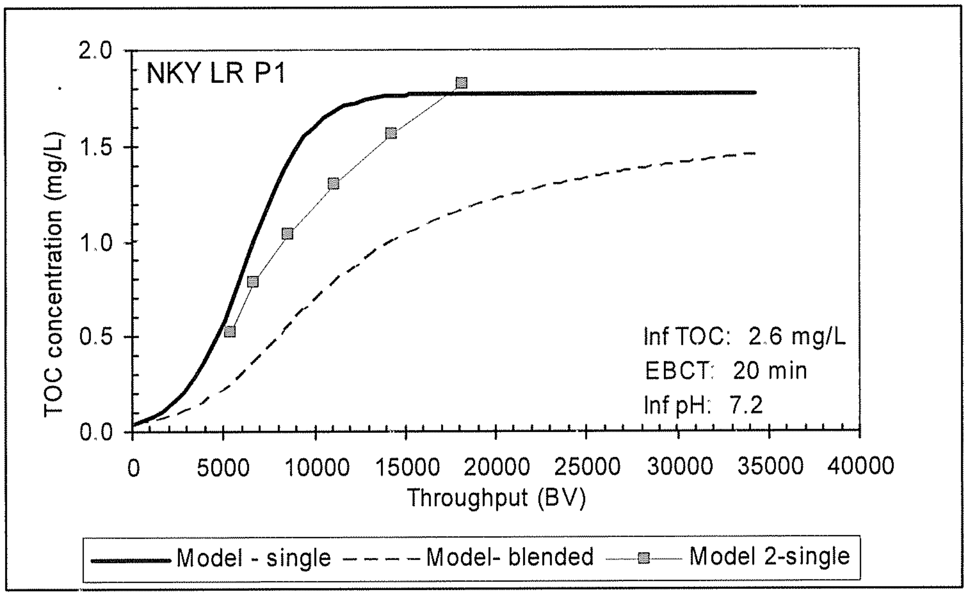
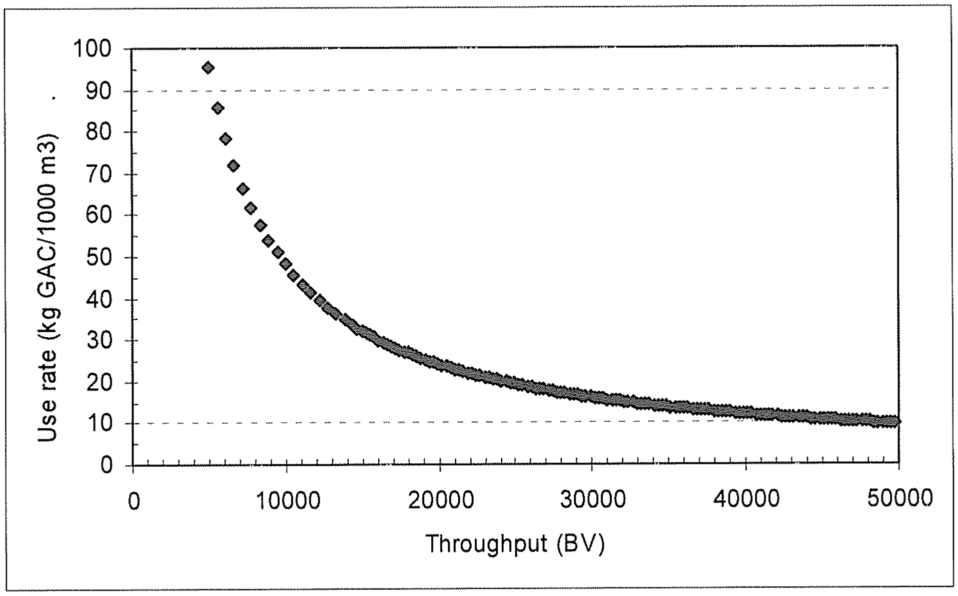


Figure 8. RSSCT modeling results – 20 min EBCT and TOC_{inf} = 2.6 mg/L.



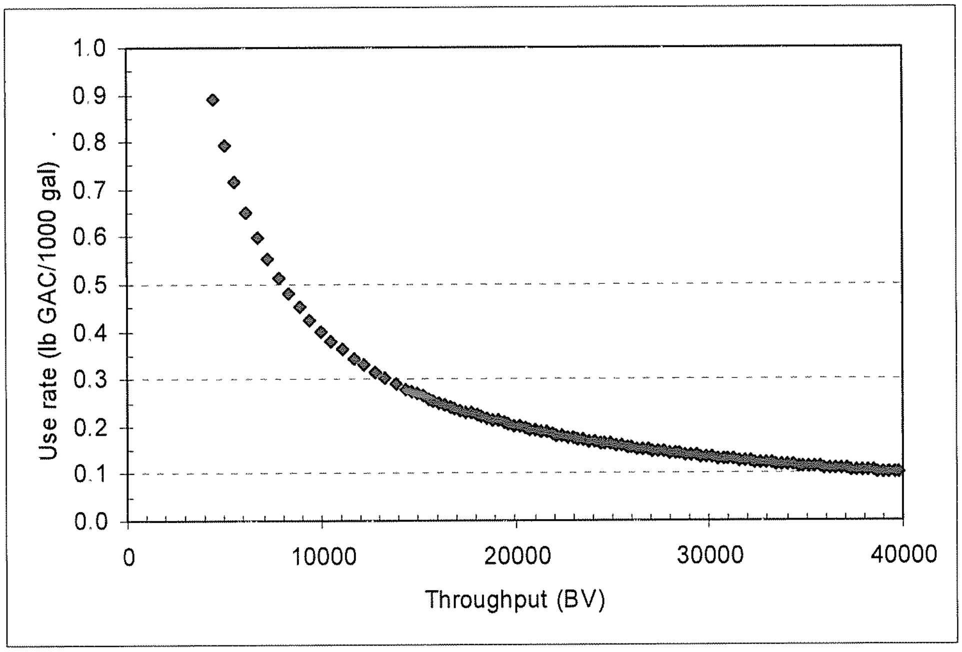


Figure 9. Relationship between GAC use rate and throughput for F400 or N1240 (ρ = 0.48 kg/L).

Modeling Notes

- I applied two models; model 2 is the newer one and we have not applied it to as many cases.

TOC_{inf} = 1.4 mg/L

- Model 1 (single column) well fits the EBCT 15 min data and does OK with the 20 min data at TOC = 1.4 mg/L (Figures 5 and 6).
- Using Model 1 (blended) we can project the plant effluent if we operated 10 GAC contactors in parallel with staged operation and blended effluent.
- Model 2 over-predicts the EBCT 15 min data, but better predicts the EBCT = 20 min data. However, we do not have a blended operation version of this model yet (which is why I most used Model 1)

TOC_{inf} = 2.6 mg/L predictions

- I used both models to predict single column results and Model 1 to predict blended plant effluent.
- I adjusted the blended results at EBCT = 20 min to reflect a better fit to the single column data at TOC = 1.4 mg/L.
- Looks to me like you could go for a year (35,000 bed volumes) at EBCT = 15 min and keep the blended plant effluent under 1.5 mg/L at all times, which would be a GAC use rate of less than 0.12 lbs/1000 gal?
- Even longer at EBCT = 20 min; less than 0.10 lbs/1000 gal

NKWD Granular Activated Carbon Preliminary Design – RSSCT Testing
Draft Report R.S. Summers 12/10/07

- Figures 1, 2 and 3 show the TOC breakthrough from the RSCCT run with EBCTs of 10 (additional data, not part of project task) , 15 and 20 min empty bed contact time (EBCT). Scaled operation time is the projection of the full-scale operation time. The TOC in the RSSCT effluent showed an immediate breakthrough of approximately 0.3 mg/L (about 10% of the influent TOC), which represents the non-adsorbable fraction of organic carbon in the source water. As expected increasing the EBCT led to longer run times as shown in Figure 1. To account for the different EBCTs or GAC mass, the run time is normalived by the EBCT to yield throughput in bed volumes (bed volumes = run time / EBCT). The TOC concentration breakthrough as fun function of throughput is shown in Figure 2. Increasing the EBCT from 10 min to 15 min yielded more throughput to a given target effluent TOC, but little difference (< 10%) outside the beginning of the breakthrough was found when the EBCT was increased from 15 min to 20 min.

- The RSSCT was considered complete at a scaled operation time of 16,000 bed volumes (~80% TOC breakthrough). Because the RSSCTs are run over a short time period (less than 2 weeks) the removal by biotreatment will not be assessed. Thus, the run times will be longer in practice.

- Figure 4 shows the relationship between throughput and GAC use rate in lbs GAC per 100 gallons treated for the F400 GAC used in the RSSCT or for an alternate GAC Norit1240, as both have bed densities of 0.48 kg/L. With the figure the GAC use rate (use rate = GAC bed density / bed volumes treated) can be calculated based on the throughput at the target effluent TOC, that is estimated from Figures 2 or 3.

- Figures 5 and 6 show the prediction of the TOC breakthrough at EBCT of 15 min, and a prediction of operating the GAC contactors in a staged parallel mode with a blended plant effluent from 10 contactors. The blended model predictions are based on an assumption of ten contactors run in parallel each with the single contactor predicted breakthrough. The GAC in each contactor is separately replaced at equal intervals which are dictated by the blended water objective. So if the blended water objective is 1.5 mg/L TOC, then the contactor with the oldest GAC can be run to an effluent of 2.0 mg/L, if it is blended with water from the contactor with the newest GAC that is producing an effluent with a TOC of 1.0 mg/L. However, the run time advantage of operating parallel GAC contactors in a staged mode decreases as the number of parallel contactors decreases. The interval between GAC replacement in a given contactor under such a staged operation is the operation time or bed volumes predicted at the blended water objective.

- Figures 7 and 8 show the prediction of the TOC breakthrough at EBCT of 20 min, and a prediction of operating the GAC contactors in a staged parallel mode with a blended plant effluent. While the model is able to well predict the EBCT 15 min results (Figures 5 and 6), it over-predicts the performance of the EBCT 20 min contactor. Adjusting the model parameters allows for an adjusted fit (simulation) of EBCT 20 min TOC breakthrough behavior (Figures 9 and 10).

- Compared to the single contactor predictions the blended model predicts two to three times longer run times to the same effluent TOC concentration in the 1.0 to 1.5 mg/L TOC range. This will lead to about a 50 to 60 % decrease in the GAC use rate.

- Samples were taken from the GAC influent and from the GAC effluent at four run times. These samples were chlorinated under the conditions shown in Table 1.

- The DBP formation results are shown in Table 2. Under these high temperature and long contact times conditions, the GAC would neeed to be replaced at an effluent TOC of about 1.5 mg/L. For a single column that would be at 7000 bed volumes or at about 75 days for an EBCT of 15 min and 100 days for an EBCT of 20 min. Under the staged blended effluent conditions that would be about 170 days for an EBCT of 15 min and 300 days for an EBCT of 20 min.

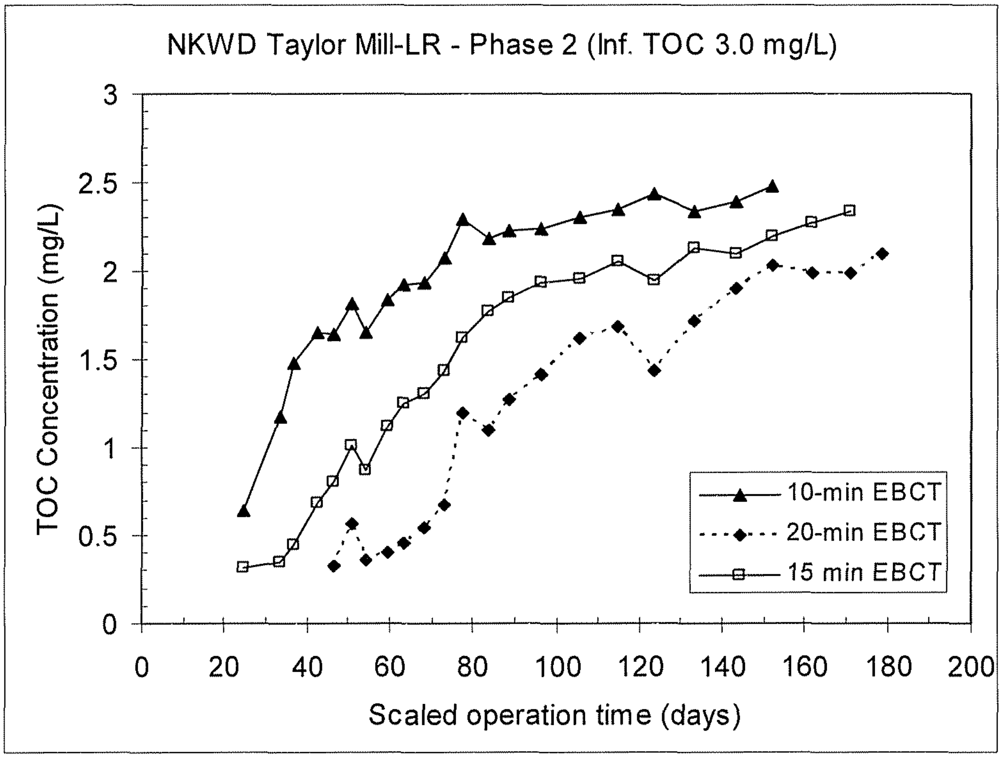


Figure 1. TOC concentration breakthrough in time at three EBCTs

Figure 2. TOC concentration breakthrough in throughput at three EBCTs

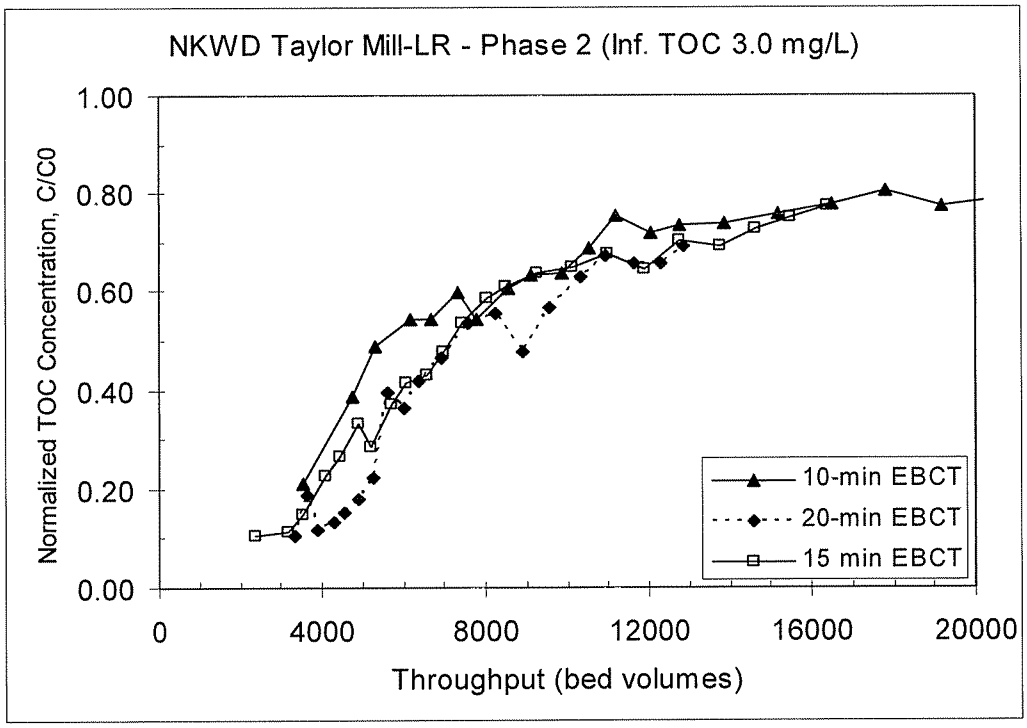


Figure 3. Normalized TOC breakthrough in throughput at three EBCTs

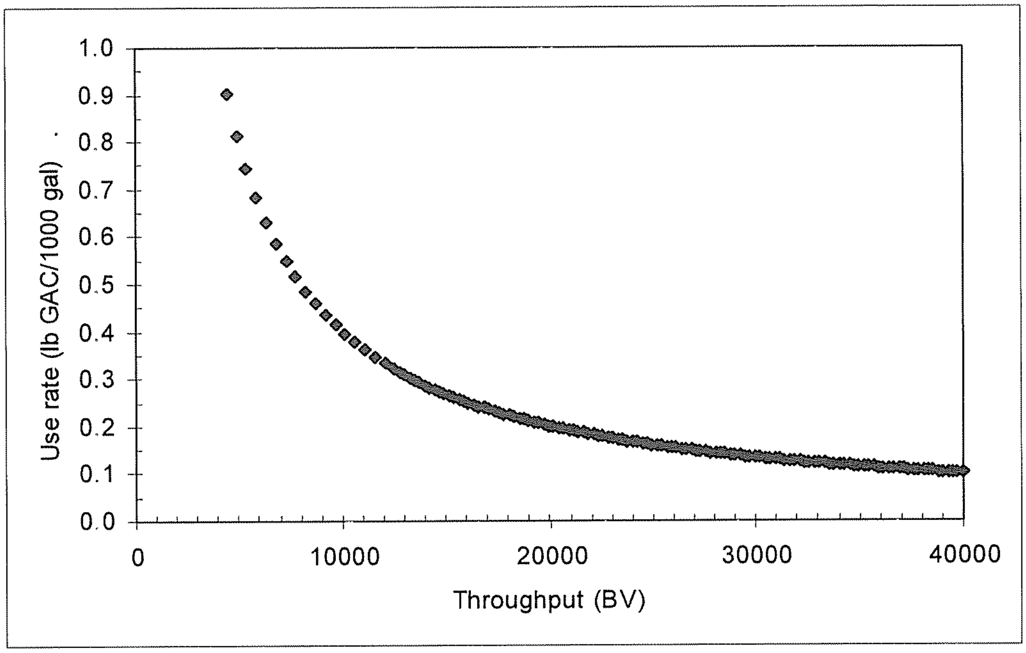


Figure 4. GAC use rate as a function of throughput for F400 or Nort1240

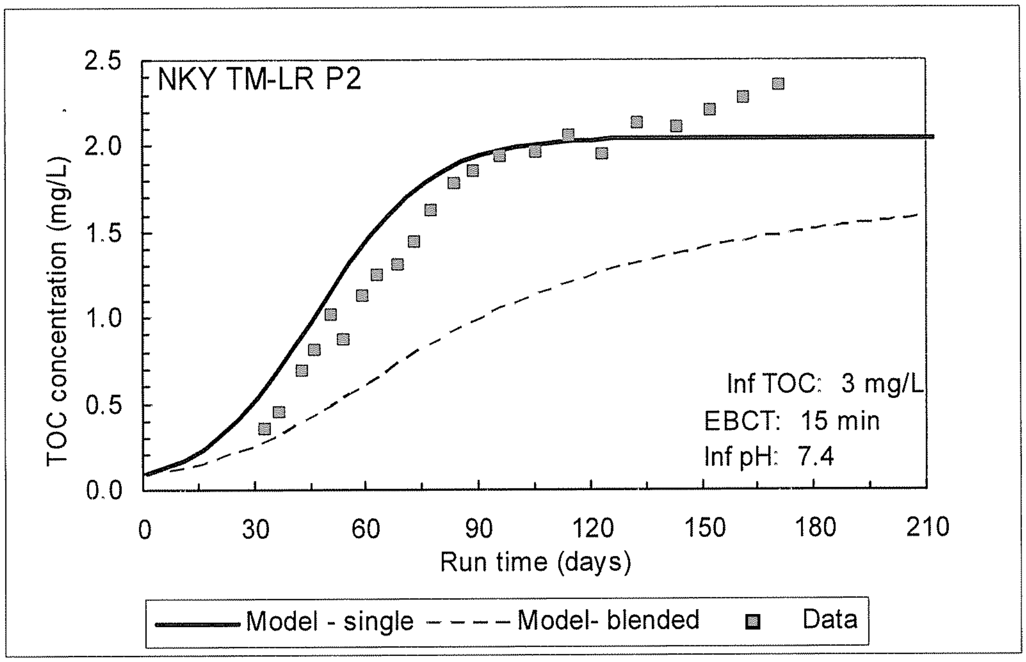


Figure 5. TOC breakthrough in time at EBCT = 15 min - Measured data (square symbols), model **prediction** (solid line) and model blended effluent prediction (dotted line).

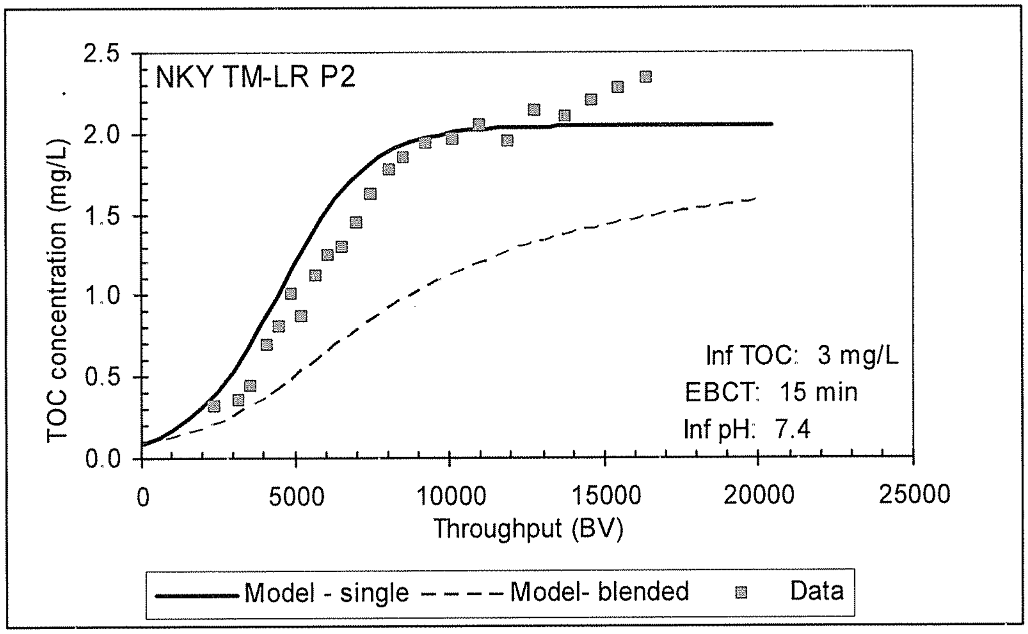


Figure 6. TOC breakthrough in throughput at EBCT = 15 min - Measured data (square symbols), model **prediction** (solid line) and model blended effluent prediction (dotted line).

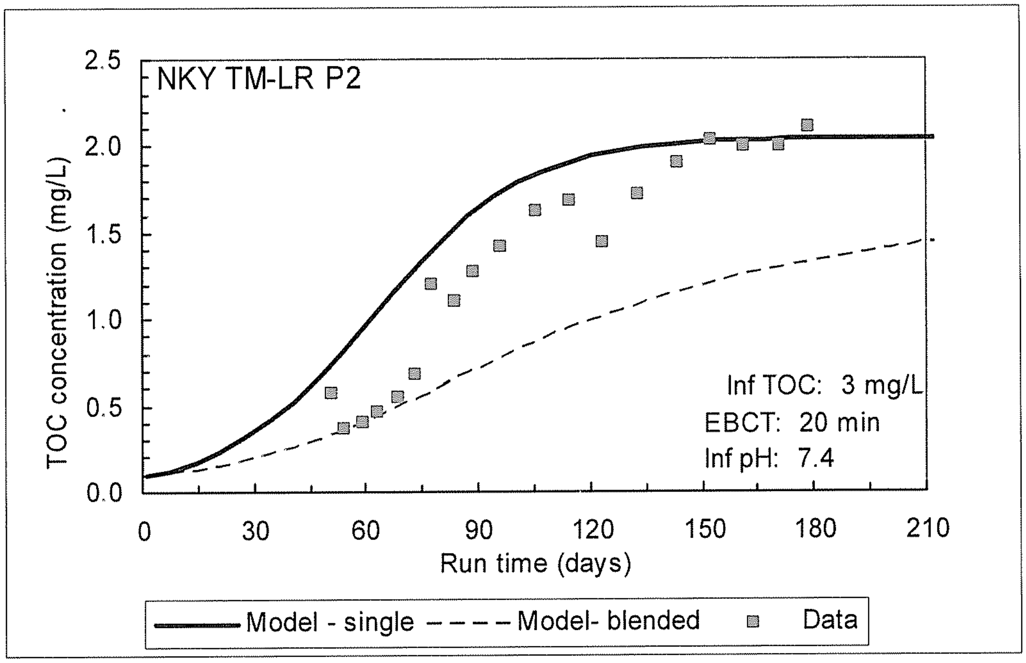


Figure 7. TOC breakthrough in time at EBCT = 20 min - Measured data (square symbols), model **prediction** (solid line) and model blended effluent prediction (dotted line).

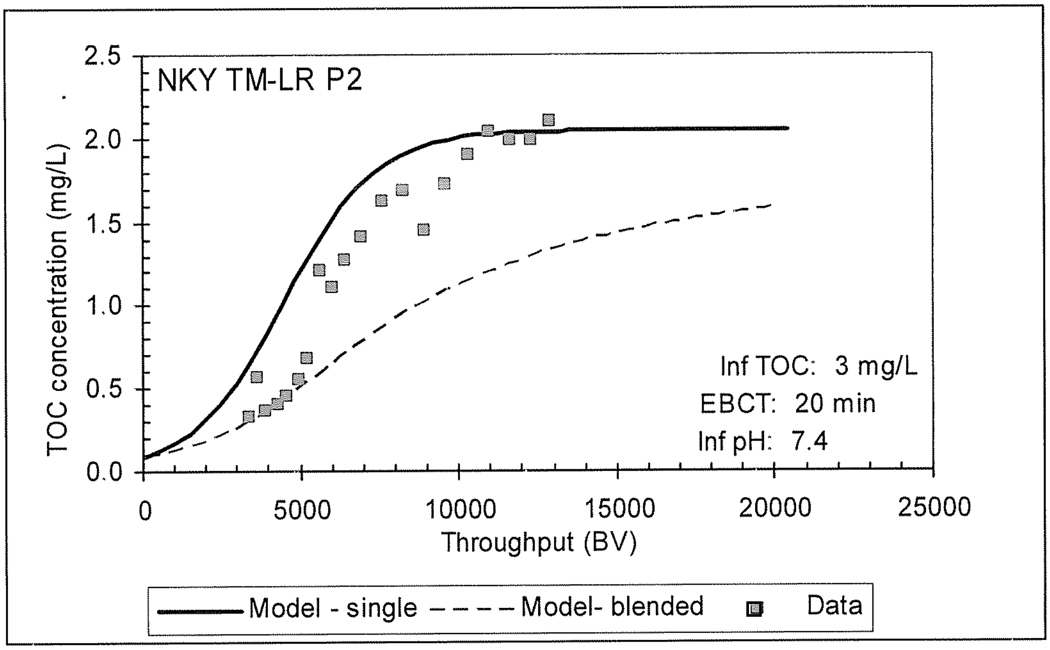


Figure 8. TOC breakthrough in throughput at EBCT = 20 min - Measured data (square symbols), model **prediction** (solid line) and model blended effluent prediction (dotted line).

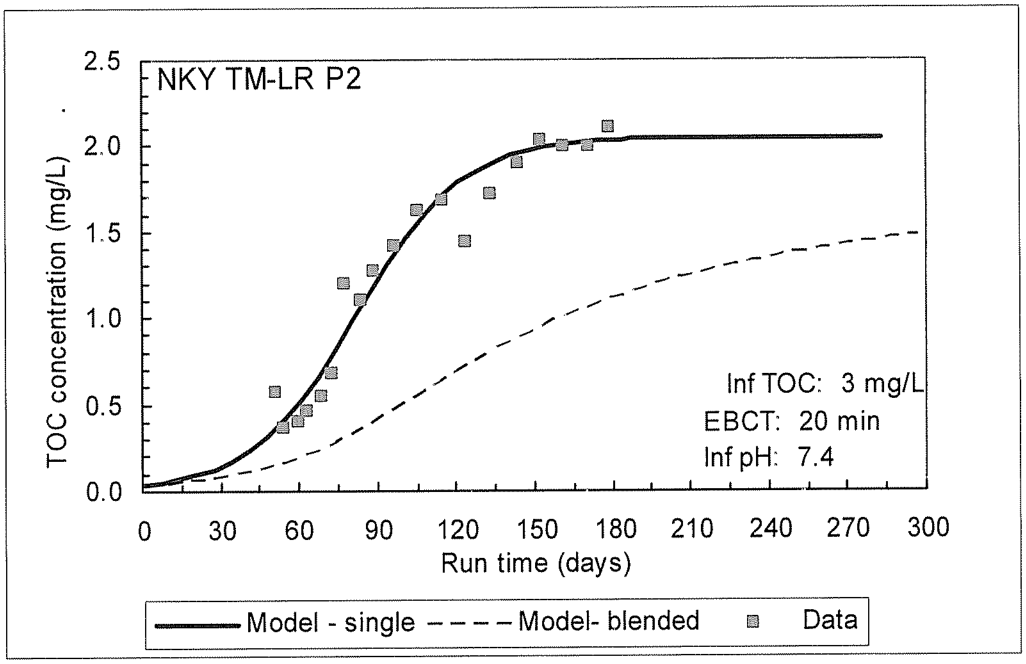


Figure 9. TOC breakthrough in time at EBCT = 20 min - Measured data (square symbols), model **best-fit** (solid line) and model blended effluent prediction (dotted line).

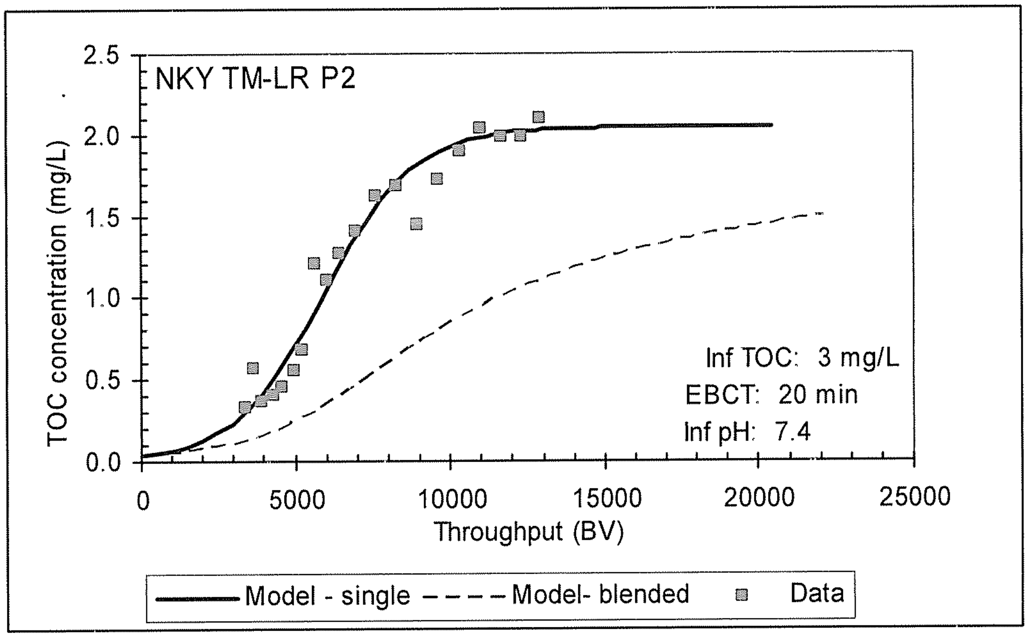


Figure 10. TOC breakthrough in throughput at EBCT = 20 min - Measured data (square symbols), model **best fit** (solid line) and model blended effluent prediction (dotted line).

Table 1
MPI –NKWD Phase 2
RSSCT and DBP Formation Testing Conditions

Task #	Task	Sample	Target Conditions		
			pH	**Temp. (°C)**	**Chlorine Residual (mg/L) after 2 hr**
1	RSSCT – 15 and 20 min EBCT w/ F400 27 TOC (3 inf & 12 eff each EBCT)	Drum	7.6	20-22	2.0-2.5
2	SDS-TTHM and SDS-HAA5 at 7 and 14 days for GAC influent	Drum	7.6	20-22	2.0-2.5
3	SDS-TTHM and SDS-HAA5 at 7 and 14 days for GAC effluent of task 1 at TOC = 1.0, 1.25, 1.5 and 1.75 mg/L	Effluents of Task 1	7.6	20-22	2.0-2.5
4	SDS-TTHM and SDS-HAA5 at 7 and 14 days for R. Miller GAC effluent and two blends with Taylor Mill (66 and 33)	Drum plus RM GAC sample	7.6	20-22	2.0-2.5

Table 2
MPI –NKWD RESULTS 12/3/07
DBP Formation Testing Results

SDS Task #	Sample	TOC (mg/L)	Cl2 Dose (mg/L)	Time (days)	pH	Cl2 Resid. (mg/L)	TTHM (µg/L)	HAA5 (µg/L)
2	TM settled - GAC inf	3.0	3.6	7	6.8	0.25	137	55.5
				14	7.0	< 0.10	142	59.8
3	Effluent 1 of Task 1	0.79	1.8	7	7.4	1.1	39.3	19.7
				14	7.3	0.95	48.5	19.1
3	Effluent 2 of Task 1	1.17	2.5	7	7.5	1.5	52.4	22.7
				14	7.5	1.25	68.9	28.4
3	Effluent 3 of Task 1	1.61	2.8	7	7.6	1.05	78	34.6
				14	7.6	0.60	86.8	33.9
3	Effluent 4 of Task 1	1.99	3.0	7	7.7	1.0	98.6	34.6
				14	7.7	0.70	123	39.6
4	Miller GAC effluent	0.70	1.7	7	7.6	1.0	54.8	40.1
				14	7.5	0.85	70.3	32.6
4	Blend 2/3 RM 1/3 TM	1.48	2.7	7	7.3	0.70	98.2	25.3
				14	7.4	0.65	128	35.2
4	Blend 1/3 RM 2/3 TM	2.43	3.3	7	7.4	0.55	124	48.4
				14	7.4	0.30	152	47.9

T* = 20 to 23 C

Northern Kentucky Water District

Northern Kentucky Water District
Preliminary Design of GAC Systems

Appendix B: Information Collection and Data Review Technical Memorandum

4775-010 / CIN

GRW, Inc.

MALCOLM PIRNIE

FINAL

NKWD PRELIMINARY DESIGN OF GAC SYSTEMS INFORMATION COLLECTION AND DATA REVIEW TECHNICAL MEMORANDUM

1.0 PROJECT BACKGROUND

The primary goal of this project is to develop full-scale design recommendations for implementing granular activated carbon (GAC) treatment at the Fort Thomas, Memorial Parkway, and Taylor Mill filtration plants. In all three cases GAC treatment would be utilized to remove disinfection byproduct (DBP) precursors (i.e., natural organic matter (NOM)); and this would reduce DBP concentrations in the NKWD distribution system and aid the NKWD in complying with the Stage 2 DBP Rule (Stage 2).

When designing a GAC system as part of a Stage 2 compliance strategy, two of the most important considerations are:

1. To what extent must the finished water NOM concentration (measured using total organic carbon (TOC) as a surrogate) be reduced so that DBP levels in the distribution system fall below the Stage 2 MCLs? In other words, what is the maximum allowable finished water TOC concentration?
2. Which GAC application (filter adsorbers or post-filter contactors) is most appropriate for achieving the finished water TOC target, and what empty-bed contact time (EBCT)[1] should it provide?

Once the TOC target is established and the appropriate GAC application identified, other design criteria such as bed depth and surface area can be developed.

The finished water TOC target is a function of the DBP formation potential of the water entering the distribution system. Stage 2 requires that the locational running annual average (LRAA) concentrations of total trihalomethanes (TTHMs) and haloacetic acids (HAA5) remain at or below 80 and 60 µg/L, respectively. The NKWD has selected internal limits of 64 and 48 µg/L (80% of the MCLs); meaning finished water TOC levels must be reduced to the extent that the LRAA concentrations of TTHMs and HAA5 at the NKWD Stage 2 sampling sites (i.e., locations that exhibit the highest DBP levels) do not exceed these limits. Furthermore, the NKWD would prefer that the TTHM and HAA5 concentrations in the distribution system (i.e., in any given sample) remain below the Stage 2 MCLs at all times.

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[1] A measure of the residence time of water moving through the adsorbers/contactors when they are empty.

Determining the appropriate GAC application and EBCT for a given treated water TOC target depends on a variety of factors, including:

- The treated water TOC target itself and whether it varies throughout the year
- The TOC concentration in the GAC influent and how it changes throughout the year
- The expected TOC removal performance of GAC systems with varying EBCTs
- Federal and/or state regulations governing GAC implementation
- The depth of the existing filter basins (for retrofitting with GAC in filter-adsorber mode)

The following sections address the issues of selecting finished water TOC targets and determining the appropriate GAC application (and EBCT) for each of the NKWD treatment plants. Decisions concerning Fort Thomas and Memorial Parkway were based on existing data for the Ohio River. The data were derived from various sources, including NKWD operating records, a bench-scale GAC performance study that was conducted for the Fort Thomas Plant, an American Water Works Association Research Foundation (AwwaRF) report on removing DBP precursors using GAC, and various reports/records concerning the post-filter contactors at the Richard Miller Water Treatment Plant (Greater Cincinnati Water Works). It should be noted that at the time of this memo, similar data sets were not available for Taylor Mill. The Taylor Mill plant draws water from the Licking River, and we are not aware of any GAC performance studies that have utilized this water. The Taylor Mill filters had previously contained GAC, and there are some data showing the TOC removal performance of these filters when the GAC was fresh. However, these data are not sufficient to establish the finished water TOC target and EBCT for the Taylor Mill plant; and some bench-scale testing will be necessary before this can be accomplished. A forthcoming memorandum will describe this testing in detail (Malcolm Pirnie, 2007).

2.0 APPLICATION OF GAC IN WATER TREATMENT PLANTS

The following sections provide a brief overview of GAC filter adsorbers and post-filter contactors. The factors that will determine which of these applications are most appropriate for the NKWD plants are highlighted in this discussion.

2.1 Filter Adsorbers

GAC filter adsorbers can often be implemented without the need for constructing new facilities (or even modifying existing structures). This approach involves replacing some or all of the granular media in a conventional filter with GAC. In other words, the GAC serves as a filter media as well as an adsorbent. However, due to the limited bed depth available in most conventional filters (i.e., 3-4 feet), the EBCT for a typical GAC filter is less than 10 minutes. Such a short EBCT generally leads to rapid TOC breakthrough and the need for frequent GAC replacement. Consequently, GAC filters are rarely used for removing TOC via adsorption.

Therefore, an important consideration relative to the viability of GAC filters for removing TOC is whether they can be operated as biological filters. GAC filters will inevitably become biologically active, and due to the "roughness" of GAC grains and their capacity to rapidly neutralize chlorine (and other disinfectants), the microbial populations in GAC filters tend to be higher than in other types of media. Under the right circumstances, a population of microorganisms will develop that effectively metabolizes (consumes) background TOC. This form of TOC removal can be sustained as long as the microbes continue to thrive. Thus, there would be no need for frequent GAC replacement. Most filter adsorbers in North America receive fresh GAC every two to three years, in response to the attrition and wear that occurs during backwashing.

Notably, the TOC removal rate of biological filters and the consistency with which it can be maintained from one season to the next are highly site-specific. As a result, biologically-active GAC filters must be carefully evaluated (via pilot testing) prior to full scale implementation.

It should be noted that GAC filters are largely ineffective for removing iron and manganese, given that they quickly neutralize chlorine and thereby interfere with iron and manganese precipitation (onto the GAC grains). Furthermore, the Kentucky Division of Water (KDoW) generally discourages biological filtration, and may not be supportive of DBP control strategies that utilize filter adsorbers (see below).

2.2 Post-Filter Contactors

Post-filter contactors are steel vessels or concrete basins (filled with GAC) located downstream of filtration. Typical EBCTs for post-filter contactors range from 10 minutes to more than 30 minutes, and the optimum EBCT for a given system is best determined through bench-scale testing (where miniature carbon contactors are used to simulate full-scale performance). The EBCT is a key factor in calculating the dimensions of a post-filter GAC system, and must therefore be established early in the design process. An additional consideration for post-filter contactors is the GAC grain size. GAC adsorption performance tends to improve as the grain size is reduced. Headloss restrictions do not allow for the use of smaller grains in GAC filter adsorbers, although these can be an option in post-filter contactors. Filter adsorbers typically utilize GACs with an 8x30 mesh size, whereas post-filter contactors utilize GACs with a 12x40 mesh size (or smaller).

A properly designed post-filter GAC contactor can remove the target contaminant(s) to non-detectable levels. However, this level of removal cannot be sustained indefinitely. Activated carbons capture contaminants within their pore structure, and as the pores become filled, removal performance declines. GAC performance is often discussed in terms of "breakthrough profiles", which are plots of effluent contaminant concentrations over time. A typical breakthrough profile usually indicates a period of complete (or near-complete) removal, followed by a gradually increasing effluent contaminant concentration. Once the effluent concentration reaches a predetermined threshold level, the GAC is replaced. For DBP control scenarios a threshold concentration for TOC is established, which corresponds to the concentration at which distribution system THM and/or HAA5 levels exceed the established limits (i.e., 80% of the MCLs). The rate of GAC replacement (often referred to as change-out frequency) varies widely depending on the influent TOC levels.

Post-filter GAC systems normally include multiple contactors, and these are usually operated in a staggered mode, during which each contactor is at a different point in its breakthrough cycle. This allows for a more efficient use of the GAC. That is, an individual contactor can operate to a point where its effluent TOC concentration exceeds the TOC target, because the effluent from that contactor is blended with the effluents from contactors that have more recently received fresh GAC (i.e., they have lower effluent TOC concentrations). But it also means that carbon replacement activities will be conducted on a more frequent basis than if the entire carbon inventory were replaced all at once. For a post-filter GAC system with 10 contactors, and a change-out frequency of 500 days, carbon replacement in a single contactor would occur every 50 days. Although there is very little particulate accumulation in post-filter contactors, they do require periodic backwashing, usually at a frequency of about once every two weeks.

3.0 SELECTING FINISHED WATER TOC TARGETS

As discussed above, the primary purpose of implementing GAC at the NKWD treatment plants is to reduce finished water TOC concentrations, such that: 1) the LRAA TTHM and HAA5 concentrations in the distribution system remain below the NKWD internal limits for these chemicals (i.e., 64 and 48 μg/L), and 2) the TTHM and HAA5 concentrations in any given sample do not exceed the Stage 2 MCLs. Figures 1 and 2 present historical TTHM and HAA5 results for distribution system sites that typically exhibit high DBP levels (as compared to other NKWD DBP sampling locations). Notably, the TTHM and HAA5 levels at these sites are normally well above the target criteria during June – November. Conversely, the levels fall well below the criteria during other months of the year. These seasonal variations are not unique, as the combination of higher TOC concentrations in the summer and higher temperatures typically increases DBP formation. These trends suggest there should be two finished water TOC targets for each plant; a relatively low target that would apply during June – November, and a higher target during December – May.

3.1 Fort Thomas and Memorial Parkway

The finished water TOC target for a given facility is heavily influenced by the DBP formation tendencies of the raw water supply; which in the case of Fort Thomas and Memorial Parkway is the Ohio River. A bench-scale study conducted in 2004 (Soward et al., 2004) investigated the DBP formation potential of this water. GAC-treated samples with varying TOC concentrations were subjected to simulated distribution system (SDS) tests in which the water was chlorinated (initial free chlorine residual ≈ 1.6 mg/L) and then stored for seven days at 19 °C. These conditions were designed to simulate the NKWD distribution system during warmer months; and the results suggest that this was a reasonably accurate simulation. Table 1 includes data from these tests, and it shows that the TTHM results for a TOC concentration of 2.5 mg/L were 130-140 μg/L. As demonstrated in Figure 1, these TTHM concentrations were similar to those observed in the NKWD distribution system during June – November, when finished water TOC levels at each of the three plants are generally between 2.0 and 3.0 mg/L (see Figures 3 and 4). Importantly, the data in Figure 1 represent TTHM levels at DBP sampling sites that were selected under the Stage 1 DBP Rule. The Initial Distribution System Evaluation (IDSE) that is required by the Stage 2 Rule may identify new sampling locations that exhibit higher DBP levels than the existing sites. The water age at some of these new sampling sites could be as high as 14 days; and the SDS tests in question simulated a residence time of seven days. Consequently, the data in Table 1 may underestimate the maximum DBP concentrations at the Stage 2 sampling locations. As discussed below, this warrants a more conservative approach in selecting the finished water TOC target.

The HAA5 data from the above-mentioned testing were not considered in this analysis. Although HAA5 concentrations in the NKWD distribution system exceed the Stage 2 MCL during the summer months, the magnitude of the exceedance is considerably less for TTHMs (see Figures 1 and 2). Thus TTHMs are the limiting factor in achieving Stage 2 compliance within the NKWD system; and the GAC implementation strategies discussed herein were developed based on the TOC removal requirements associated with TTHMs.

Table 1. SDS-TTHM Results for Ohio River Water (Reference: Soward, T.E., R.S. Summers, and B. Zachman. 2004. *Evaluation of Granular Activated Carbon Adsorption of Disinfection Byproduct Precursors for Compliance with the Stage II Disinfectant Disinfection Byproduct Rule (Prepared for: NKWD, Fort Thomas Treatment Plant).* Unpublished NKWD report)

Approximate TOC Concentration (mg/L)	SDS-TTHM Results (µg/L)
0.5	15-20
0.8	20-25
1.0	30-35
1.1	45-50
1.3	50-70
1.5	115-120
1.7	125-130
2.5	130-140

As mentioned above, the NKWD would prefer that DBP levels in their distribution system remain below the MCLs at all times. Table 1 shows that the TTHM levels following the SDS tests were less than the MCL of 80 µg/L when the TOC concentration remained at or below 1.3 mg/L. An AwwaRF report published in 1997 (Owen et al., 1997) includes similar SDS testing results for Ohio River water. These also suggest that TTHM levels will remain below 80 µg/L during warmer months if finished water TOC concentrations do not exceed 1.3 mg/L (see Figure 5). Consequently, both data sets suggest that the finished water TOC target for the Fort Thomas and Memorial Parkway plants should be about 1.3 mg/L during June – November. However, given that these results may not fully represent the TTHM formation tendencies of the DBP sampling sites that will be selected under the Stage 2 Rule, a target of 1.0 mg/L (~20% margin of safety) would be more appropriate. It should be noted that the Greater Cincinnati Water Works, which operates post-filter GAC contactors at its Richard Miller Water Treatment Plant, generally maintains a finished water TOC concentration of about 0.8 mg/L. This has led to full-scale distribution system TTHM and HAA5 levels that are consistently below 40 µg/L.

Regarding the finished water TOC target during December – May, the full-scale DBP data shown in Figures 1 and 2 indicate that the finished water TOC concentrations that have historically been achieved during those months result in TTHM and HAA5 levels that are well below the DBP target criteria. Hence the NKWD does not need to establish a specific TOC target for the December – May time period. Rather, the goal during those months should be to achieve similar finished water TOC concentrations as in previous years. More than likely this will not require GAC treatment (unless the raw water TOC increases significantly). Figure 3 shows that during December – May, the finished water TOC concentrations at Fort Thomas are usually between 1.5 and 2.0 mg/L; and Figure 4 indicates that the concentration at Memorial Parkway is typically about 1.5 mg/L.

3.2 Taylor Mill

As in the case of Fort Thomas and Memorial Parkway, the treatment goal during December – May should be to consistently achieve the historical finished water TOC levels for that time period; and this will likely not require GAC treatment. Figure 6 shows that the finished water TOC concentrations at the Taylor Mill plant are normally between 1.5 and 2.0 mg/L during December – May.

At present, there are no data available for determining the appropriate TOC target during June – November. The upcoming bench-scale evaluation for the Taylor Mill plant will include SDS tests aimed at identifying this target (Malcolm Pirnie, 2007). It should be mentioned that water treated at the Taylor Mill plant is blended with finished water from Fort Thomas prior to distribution. The extent to which blending affects the TOC target at Taylor Mill will be discussed elsewhere (Malcolm Pirnie, 2007).

4.0 EMPTY BED CONTACT TIMES

In selecting an EBCT for a GAC system it is important to consider that: a) longer EBCTs generally improve GAC performance, but require greater capital investment (to build larger adsorbers/contactors), and b) shorter EBCTs result in lower capital costs, but increase the GAC change-out frequency. The impacts of EBCT on GAC performance (change-out frequency) can be determined using breakthrough curves for the contaminant of interest. Breakthrough curves show the contaminant concentration in the GAC effluent over time. Various breakthrough curves showing TOC removal from Ohio River water were utilized in selecting an EBCT for the Fort Thomas and Memorial Parkway plants. As discussed above, the GAC performance data needed to select an EBCT for the Taylor Mill plant are not yet available, and thus the EBCT for this facility will not be determined until after the testing described in the "Taylor Mill Testing Protocol" memo has been completed.

4.1 Fort Thomas

Figure 7 shows TOC breakthrough profiles for Ohio River water that were generated during the previous bench-scale GAC evaluation for the Fort Thomas plant. The profiles were developed using miniature GAC contactors according to the "rapid small-scale column test" (RSSCT) protocol. RSSCTs are commonly used to simulate full-scale breakthrough performance, and various studies (including the AwwaRF study referenced above) have confirmed that RSSCT data are highly reliable. These results are further validated by full-scale breakthrough data from the Richard Miller Water Treatment Plant in Cincinnati. Figure 8 includes several TOC breakthrough profiles for a full-scale contactor with an EBCT of 15 minutes. The influent TOC concentration during Cycle 6 (open circles) was about 2.2 mg/L, which is relatively close to the TOC level during the tests represented in Figure 7 (about 2.5 mg/L). Both the data for Cycle 6 (Figure 8) and the 15-minute profile in Figure 7 show that the effluent TOC level reaches 1.0 mg/L after 50 days of operation, and 1.2-1.3 mg/L after 75 days of operation.

The data points in Figure 7 demonstrate the performance associated with 15- and 20-minute EBCTs. In addition, the graph includes an estimated breakthrough profile for a 25-minute EBCT. Importantly, the influent TOC concentration during these tests was approximately 2.5 mg/L; which is the average finished (filtered) water TOC level at the Fort Thomas plant during a typical June – November period (Figure 3). Therefore the results depict the GAC performance that could be expected (at Fort Thomas) during the warmer months, when the TOC target is 1.0 mg/L.

NDWD staff members have indicated that they would prefer to limit GAC change-out frequencies (at all three treatment plants) to no more than once per year. Ideally, fresh GAC would be installed in each contactor just prior to the June – November period. The contactors would then reduce the finished water TOC concentration to less than 1.0 mg/L for that timeframe (approximately 180 days). Figure 7 suggests that at Fort Thomas, contactors with an EBCT of 25 minutes, that operate in parallel and receive fresh GAC simultaneously, could maintain an effluent TOC concentration of less than 1.0 mg/L for just under 150 days. Although this is about 30 days shy of the 180-day goal, it is reasonable to assume that this level of performance would be adequate to maintain Stage 2 compliance. First, the DBP formation tendencies of Ohio River water are considerably less during the final month of the June – November time period than during previous (warmer) months. Thus, a slight increase in the finished water TOC concentration (beyond 1.0 mg/L) during the final month would have a minimal impact on DBP levels. Secondly, the filtered water TOC levels during November are generally close to 2.0 mg/L, and thus the TOC removal performance during that month will improve beyond what is shown at day 150 in Figure 7 (where the influent TOC level was 2.5 mg/L). Thirdly, GAC contactors are usually designed to provide the desired EBCT at a "maximum" flow rate (e.g., the design flow rate for the plant) that is not normally exceeded. Thus, contactors with a 25-minute EBCT generally provide more than 25 minutes of EBCT during normal operations; meaning that the breakthrough performance shown in Figure 7 is slightly conservative. Finally, post-filter contactors generally develop some biological activity, and this can further improve TOC removal rates (usually by about 5-10%).

The data in Figure 7 suggest that contactors with an EBCT of 20 minutes could produce water with a TOC concentration of less than 1.0 mg/L for about 110-120 days. For a 15-minute EBCT, this period is reduced to about 50-60 days. Both conditions would preclude an annual replacement frequency (i.e., breakthrough at 180 days together with 180 days requiring no GAC treatment). However, given that capital costs for GAC systems are proportional to EBCT, it is worth considering alternate GAC change-out strategies that would allow for the use of 15- or 20-minute contactors. As discussed in section 2.2, the GAC change-out cycles for multiple post-filter contactors are commonly staggered so as to maximize the time between change-outs. Figures 9 and 10 show the 15- and 20-minute breakthrough data from Figure 7, as well as "multi-contactor" TOC profiles that indicate the optimal change-out frequencies if more than six contactors are operating in a staggered mode. For a 15-minute EBCT, the change-out frequency corresponding to an effluent TOC target of 1.0 mg/L would be about 110 days (compared to 50 days in the absence of a staggered operation). If six contactors were in use, one of these contactors would receive fresh GAC every 110/6 or 18 days; with 12 contactors, two units would receive fresh GAC every 18 days. Thus, if contactors with an EBCT of 15 minutes were installed at Fort Thomas, the effluent TOC target of 1.0 mg/L could be maintained during June – November by replacing the GAC in one or two contactors about once every 2-3 weeks. At the end of the June – November timeframe, there would no longer be a need to install fresh GAC on a regular basis. The GAC could simply be left in place until just prior to June of the following year, at which time all the contactors would require fresh GAC. Another alternative would be to continue replacing GAC in a staggered fashion, but at a reduced frequency. This avoids the need to replace all of the GAC at once.

According to Figure 10, utilizing six or more 20-minute contactors in a staggered mode would increase the change-out frequency for achieving an effluent TOC concentration of 1.0 mg/L to about 170 days. Thus, one or two contactors would receive fresh GAC every 170/6 or 28 days. A summary of the estimated change-out frequencies associated with 15-, 20-, and 25-minute EBCTs is provided in Table 2.

Table 2. Estimated Change-Out Frequencies Associated with Various EBCTs (Fort Thomas)

EBCT (min)	Yearly change-out possible?	Staggered change-out frequency
15	No	1-2 contactors every 18 days
20	No	1-2 contactors every 28 days
25	Yes	1-2 contactors every 35 days

It is worth mentioning that the NKWD is in the process of investigating enhanced coagulation (optimizing TOC removal via coagulation) at each of its plants. This will potentially reduce filtered water TOC levels to less than the amounts shown in Figures 3, 4, and 6, thereby improving the change-out frequencies shown in Table 2 (i.e., increasing the time between change-outs).

Determining whether a 15-, 20-, or 25-minute EBCT would be most appropriate for the Fort Thomas plant requires considerable input from NKWD staff members; as it pertains directly to their preferences concerning operations and maintenance requirements, and to the capital budget for this project.

4.2 Memorial Parkway

Figure 11 shows TOC breakthrough profiles for full- and bench-scale contactors with an EBCT (real or simulated) of 15 minutes and that processed Ohio River water. The influent TOC concentration for these tests was about 2 mg/L, which is similar to the average TOC level in the finished water at Memorial Parkway during June – November (Figure 4). Figure 11 also includes estimated breakthrough profiles for 20- and 25-minute EBCTs. These estimated profiles were developed based on the following assumptions:

- The breakthrough performance of GAC contactors processing treated Ohio River water improves as the EBCT increases from 15 to 20 minutes. Specifically, Soward et al. (2004) demonstrated that an RSSCT simulating a 20-minute EBCT processed about 2000 bed volumes more (at any given effluent TOC concentration) than an RSSCT that simulated a 15-minute EBCT. Although the influent TOC concentration during these tests was about 0.5 mg/L higher than in Figure 11, the work of Zachman (2005) suggests that a 20-minute contactor (treating Ohio River water) will outperform a 15-minute contactor regardless of the influent TOC level. Importantly, the magnitude of this performance difference (i.e., the number of additional bed volumes processed) increases as the influent TOC level declines. For the purpose of this analysis, it was (conservatively) assumed that the performance difference observed at an influent TOC concentration of 2.5 mg/L would be the same as for an influent TOC concentration of 2.0 mg/L.

- The breakthrough performance of GAC contactors processing treated Ohio River water does not improve significantly as the EBCT increases from 20 to 25 minutes.

Importantly, the profiles indicate that for a 15-minute EBCT, the effluent TOC concentration reaches 1.0 mg/L after about 100 days of full-scale operation. The time to reach 1.0 mg/L TOC increases to 165 days for a 20-minute EBCT and to 190 days for a 25-minute EBCT. As discussed above, these performance levels would rule out yearly GAC change-outs for a 15-minute EBCT; although it would be possible for 20- and 25-minute EBCTs. Table 3 includes the estimated change-out frequencies associated with each EBCT if the contactors are operated in a staggered mode.

Table 3. Estimated Change-Out Frequencies associated with Various EBCTs (Memorial Parkway)

EBCT (min)	Yearly change-out possible?	Staggered change-out frequency
15	No	1-2 contactors every 27 days
20	Yes	1-2 contactors every 36-40 days
25	Yes	1-2 contactors every 44-48 days

5.0 RECOMMENDED GAC APPLICATION FOR THE NKWD PLANTS

In determining whether GAC filter adsorbers or post-filter contactors would be more appropriate for the NKWD treatment plants, a variety of factors must be considered; especially the limitations associated with filter adsorbers and the chlorination preferences of the Kentucky Division of Water (KDoW). As discussed above, filter adsorbers inevitably become biologically active. The KDoW has sought to minimize the occurrence of biologically-active filtration in the state of Kentucky by strongly encouraging utilities to apply chlorine upstream of granular media filters and maintain a measurable chlorine residual in filter effluents. Given that GAC rapidly neutralizes chlorine, it is difficult to maintain a chlorine residual in the effluent from a filter adsorber; and this can only be accomplished by applying a (very) high pre-filter chlorine dose. Adding significant amounts of chlorine prior to GAC treatment (i.e., while TOC concentrations are still relatively high) will contribute to DBP formation and should thus be minimized. Furthermore, chlorine is known to degrade the adsorption performance of GAC, and thus a high pre-filter chlorine dose would likely reduce the TOC removal performance of a filter adsorber.

For filter adsorbers with short EBCTs (as would be the case for the NKWD plants), a further reduction in TOC removal performance due to pre-filter chlorination would likely render them completely unsuitable as a DBP control measure. Even if the biological aspects of utilizing filter adsorbers at the NKWD plants are successfully managed, the filter boxes at these facilities severely limit the available EBCTs. At present, each plant could accommodate 30-40 inches of GAC (if gravel-less underdrains were installed and a minimum of sand was utilized), and this would only provide for 6-8 minutes of EBCT at a loading rate of 3 gpm/ft^2; a typical rate (for all three plants) during the summer months. As discussed in Section 5, the available GAC performance data suggest that for the Fort Thomas and Memorial Parkway plants, an EBCT of at least 15 minutes is desirable. Although GAC performance data for the Licking River has not yet been collected, the fact that filtered water (i.e., GAC influent) TOC concentrations are similar to those at Fort Thomas suggests that similar EBCT requirements would apply to Taylor Mill.

Yet another important consideration regarding the tendency of filter adsorbers to become biologically active relates to the operating schedules of the Memorial Parkway and Taylor Mill plants. Memorial Parkway is shut down eight hours per day and the Taylor Mill plant does not operate on weekends. As mentioned above, the Taylor Mill filters had previously contained GAC and NKWD staff members had observed significant biological growth in these filters during idle periods. Thus, implementing filter adsorbers at Memorial Parkway or Taylor Mill would create an ongoing need to manage the operational and water quality impacts of excessive bio-growth (in the filters) during routine shutdowns.

Based on the above-listed considerations, post-filter contactors would be a more appropriate GAC configuration for the NKWD plants. Utilizing post-filter contactors will allow for the NKWD filters to contain anthracite (instead of GAC), meaning the KDoW requirements concerning filter effluent chlorine residuals could be met with minimal pre-filter chlorine doses. In addition, post-filter contactors are not likely to develop excessive bio-growth during idle periods, and they can be designed to provide EBCTs well beyond the requirements for this project.

6.0 REFERENCES

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Owen, D.M., Z.M. Chowdhury, R.S. Summers, S.M. Hooper, G. Solarik, and K. Grey. 1997. *Removal of DBP Precursors by GAC Adsorption.* AWWARF.

Soward, T.E., R.S. Summers, and B. Zachman. 2004. *Evaluation of Granular Activated Carbon Adsorption of Disinfection Byproduct Precursors for Compliance with the Stage II Disinfectant Disinfection Byproduct Rule (Prepared for: NKWD, Fort Thomas Treatment Plant).* Unpublished NKWD report.

Zachman, B. 2005. *Understanding and Predicting Natural Organic Matter Adsorption by GAC Columns.* Masters Thesis. University of Colorado (Boulder).

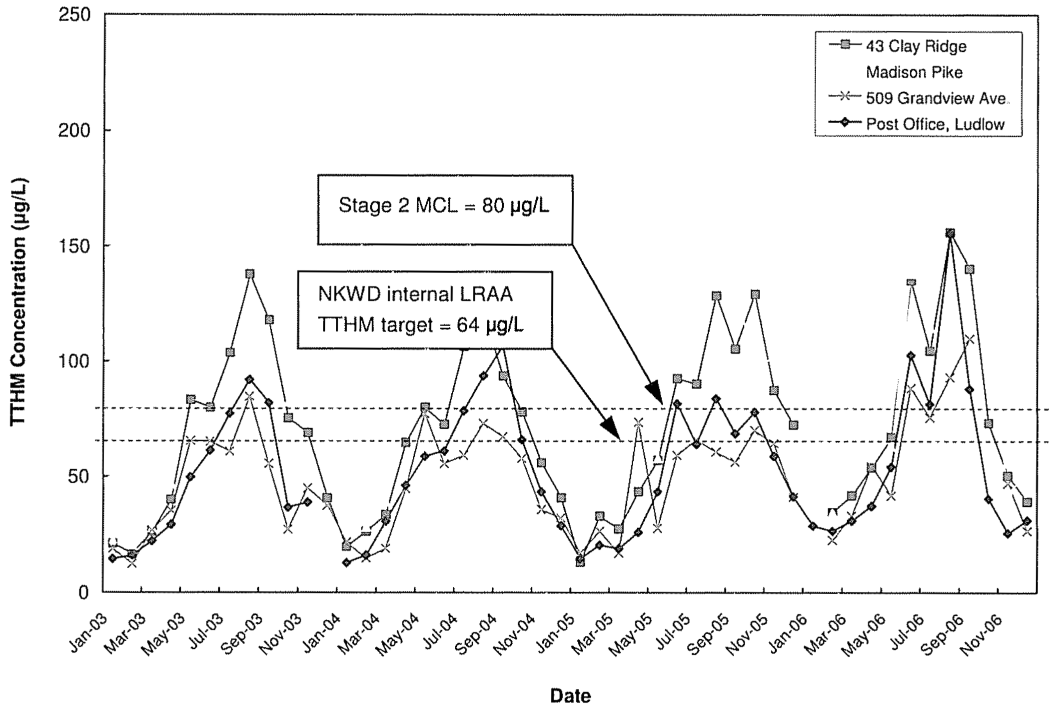


Figure 1. Monthly TTHM results for NKWD distribution system sites that typically exhibit the highest DBP concentrations (of any current NKWD DBP sampling sites).

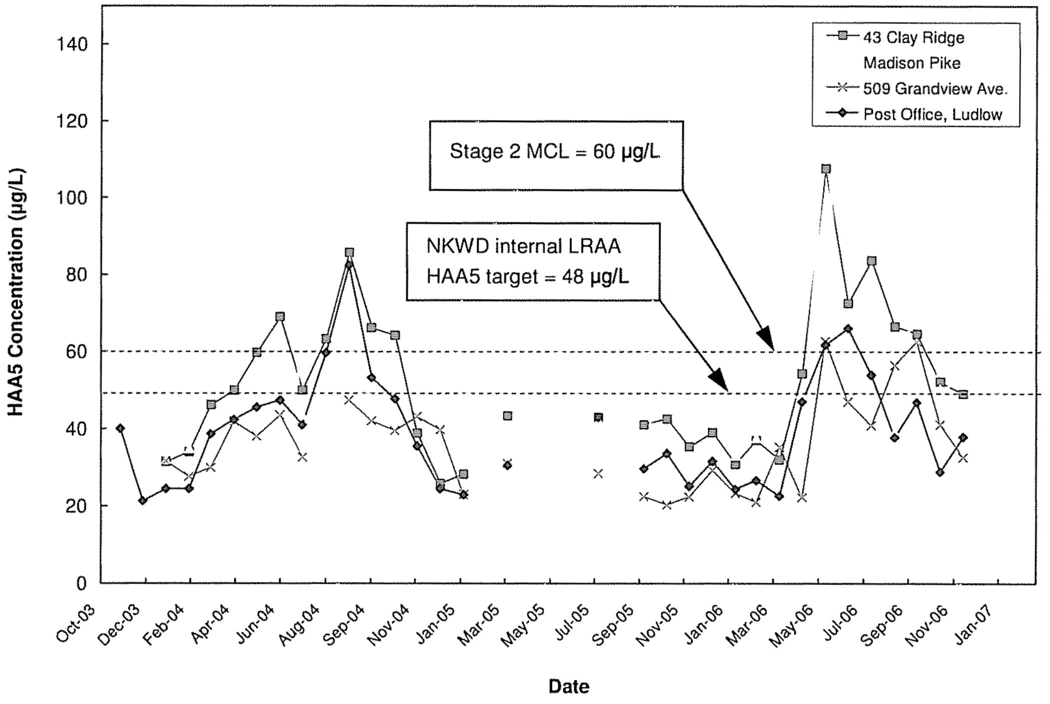


Figure 2. Monthly HAA5 results for NKWD distribution system sites that typically exhibit the highest DBP concentrations (of any current NKWD DBP sampling sites).

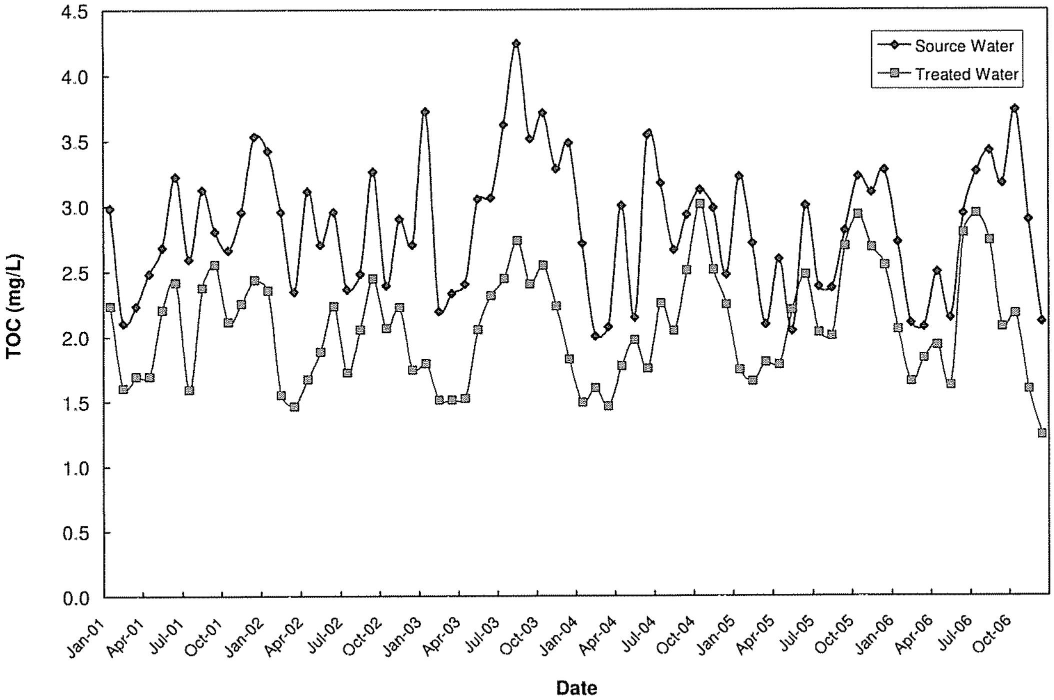


Figure 3. Raw and finished water TOC levels at the Fort Thomas plant.

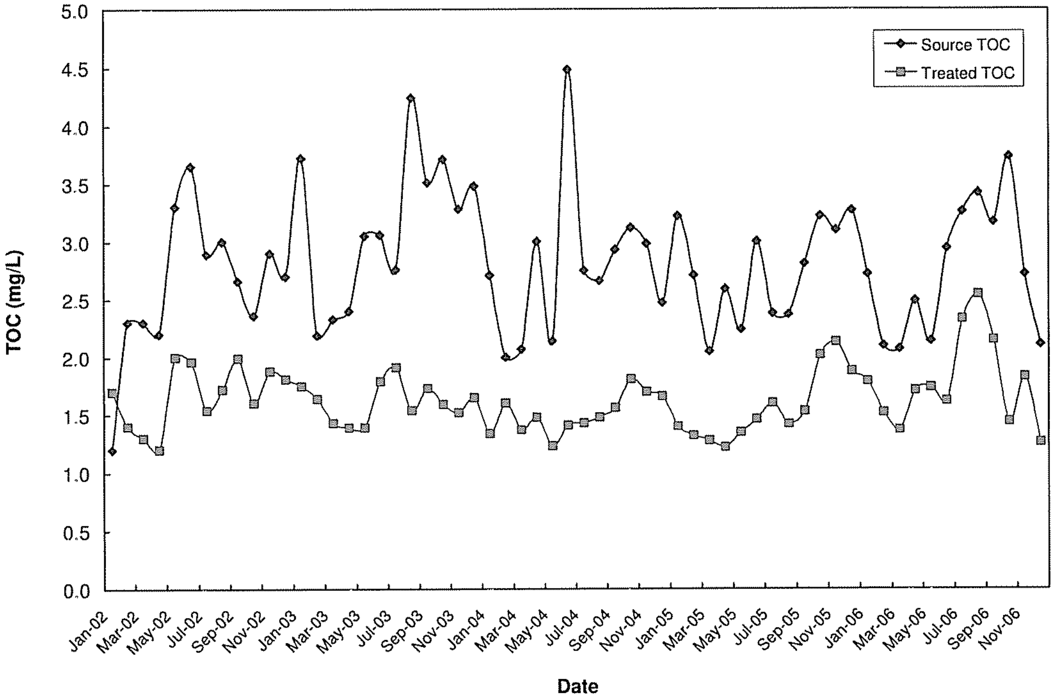


Figure 4. Raw and finished water TOC levels at the Memorial Parkway plant.

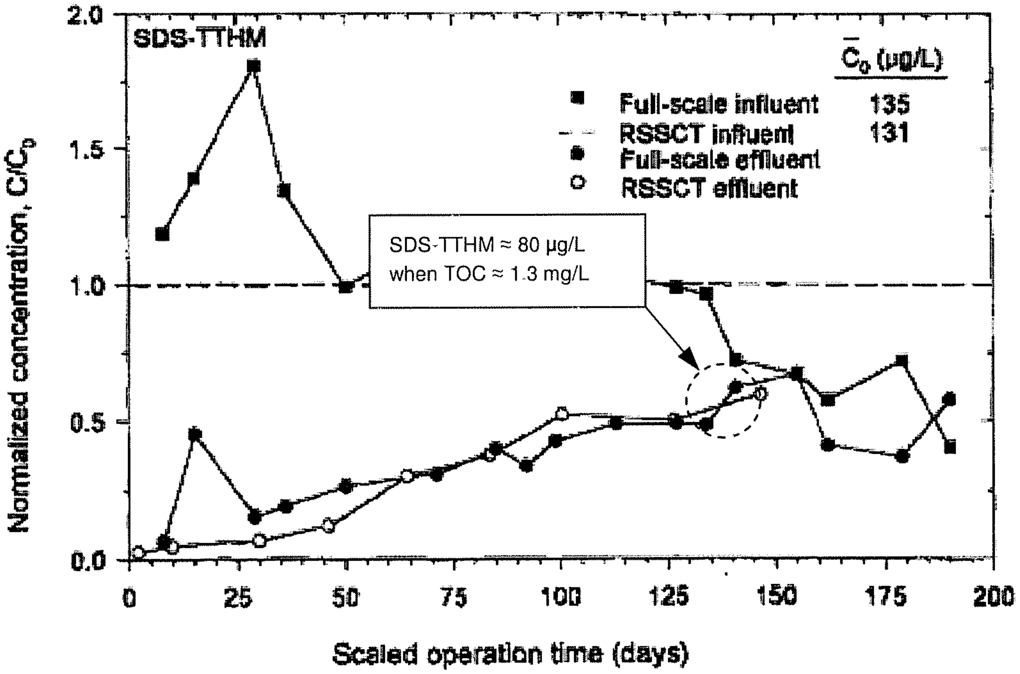


Figure 5. Full-scale and RSSCT SDS-TTHM breakthrough for Ohio River water. (Reference: Owen, D.M., Z.M. Chowdhury, R.S. Summers, S.M. Hooper, G. Solarik, and K. Grey. 1997. *Removal of DBP Precursors by GAC Adsorption*. AWWARF.)

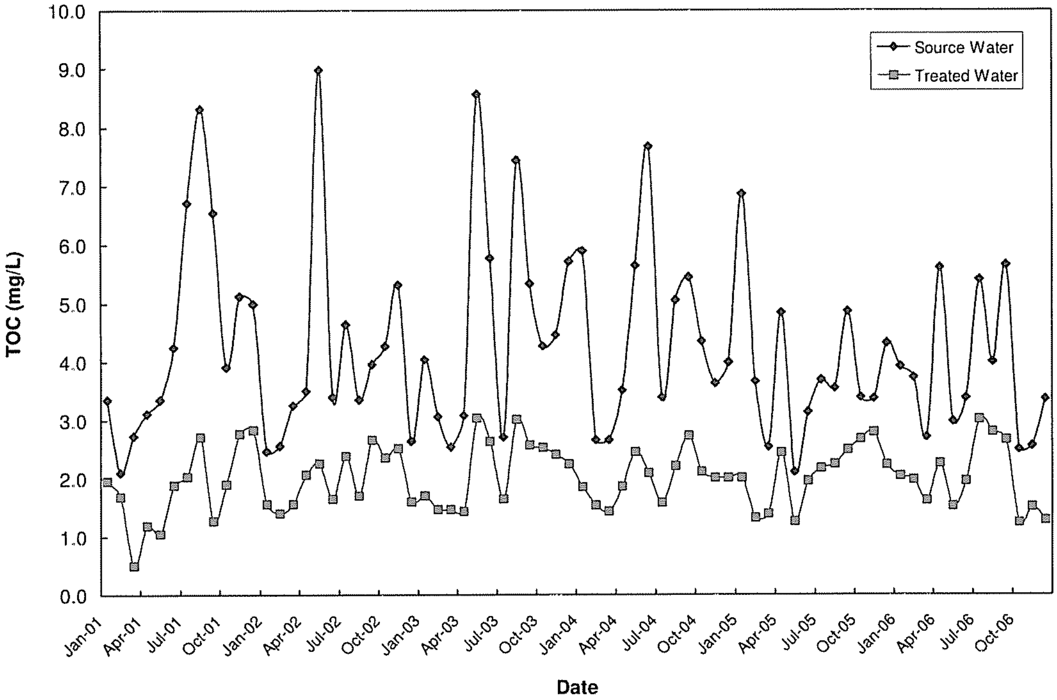


Figure 6. Raw and finished water TOC levels at the Taylor Mill plant.

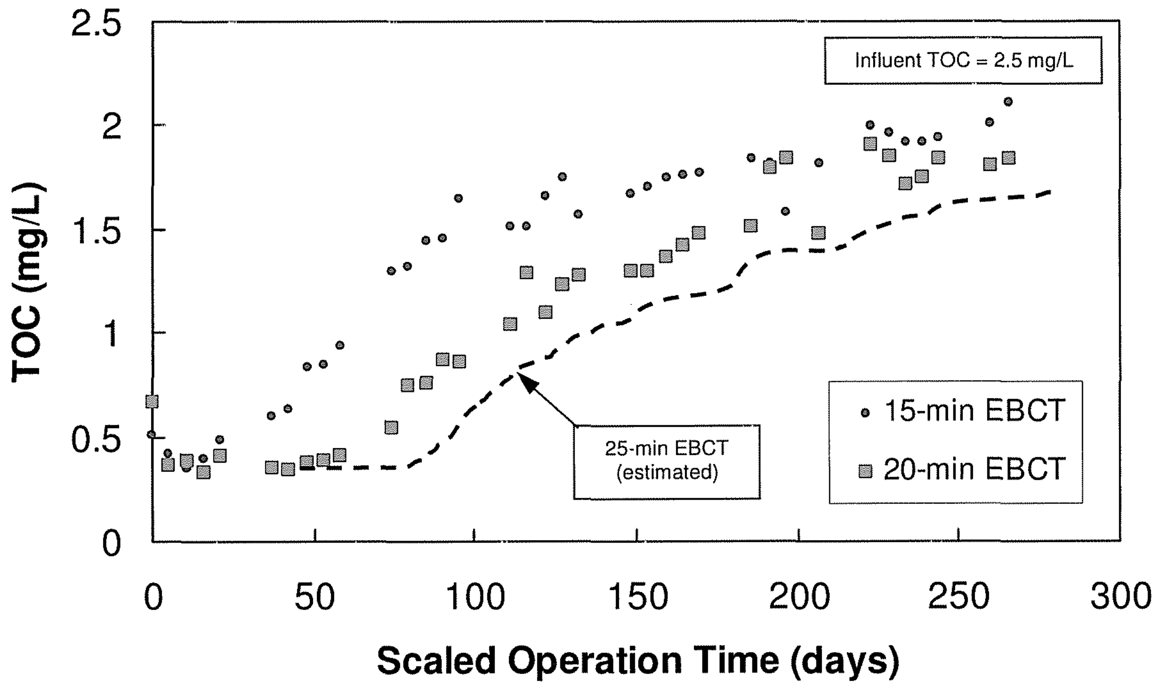


Figure 7. TOC breakthrough profiles for bench-scale (RSSCT) contactors processing Ohio River water. (Reference: Soward, T.E., R.S. Summers, and B. Zachman. 2004. *Evaluation of Granular Activated Carbon Adsorption of Disinfection Byproduct Precursors for Compliance with the Stage II Disinfectant Disinfection Byproduct Rule (Prepared for: NKWD, Fort Thomas Treatment Plant).* Unpublished NKWD report.)

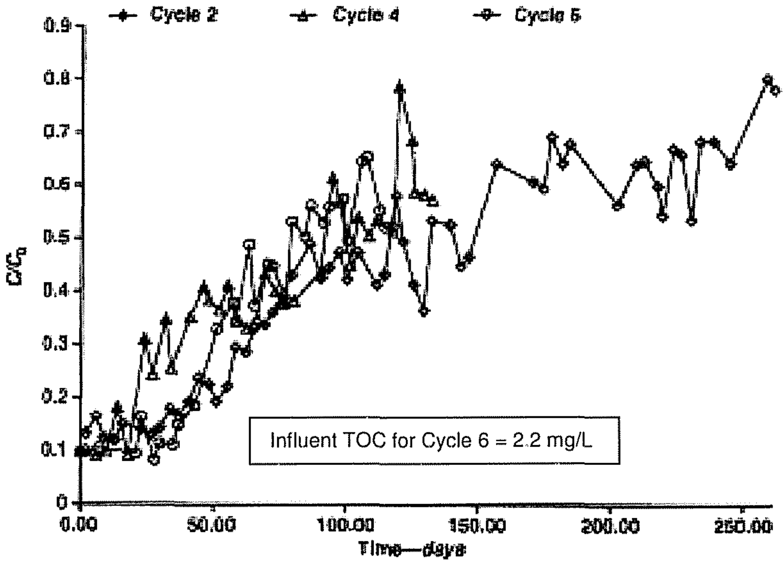


Figure 8. TOC breakthrough profiles for the full-scale post-filter contactors at the Richard Miller Water Treatment Plant. (Reference: Moore, B.C., F.S. Cannon, D.H. Metz, and J. DeMarco. 2003. GAC Pore Structure in Cincinnati during Full-Scale Treatment/Reactivation. *Journal AWWA*, 95:2:103.)

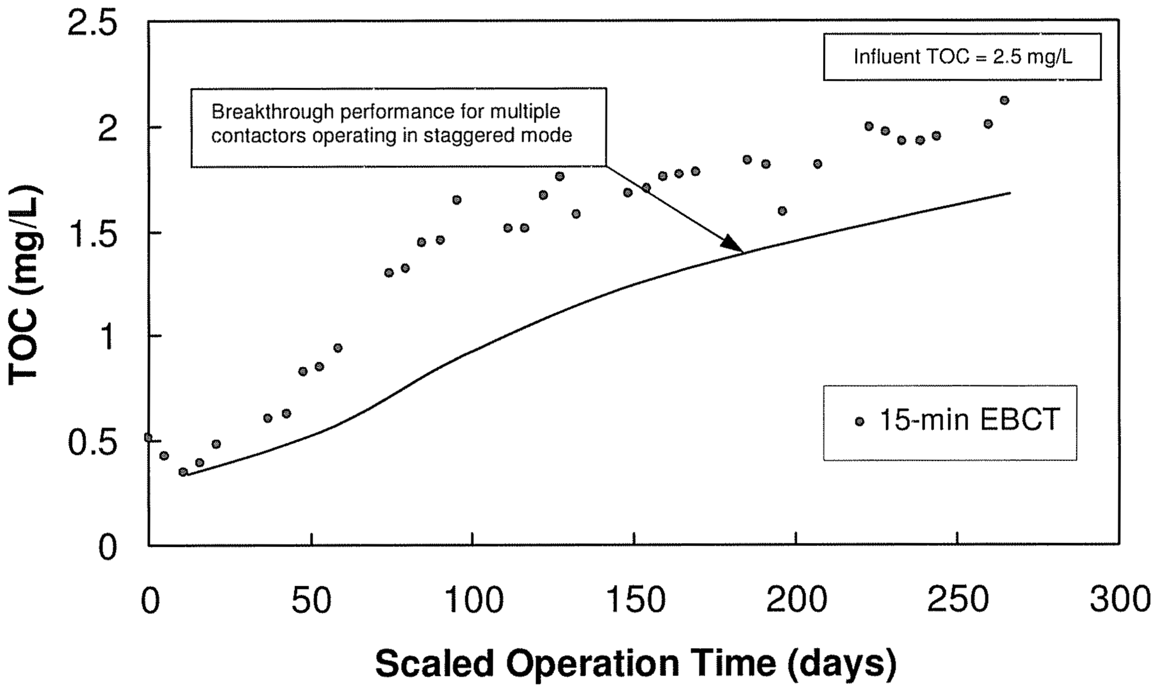


Figure 9. TOC breakthrough data from Figure 7 (15-minute EBCT) along with the associated performance profile for a multi-contactor system with staggered GAC change-out.

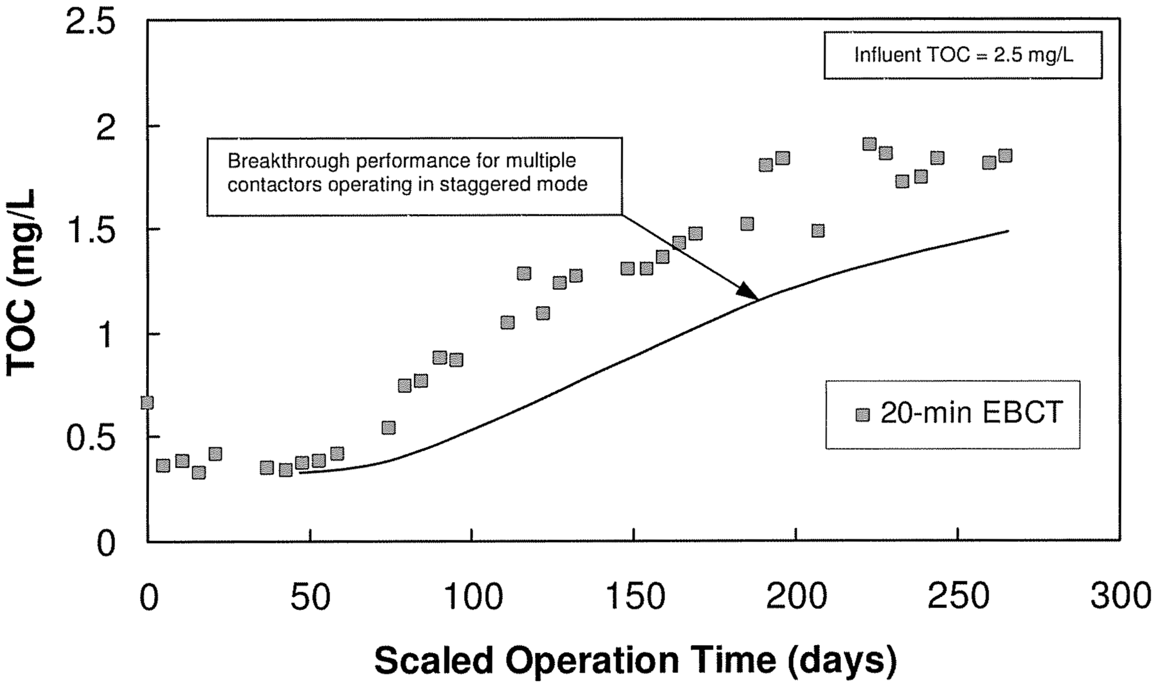


Figure 10. TOC breakthrough data from Figure 7 (20-minute EBCT) along with the associated performance profile for a multi-contactor system with staggered GAC change-out.

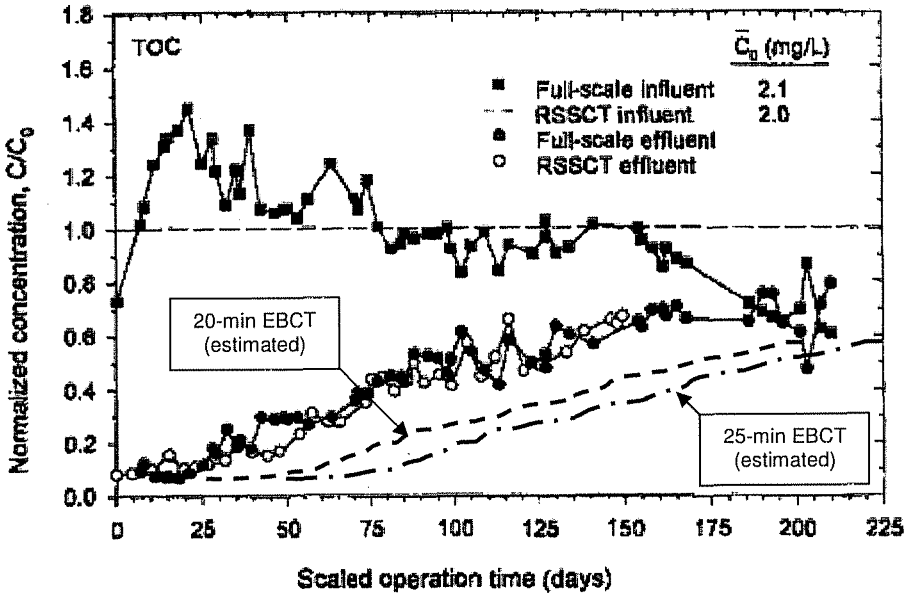


Figure 11. TOC breakthrough profiles for bench- and full-scale contactors processing Ohio River water; EBCT = 15 minutes. (Reference: Owen, D.M., Z.M. Chowdhury, R.S. Summers, S.M. Hooper, G. Solarik, and K. Grey. 1997. *Removal of DBP Precursors by GAC Adsorption.* AWWARF.)

Northern Kentucky Water District

Northern Kentucky Water District
Preliminary Design of GAC Systems

Appendix C: Detailed Cost Comparisons

4775-010 / CIN

GRW, Inc.

MALCOLM PIRNIE

Northern Kentucky Water District
Preliminary Design of GAC Systems
Fort Thomas GAC Facility - Option 3
Opinion of Probable Construction Costs

		Division Subtotal	% of Total
Division 1 - General Requirements		$200,000	1%
Division 2 - Sitework		$1,500,000	6%
Division 3 - Concrete		$5,000,000	20%
Division 4 - Masonry		$200,000	1%
Division 5 - Metals		$200,000	1%
Division 6 - Woods and Plastics		$0	0%
Division 7 - Element Protection		$200,000	1%
Division 8 - Doors and Windows		$300,000	1%
Division 9 - Finishes		$100,000	0%
Division 10 - Specialities		$100,000	0%
Division 11 - Equipment		$3,600,000	15%
Division 12 - Furnishing		$0	0%
Division 13 - Instrumentation		$2,400,000	10%
Division 14 - Hoisting Equipment		$0	0%
Division 15 - Mechanical		$6,300,000	26%
Division 15 - Plumbing & HVAC		$1,600,000	6%
Division 16 - Electrical		$3,000,000	12%
	Subtotal	**$24,700,000**	100%
Mobilization and Insurance	5.00%	$1,200,000	
Overhead & Profit	15.00%	$3,700,000	
	Construction Cost Subtotal	$29,600,000	
	Construction Cost Subtotal	$33,500,000	
	UV Facility	$2,800,000	
Contingency	20.00%	$7,300,000	
	Engineering	$5,400,000	
Total Cost (2010)		**$49,000,000**	

Northern Kentucky Water District
Preliminary Design of GAC Systems

Memorial Parkway GAC Facility - Option 2

Opinion of Probable Construction Costs

		Division Subtotal	**% of Total**
Division 1 - General Requirements		$100,000	1%
Division 2 - Sitework		$800,000	6%
Division 3 - Concrete		$2,400,000	18%
Division 4 - Masonry		$200,000	1%
Division 5 - Metals		$100,000	1%
Division 6 - Woods and Plastics		$0	0%
Division 7 - Element Protection		$100,000	1%
Division 8 - Doors and Windows		$200,000	1%
Division 9 - Finishes		$0	0%
Division 10 - Specialities		$100,000	1%
Division 11 - Equipment		$2,000,000	15%
Division 12 - Furnishing		$0	0%
Division 13 - Instrumentation		$1,400,000	10%
Division 14 - Hoisting Equipment		$0	0%
Division 15 - Mechanical		$3,600,000	26%
Division 15 - Plumbing & HVAC		$1,100,000	8%
Division 16 - Electrical		$1,500,000	11%
Subtotal		**$13,600,000**	100%
Mobilization and Insurance	5.00%	$700,000	
Overhead & Profit	15.00%	$2,000,000	
Construction Cost Subtotal		$16,300,000	
Construction Cost Subtotal		$18,500,000	
UV Facility		$2,300,000	
Contingency	20.00%	$4,100,000	
Engineering		$3,100,000	
Total Cost (2010)		**$28,000,000**	

Northern Kentucky Water District

Preliminary Design of GAC Systems

Taylor Mill GAC Facility - Option 2

Opinion of Probable Construction Costs

		Division Subtotal	% of Total
Division 1 - General Requirements		$100,000	1%
Division 2 - Sitework		$400,000	4%
Division 3 - Concrete		$2,800,000	25%
Division 4 - Masonry		$0	0%
Division 5 - Metals		$0	0%
Division 6 - Woods and Plastics		$0	0%
Division 7 - Element Protection		$0	0%
Division 8 - Doors and Windows		$0	0%
Division 9 - Finishes		$30,000	0%
Division 10 - Specialities		$10,000	0%
Division 11 - Equipment		$4,700,000	42%
Division 12 - Furnishing		$0	0%
Division 13 - Instrumentation		$700,000	6%
Division 14 - Hoisting Equipment		$0	0%
Division 15 - Mechanical		$1,200,000	11%
Division 15 - Plumbing & HVAC		$0	0%
Division 16 - Electrical		$1,300,000	12%
	Subtotal	**$11,200,000**	100%
Mobilization and Insurance	5.00%	$600,000	
Overhead & Profit	15.00%	$1,700,000	
	Construction Cost Subtotal	$13,500,000	
	Construction Cost Subtotal	$15,300,000	
Contingency	20.00%	$3,100,000	
	Engineering	$2,300,000	
Total Cost (2010)		**$20,700,000**	

Northern Kentucky Water District

Northern Kentucky Water District
Preliminary Design of GAC Systems

Appendix D: Contactor Comparisons

4775-010 / CIN

GRW, Inc.

MALCOLM PIRNIE

Comparison of NKWD Design Criteria VS GCWW Design Criteria

											Amount of GAC per Conatctor			
WTP Flow		No. of Contactors		Flowrate per Contactor In-Service (MGD)	GAC Contactor Dimensions			Surface Area per Contactor	Surface Loading Rate	Empty Bed Contact Time	Volume	Dry Weight	Virgin (dry)	Spent Drained
(MGD)	Flow Condition	Equipped	In-Service	(MGD)	Length	Width	Bed Depth	(sf)	(gpm/sf)	(minutes)	(cf)	(lbs.)	Truckloads	Truckloads
Richard Miller WTP (Cincinnati)														
124	Annual Average Flow	12	11	11.3	30	65	11.5	1,950	4.0	21.4	22,425	616,688	15.4	30.8
175	Max Daily Flow	12	11	15.9	30	65	11.5	1,950	5.7	15.2	22,425	616,688	15.4	30.8
Fort Thomas WTP														
Routine Operation (All contactors in service)														
12	Current Minimum Flow for Design	8	8	1.5	20	44	12	880	1.2	75.8	10,560	290,400	7.3	14.5
17	Current Minimum Daily Flow	8	8	2.1	20	44	12	880	1.7	53.5	10,560	290,400	7.3	14.5
21.7	Current Typical Annual Average Day Flow	8	8	2.7	20	44	12	880	2.1	41.9	10,560	290,400	7.3	14.5
35	2012 Expected Average Daily Flow	8	8	4.4	20	44	12	880	3.5	26.0	10,560	290,400	7.3	14.5
41	2012 Expected Peak Daily Flow	8	8	5.1	20	44	12	880	4.0	22.2	10,560	290,400	7.3	14.5
44	Current WTP Hydraulic Capacity	8	8	5.5	20	44	12	880	4.3	20.7	10,560	290,400	7.3	14.5
During Carbon Changeouts (1 equipped contactor off-line)														
12	Current Minimum Flow for Design	8	7	1.7	20	44	12	880	1.4	66.4	10,560	290,400	7.3	14.5
17	Current Minimum Daily Flow	8	7	2.4	20	44	12	880	1.9	46.8	10,560	290,400	7.3	14.5
21.7	Current Typical Annual Average Daily Flow	8	7	3.1	20	44	12	880	2.4	36.7	10,560	290,400	7.3	14.5
35	2012 Expected Average Daily Flow	8	7	5.0	20	44	12	880	3.9	22.8	10,560	290,400	7.3	14.5
41	2012 Expected Peak Daily Flow	8	7	5.9	20	44	12	880	4.6	19.4	10,560	290,400	7.3	14.5
44	Current WTP Hydraulic Capacity	8	8	5.5	20	44	12	880	4.3	20.7	10,560	290,400	7.3	14.5
Memorial Parkway WTP														
Routine Operation (Current Design Capacity: 3 contactors in service; Future Design Capacity: All contactors in service)														
1.8	Current Minimum Flow for Design	6	3	0.6	15	34	12	510	0.8	109.9	6,120	168,300	4.2	8.4
1.8	Current Minimum Daily Flow	6	3	0.6	15	34	12	510	0.8	109.9	6,120	168,300	4.2	8.4
3.2	Current Typical Annual Average Daily Flow	6	3	1.1	15	34	12	510	1.5	61.8	6,120	168,300	4.2	8.4
6.3	2012 Expected Average Daily Flow	6	3	2.1	15	34	12	510	2.9	31.4	6,120	168,300	4.2	8.4
8.1	2012 Expected Peak Daily Flow	6	3	2.7	15	34	12	510	3.7	24.4	6,120	168,300	4.2	8.4
10	Current WTP Hydraulic Capacity	6	3	3.3	15	34	12	510	4.5	19.8	6,120	168,300	4.2	8.4
20	Future WTP Hydraulic Capacity	6	6	3.3	15	34	12	510	4.5	19.8	6,120	168,300	4.2	8.4
During Carbon Changeouts (Current Design Capacity: 1 equipped contactor off-line; Future Design Capacity: 1 equipped contactor off-line)														
1.8	Current Minimum Flow for Design	6	2	0.9	15	34	12	510	1.2	73.3	6,120	168,300	4.2	8.4
1.8	Current Minimum Daily Flow	6	2	0.9	15	34	12	510	1.2	73.3	6,120	168,300	4.2	8.4
3.2	Current Typical Annual Average Daily Flow	6	2	1.6	15	34	12	510	2.2	41.2	6,120	168,300	4.2	8.4
6.3	2012 Expected Average Daily Flow	6	2	3.2	15	34	12	510	4.3	20.9	6,120	168,300	4.2	8.4
8.1	2012 Expected Peak Daily Flow	6	2	4.1	15	34	12	510	5.5	16.3	6,120	168,300	4.2	8.4
10	Current WTP Hydraulic Capacity	6	2	5.0	15	34	12	510	6.8	13.2	6,120	168,300	4.2	8.4
20	Future WTP Hydraulic Capacity	6	5	4.0	15	34	12	510	5.4	16.5	6,120	168,300	4.2	8.4

Northern Kentucky Water District

Northern Kentucky Water District
Preliminary Design of GAC Systems

Appendix E: GAC Manufacturer Information

GRW, Inc.

MALCOLM PIRNIE

Calgon Carbon Corporation PB-1042-08/98

Product Bulletin

FILTRASORB® 300 & 400

GRANULAR ACTIVATED CARBONS FOR POTABLE WATER

Description

Filtrasorb 300 and Filtrasorb 400 are two high activity granular activated carbons developed by Calgon Carbon Corporation for the removal of taste and odor compounds and dissolved organic compounds from water treatment.

These activated carbons are made from selected grades of bituminous coal to produce a high activity, durable granular product capable of withstanding the abrasion associated with repeated backwashing, air scouring and hydraulic transport. Activation is carefully controlled to produce exceptionally high internal surface area with optimum pore size for effective adsorption of a broad range of high and low molecular weight organic contaminants. The product is also formulated to comply with all the applicable provisions of the AWWA Standard for Granular Activated Carbon, edition B604-96, the stringent extractable metals requirements of ANSI/NSF Standard 61 and the Food Chemicals Codex.

Applications

Filtrasorb 300 and 400 activated carbons can be used to treat surface and ground water sources for the production of drinking water. These products can be used as a complete replacement for sand and anthracite media. Filtrasorb 300 and 400 activated carbons function as dual purpose media, providing both filtration and adsorption.

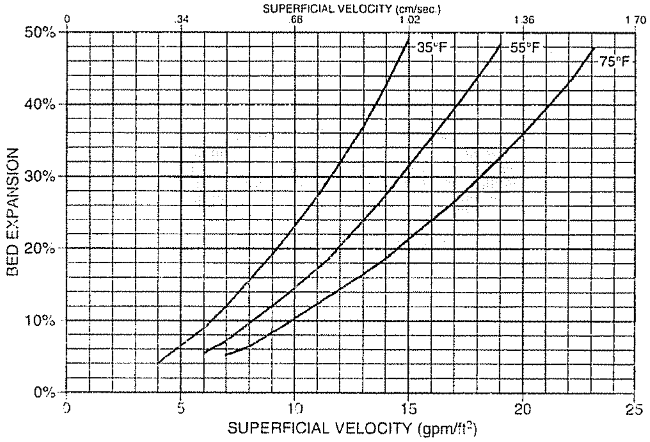
Design Considerations

As a replacement for existing filter media, conversion to Filtrasorb 300 and 400 granular activated carbons impose no major changes to a plant's normal filtration operations. Calgon Carbon Corporation can also provide complete modular adsorption systems as an add-on treatment stage if required.

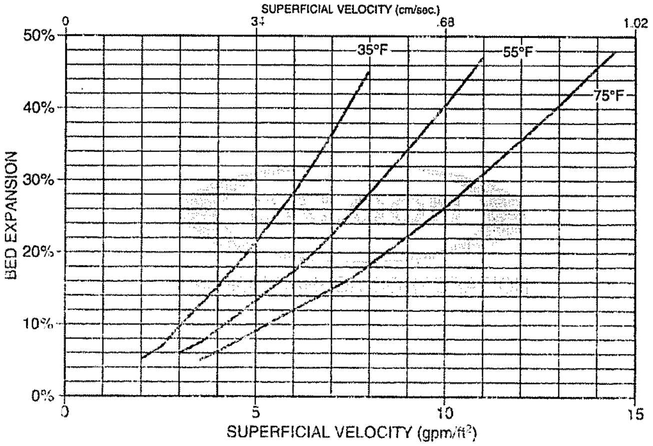
Specifications

	F300	F400
Iodine Number, mg/g (Min.)	900	1000
Moisture, weight % (Max.%)	2	2
Abrasion Number (Min.)	78	75
Effective Size, mm	0.8 - 1.0	0.55-0.75
Uniformity Coefficient (Max.)	2.1	1.9
Ash, weight % (Max.)	8	9
Apparent Density, g/cc (Min.)	0.48	0.44
Screen Size, U. S. Sieve Series, weight %		
Larger than No. 8 (Max.)	15	-
Smaller than No. 30 (Max.)	4	-
Larger than No. 12 (Max.)	-	5
Smaller than No. 40 (Max.)	-	4

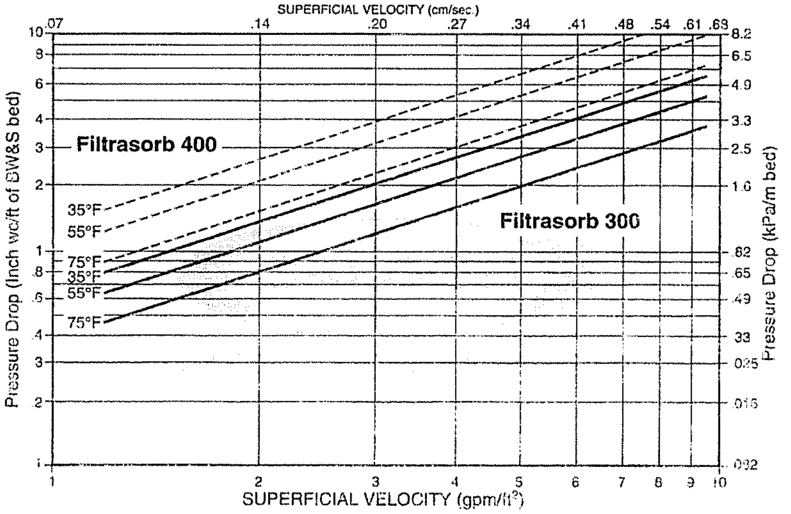
FILTRASORB 300 - BED EXPANSION
BACKWASHED & SEGREGATED BED



FILTRASORB 400 - BED EXPANSION
BACKWASHED & SEGREGATED BED



FILTRASORB DOWNFLOW PRESSURE DROP
BACKWASHED & SEGREGATED BED



Safety Message

Wet activated carbon preferentially removes oxygen from air. In closed or partially closed containers and vessels, oxygen depletion may reach hazardous levels. If workers are to enter a vessel containing carbon, appropriate sampling and work procedures for potentially low oxygen spaces should be followed, including all applicable federal and state requirements.

CALGON
CALGON CARBON CORPORATION

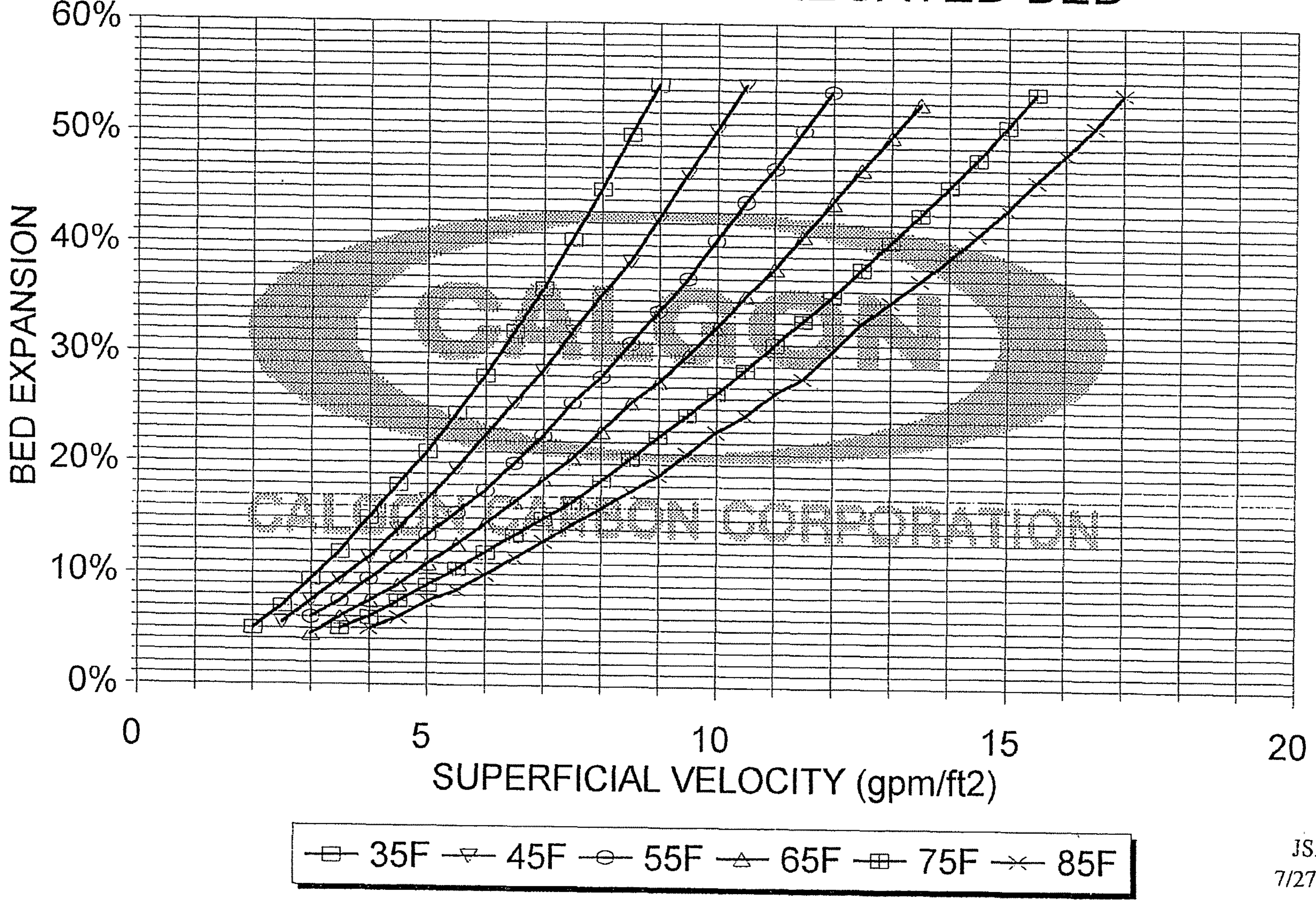
Calgon Carbon Corporation
P.O. Box 717
Pittsburgh, Pa 15230

Chemviron Carbon
Zoning Industriel C
B-7181 Feluy, Belgium

Chemviron Carbon

FILTRASORB 400 - BED EXPANSION

BACKWASHED & SEGREGATED BED



JSR
7/27/94

ISO 9002

FM 39843

NORIT Americas Inc.

Most Choices + Precise Fit = Best Performance.

DATASHEET

No. 2201
Apr 2002

NORIT® GAC 1240

GRANULAR ACTIVATED CARBON

NORIT GAC 1240 is a granular activated carbon produced by steam activation of select grades of coal. As a result of a unique patented activation process and stringent quality control, **NORIT GAC 1240** offers excellent adsorption properties and is recommended for removal of impurities from water and industrial process applications. **NORIT GAC 1240** meets all AWWA B100-96 and B604-96 standards for potable water use. **NORIT GAC 1240** is Kosher certified and meets ANSI/NSF Standard 61.

Product Specifications

Iodine number, mg/g	1020 min.
Molasses number	230 min.
Abrasion number (AWWA)	75 min.
Moisture, % as packed	2 max.
Mesh size (U.S. Sieve Series)	
Greater than 12 mesh (1.70 mm), %	5 max.
Less than 40 mesh (0.42 mm), %	4 max.

Typical Properties*

Apparent density, vibrating feed, g/mL	0.50
lb/ft^3	31
Bed density, backwashed and drained, lb/ft^3	27.5
Effective size, mm	0.65
Uniformity coefficient	1.6
Food Chemical Codex (4th edition, 1996)	Passes

*For general information only, not to be used as purchase specifications.

Packaging/Transportation

Standard package is woven polypropylene bulk bags with a net weight of 1,000 lbs.
Activated carbon (NOT REGULATED)
  Exempt from DOT, IATA, and IMDG regulations
Import/Export classification: 3802.10.0000 (HS Tariff Classification)
Domestic Freight Classification: NMFC 040560
CAS # 7440-44-0

Safety

Wet activated carbon depletes oxygen from air and, therefore, dangerously low levels of oxygen may be encountered. Whenever workers enter a vessel containing activated carbon, the vessel's oxygen content should be determined and work procedures for potentially low oxygen areas should be followed. Appropriate protective equipment should be worn. Avoid inhalation of excessive carbon dust. No problems are known to be associated in handling this material. However, the product may contain up to 12% silica (quartz). Long-term inhalation of high dust concentrations can lead to respiratory impairment. Use forced ventilation or a dust mask when necessary for protection against airborne dust exposure (see Code of Federal Regulations - Title 29, Subpart Z, par. 1910.1000, Table Z-3).

(continued on reverse side)

DATASHEET

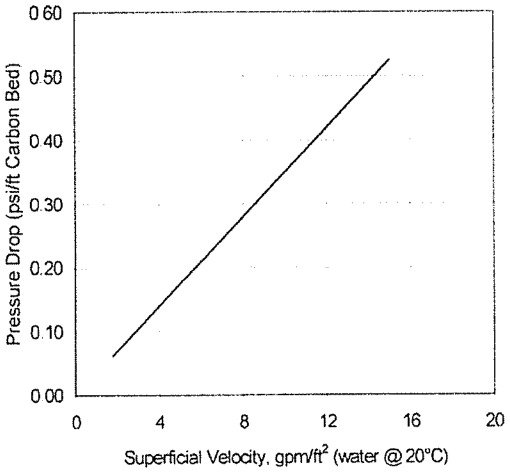
No. 2201
Apr 2002

NORIT® GAC 1240

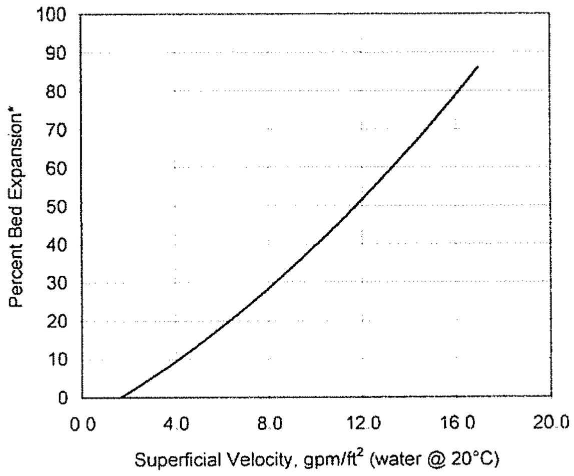
(continued)

Engineering Data

Pressure Drop Curve
for NORIT GAC 1240



Bed Expansion Curve
for NORIT GAC 1240

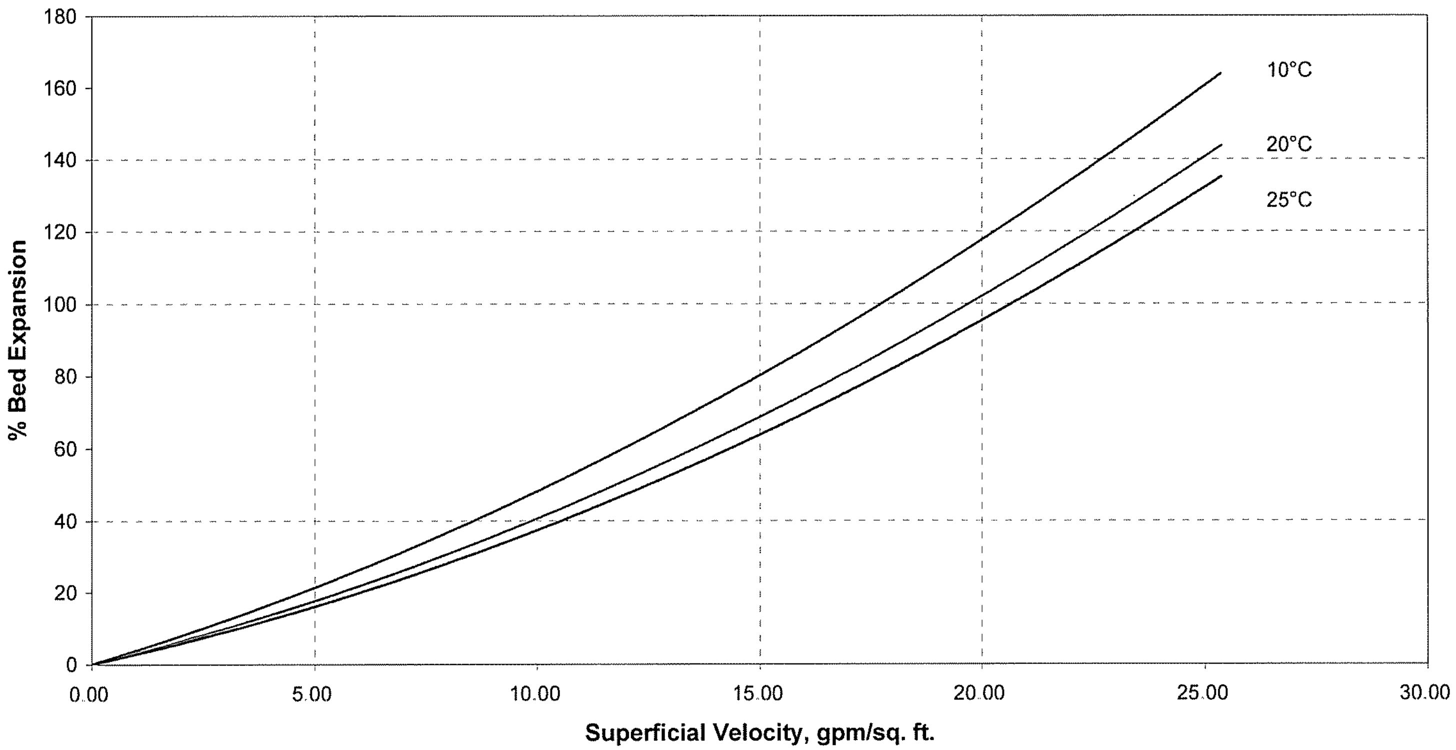


***Expansion is expressed as percent of the backwashed and settled bed depth.**

NORIT Americas Inc. - Hydraulic Data

NORIT GAC 1240

Bed Expansion Curves



DISCLAIMER :

Every situation is unique and applied flowrates could vary for a variety of reasons from the mechanical design of the system to the calibration of the devices intended to control and measure the amount of water delivered to the filter.

Every effort is made to provide accurate and complete information, however the data shown on the graph should not be considered as representing absolute values. The curves are intended to show the relative bed expansion that will be achieved at different water temperature and flowrates.

The Purification Company

Northern Kentucky Water District

Northern Kentucky Water District
Preliminary Design of GAC Systems

Appendix F: NKWD Screening of Alternatives for Taylor Mill Treatment Plant Technical Memorandum

4775-010 / CIN

GRW, Inc.

MALCOLM PIRNIE

1.0 BACKGROUND AND PURPOSE

The concrete in the rapid mix, flocculation, and sedimentation basins at Northern Kentucky Water District's (NKWD) Taylor Mill Treatment Plant (TMTP) is extremely deteriorated. The basins and equipment associated with these processes have reached the end of their useful life and must be replaced. One purpose of this evaluation is to screen alternative processes and equipment for replacement of the rapid mix, flocculation, and sedimentation processes at the plant.

The Stage 2 Disinfectants/Disinfection Byproducts Rule will require NKWD to comply with much more stringent maximum contaminant levels for total trihalomethanes and haloacetic acids. It will be necessary to remove more organic matter from the water to limit the formation of these disinfection byproducts. NKWD is considering the addition of granular activated carbon (GAC) contactor facilities to remove additional organic matter. Another purpose of this evaluation is to determine the feasibility of using the MIEX® DOC ion exchange process in lieu of GAC for advanced treatment.

2.0 PLANT CAPACITY

The TMTP has a nominal design capacity of 10 MGD. NKWD has determined that, with the exception of the rapid mix, flocculation, and sedimentation processes, the plant can treat 12 MGD. The new ultraviolet disinfection process that will soon be constructed has been sized for 12 MGD. This evaluation will be based on rapid mix, flocculation, and sedimentation facilities sized to treat 12 MGD.

3.0 TREATMENT GOALS

NKWD has established a goal to achieve disinfection byproduct concentrations no higher than 80 percent of the regulatory maximum contaminant levels. Although finished water total organic carbon (TOC) goals for TMTP have not yet been set, the TOC goal will probably be in the range of 0.8 to 1.2 mg/L.

The settled water turbidity goal is less than 1.0 NTU during low turbidity conditions and less than 2.0 NTU during high turbidity conditions

4.0 SITE CONSIDERATIONS

4.1 Construction Sequence

NKWD indicated that the plant could operate on one set of existing flocculation and settling basins during the 7 months from May through October, if necessary. A contractor was contacted concerning the feasibility of constructing new facilities within the space provided by one of the existing flocculation and sedimentation basins while leaving the second flocculation and sedimentation basin in service. The contractor indicated that such work could be completed in the 7-month period if the contractor is provided sufficient time to mobilize and procure equipment and materials prior to the start of that period.

4.2 Geotechnical Considerations

The soils at the existing TMTP site are relatively deep. In the area of the existing flocculation and sedimentation basins they are believed to extend to approximately the elevation of the creek. It is believed these soils are subject to excessive settling where heavy structure loadings are imposed. New structures should be constructed with foundations that include steel pilings or concrete caissons to limit settling. A geotechnical investigation should be performed during the design phase of the project to determine specific requirements.

The soils at the existing TMTP site also have a history of horizontal instability. Soon after the original plant was constructed, roughly 30 years ago, there was a landslide immediately north of the filter building. Several years ago cracks and leaks, not entirely related to concrete deterioration, developed in the southwest corner of the south sedimentation basin. A few years ago there was a slide near the creek east of Howard Avenue that impacted a NKWD transmission main. There is some movement currently occurring near the creek north of the filter building. In general, the area just along the steep slopes near the filter building and flocculation and sedimentation basins are subject to horizontal movement and instability. The areas more distant from the creek are probably not subject to instability.

If new structures are constructed in the place of the existing north flocculation and sedimentation basins, then a retaining wall should be constructed between the plant and the creek to stabilize the area. If new structures are constructed in the place of the existing south flocculation and sedimentation basins then the retaining wall would not be necessary.

Ultimately NKWD will probably have to protect the filter building from the horizontal instability by installing a retaining wall between the filter building and the creek. If new basins are proposed to be constructed in the place of the existing north flocculation and sedimentation basins then the retaining wall project should be constructed concurrent with the plant improvements. If new basins are not proposed to be constructed in the place of the existing north basins, then the retaining wall could be constructed later.

The "valley" area west of the chemical building contains fill material consisting of uncompacted excess trench excavation and other unknown fill materials. It was necessary to remove some of this material when the existing chemical building was constructed. New structures should not be placed in this area, if it can be avoided.

The area along Grand Avenue just west of the Grand Avenue plant entrance is virgin soil and would be suitable for new construction.

If new basins are constructed in the place of the existing flocculation and settling basins care must be taken to not adversely impact the existing chemical building and existing filter building. Deep excavations should not undermine the existing chemical building which has a shallow foundation. New excavations should allow a minimum 1:1 excavated slope from the chemical building footer to the bottom of the new excavation.

5.0 MAGNETIC ION EXCHANGE PROCESS FOR ADVANCED TREATMENT

MIEX® DOC is a proprietary advanced treatment process that removes dissolved organic matter from raw water prior to treatment by the conventional treatment processes. A slurry of small ion exchange resin particles is mixed with raw water, allowed to react for a period of time, separated from the raw water, and then regenerated for reuse. The pretreated water is then treated using conventional treatment processes.

NKWD staff performed bench testing on April 24, 2007 using MIEX® DOC ion exchange resin. This testing was intended to occur during a period when TOC concentrations are typically relatively low. The testing results are summarized in Table 5.1.

Table 5.1
MIEX® DOC Bench Testing Results

Sample Source	TOC[1] mg/L	UV-254[1]	14 Day TTHM Formation Potential, µg/L	14 Day HAA5 Formation Potential µg/L
Raw Water	1.88	0.062	--	--
Settled Water with Chlorine from Full-Scale Plant	0.75	0.021	65[2]	47[2]
Finished Water from Full-Scale Plant	0.67	0.015	63[1]	--
MIEX® plus Coagulation & Settling	0.62	0.014	51[2]	34[2]

[1] Analyses performed by NKWD and/or a local commercial laboratory Samples prepared and shipped by NKWD

[2] Analyses performed by the University of Colorado Samples prepared and shipped by NKWD

The results indicate the process met the project goals for finished water TOC and DBPs but that may have been because the raw water TOC was relatively low in April. The ion exchange process coupled with coagulation and settling reduced the 14-day total trihalomethanes (TTHM) formation potential by 22 percent when compared to coagulation and settling alone. It reduced the 14-day haloacetic acids (HAA5) formation potential by 28 percent when compared to coagulation and settling alone.

The data suggest the MIEX® DOC process may not remove enough additional organic matter to achieve the project goals when the raw water TOC is normally high in the summer.

The GAC rapid small scale column tests indicated TTHMs reduction to 28 to 42 µg/L and HAA5 reduction to 28 to 44 µg/L. This was significantly better than with MIEX® DOC.

6.0 PRELIMINARY TREATMENT ALTERNATIVES

A total of five separate alternatives were chosen to be part of the screening process to replace the existing preliminary treatment facilities. Those alternatives are listed below:

- Alternative #1 - ACTIFLO®
- Alternative #2 - Inclined Plate Settlers
- Alternative #3 - Conventional Sedimentation
- Alternative #4 - Replace Existing Floc/Sed Basins
- Alternative #5 - Dissolved Air Flotation (DAF)

During the early stages of the evaluation it was determined that Alternative #5 - Dissolved Air Flotation was not an appropriate process for treating Licking River raw water due to the encountered high raw turbidities. Therefore the DAF alternative was eliminated from further evaluation, leaving the remaining four alternatives to be considered.

6.1 Alternative #1 - Actiflo®

ACTIFLO® is a proprietary treatment process that has been developed over the last 20 years. It has proven to perform well in regards to settled water turbidity. It has a very small footprint that is useful for retrofitting and expanding existing treatment plants. It also has a high operating flexibility during start-up, shut-down, and transient flows.

This process includes the rapid mix, flocculation, and sedimentation processes. It is a high rate process that uses polymer to attach floc particles to fine sand to accelerate settling. The settled sand is recycled.

The Kentucky Division of Water requires the installation of a detention basin following ACTIFLO®. This basin must have a volume sufficient to provide for 30 minutes of detention time.

ACTIFLO® is typically provided in two treatment trains each designed to achieve a settled water turbidity of 1.0 NTU when treating half the plant capacity. If one train is out of service, the remaining train can be designed to treat 75 percent of the plant capacity to achieve a settled water turbidity of 2.0 NTU. However, NKWD desires sufficient redundancy to allow one train to treat the plant capacity of 12 MGD while achieving a settled water turbidity of 2.0 NTU. The reason is that the ACTIFLO® process is mechanical equipment intensive and is more subject to downtime than are other processes.

The size of the ACTIFLO® process would allow it to be constructed in the place of the existing south set of flocculation and sedimentation basins without the need for any additional horizontal stability provided by a retaining wall. The bottom of the basins would be at approximately the same elevation as the bottom of the existing basins. The top elevation of the basins would be about 2 feet above the elevation of the top of the existing basins. A site plan is attached.

Unlike the existing sedimentation process at the plant, ACTIFLO® produces a dilute waste stream with a constant flow rate of about 400 GPM. A new thickener would be required to settle and thicken this waste stream.

The ACTIFLO® alternative will include the following:

- Two 8 MGD treatment trains with attached pumping room
- Both trains approximately 40' wide x 78' long (including pump room) x 17' deep
- Modifications to the existing coagulant feed system
- Addition to existing chemical building for sand and polymer storage, preparation, and feed facility
- 75 foot diameter sludge thickener
- 250,000 gallon covered detention basin

Design criteria are as follows:

- Settling basin overflow rate of 16 GPM/SF @ 6 MGD/train
- Settling basin overflow rate of 32 GPM/SF @ 12 MGD/train
- Thickener design for solids loading of less than 10 lbs/day/SF at design solids loading
- Thickener design solids loading of 54,254 lbs/day based on 6 MGD @ 800 NTU raw turbidity or 12 MGD @ 400 NTU raw turbidity

The estimated project cost for this alternative is $6,100,000. Estimated annual operations and maintenance costs (excluding coagulant) are $99,000. The estimated 20-year salvage value for this alternative is $1,600,000. All estimates include both the ACTIFLO® process and the necessary residuals thickener.

6.2 Alternative #2 – Inclined Plate Settlers

Inclined plate settlers were developed to provide the settling process in a much smaller area. It has proven to perform well in regards to settled water turbidity with results averaging less than 1.0 NTU. The very small footprint is useful for retrofitting and expanding existing treatment plants.

Plate settlers are designed to be vertically inclined to allow settled solids to slide down the inclined surface and drop into the basin below. The process is relatively simple to operate and contains no moving parts thus minimizing operations and maintenance costs.

Conventional coagulation and flocculation methods can be used along with the inclined plate settler basins. For this evaluation, vertical flocculators were considered at a total detention time of 30 minutes.

Inclined plate settlers are typically provided in plate packs with the effective gravity settling area of each inclined plate equal to that plate's area projected onto a horizontal surface. Loading rates normally used for designing conventional sedimentation basins can, in general, be applied directly to the sizing of plate settlers by substituting projected area for surface settling area in a conventional settling basin.

The volume of the residuals waste stream discharged from the plate settler basins depends on the type of residuals removal equipment employed. Most designers today use suction type equipment similar to that manufactured by Trac Vac or Meurer Research. However, that equipment produces a high residuals flow rate that requires a thickener. The plate settler alternative, as evaluated, includes scraper type residuals removal equipment such as chain-and-flight or Parkson's Super Scraper system. The scraper mechanisms would scrape settled solids to troughs and hoppers where it would be partially thickened similar to the way the existing sedimentation basins function. The thickened solids would be periodically decanted using decanters similar to the existing units.

The size of the inclined plate settler process would allow it to be constructed in the place of one of the existing sets of the south flocculation basins and one existing south sedimentation basin without the need for any additional horizontal stability provided by a retaining wall. The bottom of the basins would be at approximately 1 foot lower than the elevation at the bottom of the existing basins. The top elevation of the basins would be about 2 feet above the elevation of the top of the existing basins. The basins would be covered to eliminate nuisance algae growth and prevent freezing during severe weather and weekend shutdowns. A site plan is attached.

The Inclined Plate Settler alternative will include the following:

- Two 6 MGD settling basins each approximately 35' wide x 40' long x 17' deep
- Building to cover the settling basins
- Four floc trains, each with three stages, approximately 17.5' wide x 16' wide x 14' deep
- Rapid mix tank

Design criteria are as follows:

- 16 Lamella plate packs with 8 packs per settling basin
- 2 plate packs per row with 65 plates per pack
- Plate width-60", Plate length-120", Angle of incline-55°
- Effective plate area of approximately 24,000 ft^2, all basins
- Overflow loading rate of 0.35 GPM/SF

The estimated project cost for this alternative is $5,800,000. Estimated annual operations and maintenance costs (excluding coagulant) are $52,000. The estimated 20-year salvage value for this alternative is $1,900,000.

6.3 Alternative #3 – Conventional Sedimentation

This alternative provides a similar treatment process to what already exists at the TMTP but in a more conventional long rectangular settling basin configuration. The conventional settling basins would probably perform better than the existing treatment process and would have a detention time of no more than 2 hours. Because of the larger footprint associated with this alternative, the entire preliminary treatment process would be moved to the area west of the existing chemical building near the Grand Avenue plant entrance. This would put the coagulation, flocculation, and sedimentation process further away from the operating center of the plant and further from chemical storage.

The Conventional Sedimentation alternative will include the following:

- Four 3 MGD conventional settling basins with tube settlers each 20' wide x 115' long x 14' deep
- Four floc trains, each with three stages approximately 17' wide x 15' long x 14' deep
- Rapid mix basin

Design criteria are as follows:

- Conventional settling basins with tube settlers based on 2 hours detention time
- Flocculation basins based on 30 minutes detention time

The estimated project cost for this alternative is $6,300,000. Estimated annual operations and maintenance costs (excluding coagulant) are $52,000. The estimated 20-year salvage value for this alternative is $2,500,000.

6.4 Alternative #4 – Replace Existing Flocculation/Settling Basins

This alternative involves replacing the flocculation and settling basins already existing on the TMTP site. It would require minimal changes to other plant infrastructure. This alternative provides for less flocculation time and may not perform well at 12 MGD with extremely high turbidity. This alternative would require a retaining wall to stabilize the area near the slope overlooking the creek. The cost of a retaining wall is unknown and was not included in the project cost estimate for this alternative.

The Replace Existing Flocculation/Settling Basins alternative will include the following:

- Two 6 MGD Settling Basins with Tube Settlers each approximately 68' wide x 65' long x 17' deep

- Two Flocculation trains, each with four stages approximately 16’ wide x 15’ long x 15’ deep
- Replace existing flocculation and settling basin equipment

Design criteria are as follows:

- Settling Basins with tube settlers based on 2 hours detention time
- Flocculation Basins based on 26 minutes detention time

The estimated project cost for this alternative is $6,500,000. Estimated annual operations and maintenance costs (excluding coagulant) are $49,000. The estimated 20-year salvage value for this alternative is $2,700,000.

7.0 PRELIMINARY TREATMENT ALTERNATIVES EVALUATION

A summary of costs estimated for each alternative is presented in Table 7.1.

TABLE 7.1
SUMMARY OF ESTIMATED COSTS

	Alternative 1	Alternative 2	Alternative 3	Alternative 4
Project Cost	**$6,100,000**	**$5,800,000**	**$6,300,000**	**$6,500,000**
Annual O&M Costs	$99,000	$52,000	$52,000	$49,000
Salvage Value	$1,600,000	$1,900,000	$2,500,000	$2,700,000

Using the cost estimates in Table 7.1, the total present worth cost was calculated for each alternative as presented in Table 7.2.

TABLE 7.2
PRESENT WORTH COST ANALYSIS AND COMPARISON

	Alternative 1	Alternative 2	Alternative 3	Alternative 4
Project Cost	**$6,100,000**	**$5,800,000**	**$6,300,000**	**$6,500,000**
Present Worth of O&M Costs[1]	$1,100,000	$600,000	$600,000	$570,000
Present Worth of Salvage Value[2]	($630,000)	($590,000)	($810,000)	($850,000)
Total Present Worth	**$6,600,000**	**$5,800,000**	**$6,100,000**	**$6,200,000**

[1] Annual O&M cost multiplied by 20-yr Present Worth Factor of 11.470 (based on 6% interest rate)
[2] Salvage Value in 20-yrs multiplied by Present Worth Factor of 0.3118 (based on 6% interest rate)

Due to a combination of costs and the advantages and disadvantages of each alternative, Alternatives 3 and 4 were eliminated from further consideration at a project progress meeting on June 8, 2007. A comparison of non-cost factors for Alternatives 1 and 2 is presented in Table 7.3.

TABLE 7.3
COMPARISON OF NON-COST FACTORS
ALTERNATIVES 1 AND 2

Factor	ACTIFLO®	Plate Settlers
Enhanced Organics Removal	Yes[1]	No
Average Settled Water Turbidity	0.5-1.0 NTU	<1.0 NTU
Weather Protected	Yes	Yes
Provides Added Disinfection Time	Yes[2]	No
Thickener Required	Yes	No
Ease of Operation	Moderate	High
Maintenance Requirements	High	Low
Constructability	Good	Slightly Lower

[1] Possibly due to its ability to tolerate higher coagulant doses
[2] This may not be a benefit once UV is installed

8.0 CONCLUSIONS AND RECOMMENDATIONS

The MIEX® DOC advanced treatment process did not perform as well in bench tests as did GAC contactors. It was also concluded that MIEX® DOC might not be able to meet TOC removal objectives during periods of high raw water TOC. It is recommended that the MIEX® DOC process not be considered further as an alterative for advanced treatment at TMTP.

Alternative #2 Inclined Plate Settlers is the most cost-effective alternative for preliminary treatment. It is recommended that this process be selected to replace the rapid mix, flocculation, and sedimentation processes at the TMTP.

MALCOLM PIRNIE

GRW Engineers, Inc.
Engineers, Architects, Planners

REVISIONS			
NO.	BY	DATE	REMARKS

DES ____
DWN ____
CKD ____

NORTHERN KENTUCKY WATER DISTRICT
TAYLOR MILL WATER TREATMENT PLANT

PRELIMINARY DESIGN OF GAC SYSTEMS

ALTERNATIVE 1 – ACTIFLO
TAYLOR MILL TREATMENT PLANT

SCALE: 1" = 75'

DATE AUGUST, 2007
SHEET ____ OF ____
CAD REF. NO. ____

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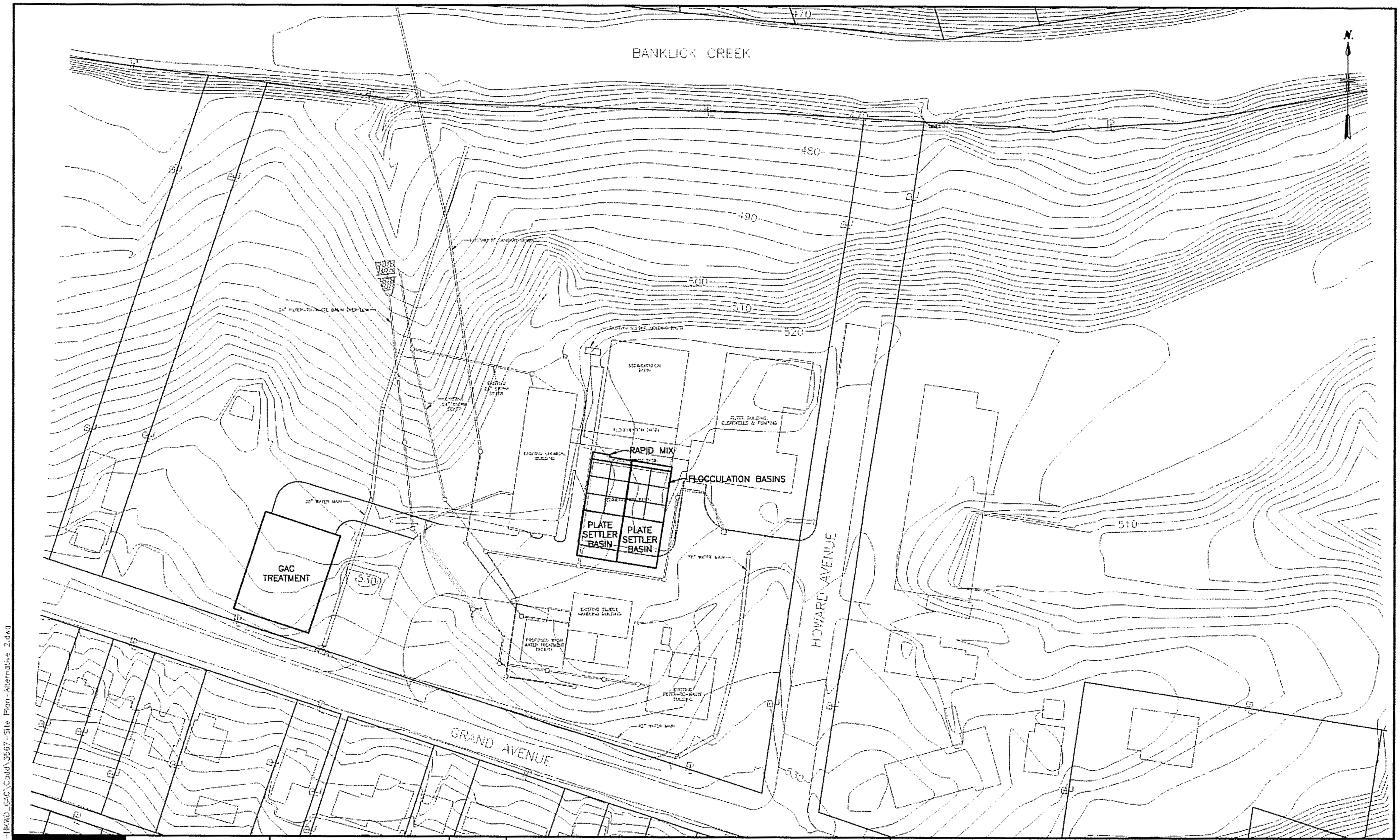

MALCOLM PIRNIE

GRW Engineers, Inc.
Engineers, Architects, Planners

REVISIONS			
NO.	BY	DATE	REMARKS

DES ________
DWN ________
CKD ________

NORTHERN KENTUCKY WATER DISTRICT
TAYLOR MILL WATER TREATMENT PLANT

PRELIMINARY DESIGN OF GAC SYSTEMS

ALTERNATIVE 2 – INCLINED PLATE SETTLERS
TAYLOR MILL TREATMENT PLANT

SCALE: 1" = 75'

DATE AUGUST, 2007
SHEET ____ OF ____
CAD REF. NO. ________

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