City of St. Joseph, Missouri

Facilities Plan

Technical Memorandum No. TM-WW-7

Hydraulic Analysis and Effluent Pump Station

By

BLACK & VEATCH
Building a world of difference®

Work Order No. 09-001
B&V Project 163509

May 20, 2010

Table of Contents

Figures

Hydraulic Analysis and Effluent Pump Station

1.0 Executive Summary

The purpose of this assessment is to perform hydraulic analyses for the proposed improvements at the St. Joseph Water Protection Facility (WPF). The facilities evaluated include the following:

- Disinfection Facilities and Effluent Pump Station
- High Rate Treatment (HRT) Facility
- Phase I – Industrial Ammonia Removal Facilities
- Phase III – Industrial Total Nitrogen Removal Facilities

Phase II of the nutrient removal plan was not included in the evaluation as the addition of chemical for phosphorous removal does not have any significant impact on hydraulics.

For there to be sufficient hydraulic head for the proposed facilities and the required future flows, the following modifications must be made. The hydraulic issues are as noted.

- The Disinfection Facilities and Effluent Pump Station will require replacement piping and/or additional piping for the existing 60 inch pipe from the Final Clarifiers. Velocities in pipes from the Final Clarifiers to the Effluent Pump Station are low (0.9 feet per second at average flow); however this piping does not carry significant solids.
- The High Rate Treatment Facility will require modifications (increased pump capacity and pressure) to the Whitehead Pump Station as described in TM-CSO-9 – Whitehead Pump Station Improvements.
- Phase I – Industrial Ammonia Removal Facilities will require raising the walls of the existing aerobic digesters by approximately 2 feet, to provide sufficient hydraulic head. Velocities in several pipes are low (0.4 to 1.2 feet per second), and the liquids in these pipes will contain significant solids. Weirs in the existing Industrial Primary Clarifier will be

submerged at peak day flow. However, weirs at this location would be submerged at the peak day flow regardless of downstream hydraulics. The Industrial Primary Clarifier wall will not be overtopped at the peak day flow.

- Phase III – Industrial Total Nitrogen Facilities will require raising the walls of the existing aerobic digesters by approximately 4 feet, to provide sufficient hydraulic head. Velocities in several pipes are low (0.4 to 0.7 feet per second), and the liquids in several of these pipes will contain significant solids. Weirs in the existing Industrial Primary Clarifier will be submerged at peak day flow. However, weirs at this location would be submerged at the peak day flow regardless of downstream hydraulics. The Industrial Primary Clarifier wall will not be overtopped at the peak day flow.

A plan, sectional plan, and section for the Effluent Pump Station are presented on Figures 5, 6, and 7 (following page 11). The Effluent Pump Station will operate approximately 6 percent of the time for the interim period on an annual basis. In the future, when the HRT is operating, the Effluent Pump Station will operate approximately 14 percent of the time with no dry weather treatment through the future HRT facility. The Effluent Pump Station will begin pumping when the Missouri River reaches an approximate stage of 18 feet (based on no more than 8 mgd upstream flow in the Missouri Avenue Outfall and a maximum of 54 mgd effluent flow from the plant). The opinion of probable project cost for the Effluent Pump Station will be developed as part of the design memorandum for the Disinfection Facilities and Effluent Pump Station project.

2.0 Purpose of Study

The purpose of this memorandum is to document an assessment of hydraulics for the future facilities planned for the WPF to determine if there are any hydraulic concerns with the facilities. The objectives of this assessment are:

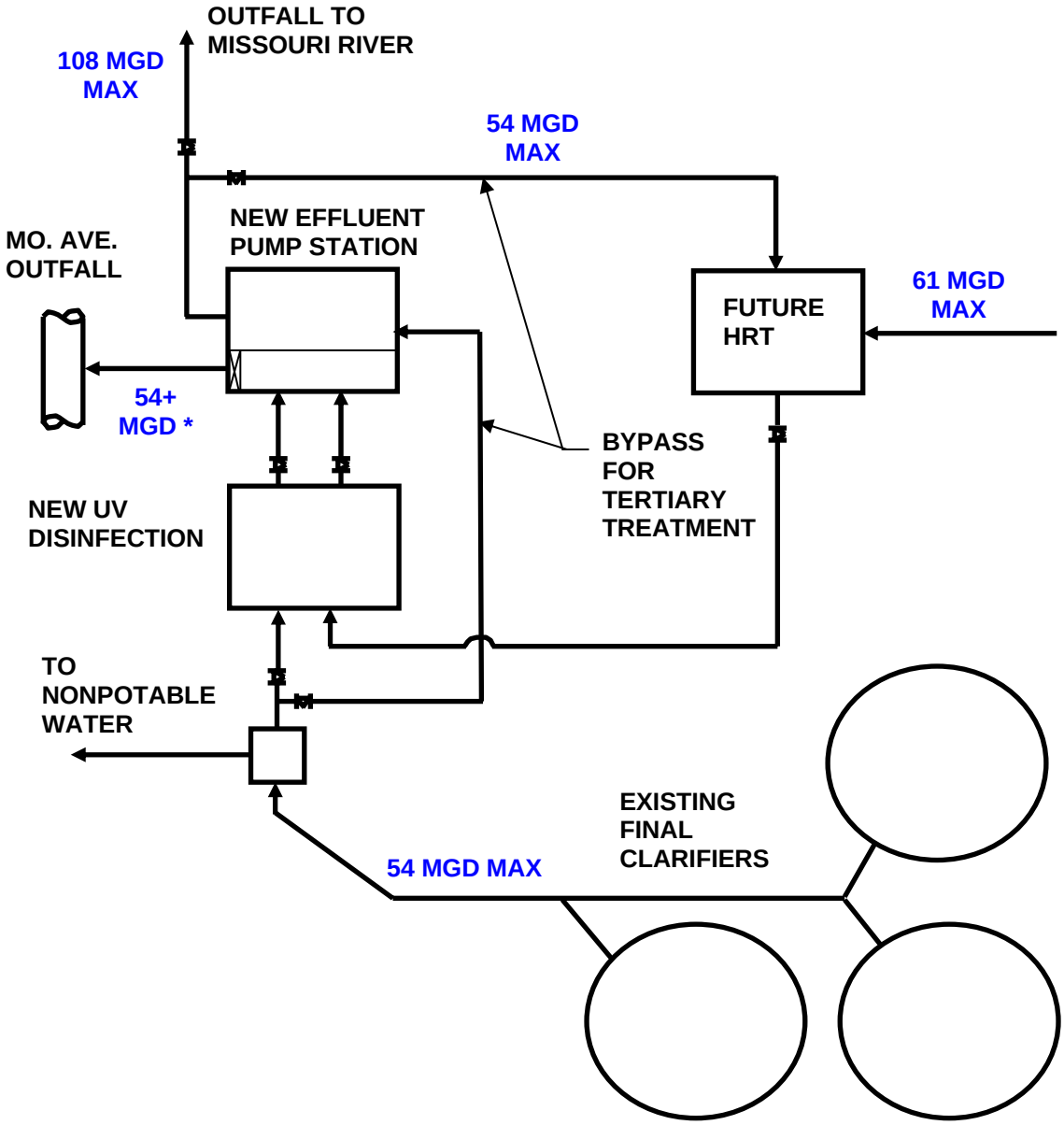
- Hydraulic assessment of the proposed Disinfection Facilities and Effluent Pump Station. The assessment includes a determination of the amount of time the Effluent Pump Station will operate.
- Hydraulic assessment of the future High Rate Treatment Facility.
- Hydraulic assessment of the proposed Phase I – Industrial Ammonia Removal Facilities modifications and additions.
- Hydraulic assessment of the proposed Phase III – Industrial Total Nitrogen Removal Facilities modifications and additions.

Phase II of the nutrient removal plan was not included in the evaluation as the addition of chemical for phosphorous removal does not have any significant impact on hydraulics.

3.0 Overview of Existing and Proposed Facilities

3.1 Disinfection Facilities and Effluent Pump Station

Elements of the Disinfection Facilities and Effluent Pump Station included in the hydraulic analysis are indicated on Figure 1. WPF effluent from the existing Final Clarifiers would flow to the new Ultraviolet (UV) Disinfection Facility. After UV treatment, WPF effluent would flow into the weir overflow channel at the new Effluent Pump Station. If the Missouri River and Missouri Avenue Outfall water levels are low, effluent would flow by gravity to the Missouri Avenue Outfall. If the Missouri River or Missouri Avenue Outfall water levels are high, some or all flow would be diverted over the weir and the Effluent Pump Station would pump the effluent directly to the Missouri River through a new outfall.



* ABILITY TO FLOW BY GRAVITY IS DEPENDENT ON RIVER ELEVATION AND STORM WATER FLOW IN MISSOURI AVENUE OUTFALL.

Figure 1 – UV Disinfection and Effluent Pump Station

The hydraulic analysis included using the future HRT Facility as tertiary treatment for WPF effluent. For this analysis, it was assumed that during dry weather periods, WPF effluent from the Final Clarifiers could be initially bypassed around the UV Disinfection Facility and flow directly to the Effluent Pump Station wetwell (bypassing

both the UV Facility and the Effluent Pump Station weir channel). The Effluent Pump Station would pump the WPF effluent to the future HRT Facility. The liquid would flow from the HRT to the UV Facility for disinfection. The UV Facility effluent would flow to the Effluent Pump Station weir channel and then to the Missouri Avenue Outfall. This scenario would only take place during dry weather when the Missouri Avenue Outfall has no storm water flow and the Missouri River elevation is low.

The hydraulic analysis was performed assuming primarily plug valves in pipes for shutoff in order to keep headloss to a minimum. In some locations, sluice gates were determined to be more appropriate and have been included in the calculation of hydraulic losses. The analysis also assumes that effluent magnetic flowmeters would not be required.

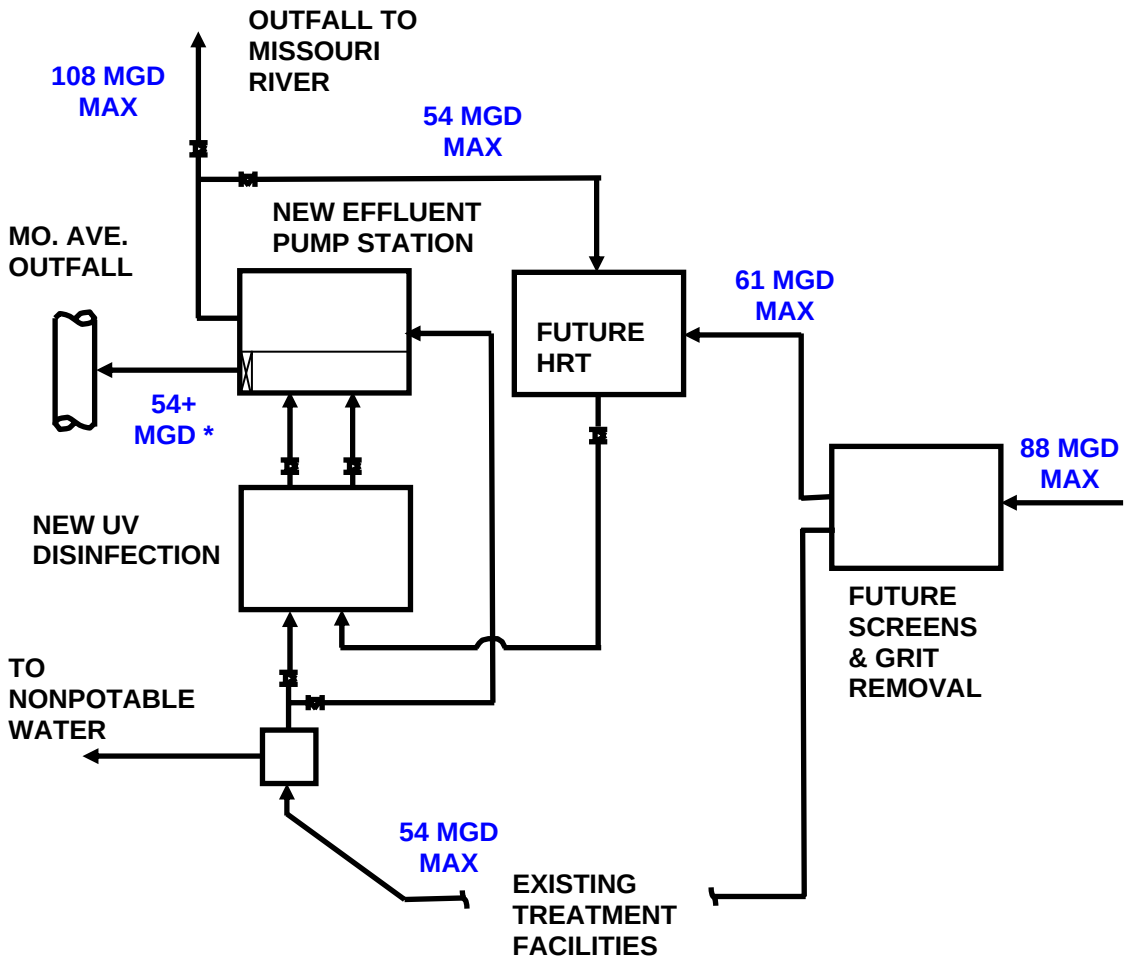
3.2 High Rate Treatment Facility

Elements of the HRT Facility included in the hydraulic analysis are indicated on Figure 2. WPF influent would be pumped from the Whitehead Pump Station to the future Screening and Grit Removal Facility. The hydraulic analysis assumed that the improvements (pump modifications to increase pump capacity and discharge pressure) to the Whitehead Pump Station as outlined in TM-CSO-9 – Whitehead Pump Station Improvements are completed. From the Screening and Grit Removal Facility, liquid would flow to the HRT Facility. From there, it would flow to the UV Disinfection Facility and then to the Effluent Pump Station weir channel. Under this scenario, WPF effluent would flow directly to the UV Disinfection Facility and then into the Effluent Pump Station weir channel.

During wet weather, or when the Missouri River is above a stage of 18 feet, it is likely that effluent pumping will be required for the combined HRT and WPF effluent. Depending on the flow, the amount of storm water in the Missouri Avenue Outfall, and the Missouri River elevation, it may be possible for some combined effluent to flow by gravity to the Missouri River Outfall. Frequency of effluent pumping is discussed in Section 5.2.

The hydraulic analysis was performed assuming primarily plug valves in pipes for shutoff in order to keep headloss to a minimum. In some locations, sluice gates were

determined to be more appropriate and have been included in the calculation of hydraulic losses. The analysis also assumes that effluent magnetic flowmeters would not be required.



* ABILITY TO FLOW BY GRAVITY IS DEPENDENT ON RIVER ELEVATION AND STORM WATER FLOW IN MISSOURI AVENUE OUTFALL.

Figure 2 – Wet Weather Treatment Facilities

3.3 Phase I – Industrial Ammonia Removal (Nitrification)

Elements of Phase I – Industrial Ammonia Removal Facilities included in the hydraulic analysis are indicated on Figure 3. A detailed description of the proposed facilities is included in TM-WW-4 – Nutrient Removal Facilities. Effluent from the

existing Industrial Primary Clarifier would flow to the Industrial Activated Sludge Basins (four modified aerobic digesters). Once through the Industrial Activated Sludge Basins, liquid would flow to the new Industrial Final Clarifier. Return activated sludge (RAS) would be pumped to upstream of the Industrial Activated Sludge Basins. Effluent from the Industrial Final Clarifier would flow to existing Junction Box No. 2 where it would combine with WPF flow upstream of the existing Intermediate Pump Station.

The hydraulic analysis was performed assuming primarily plug valves in pipes for shutoff in order to keep headloss to a minimum. RAS flows of 2.4 mgd for average day, 6 mgd for maximum month, and 5 mgd for peak day were included in the hydraulic analysis.

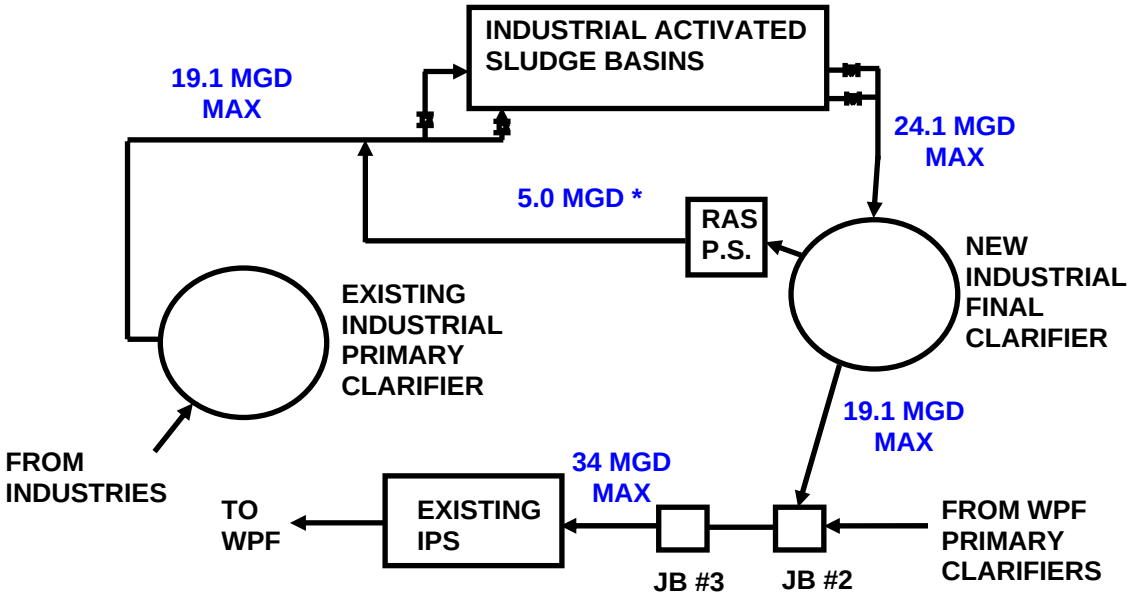


Figure 3 – Phase I – Industrial Ammonia Removal Facilities

3.4 Phase III – Industrial Total Nitrogen Removal (Nitrification/ Denitrification)

Elements of Phase III – Industrial Total Nitrogen Removal Facilities included in the hydraulic analysis are indicated on Figure 4. A detailed description of the proposed facilities is included in TM-WW-4 – Nutrient Removal Facilities. Effluent from the

existing Industrial Primary Clarifier would flow to the Industrial Activated Sludge Basins (six modified aerobic digesters, including anoxic, oxic, post-aeration, and reaeration zones for each basin). Once through the Industrial Activated Sludge Basins, liquid would flow to the new Industrial Final Clarifier. RAS would be pumped to upstream of the Industrial Activated Sludge Basins. Effluent from the Industrial Final Clarifier would flow to a new junction box located upstream of the UV Disinfection Facilities where it would combine with WPF effluent.

The hydraulic analysis was performed assuming primarily plug valves in pipes for shutoff in order to keep headloss to a minimum. RAS flows of 2.4 mgd for average day, 6 mgd for maximum month, and 5 mgd for peak day were included in the hydraulic analysis. The hydraulic analysis was limited to the industrial portion of the nitrification/denitrification process. The hydraulics for the domestic side were not reviewed in depth as flow would be less than current flows and the trickling filters would be removed.

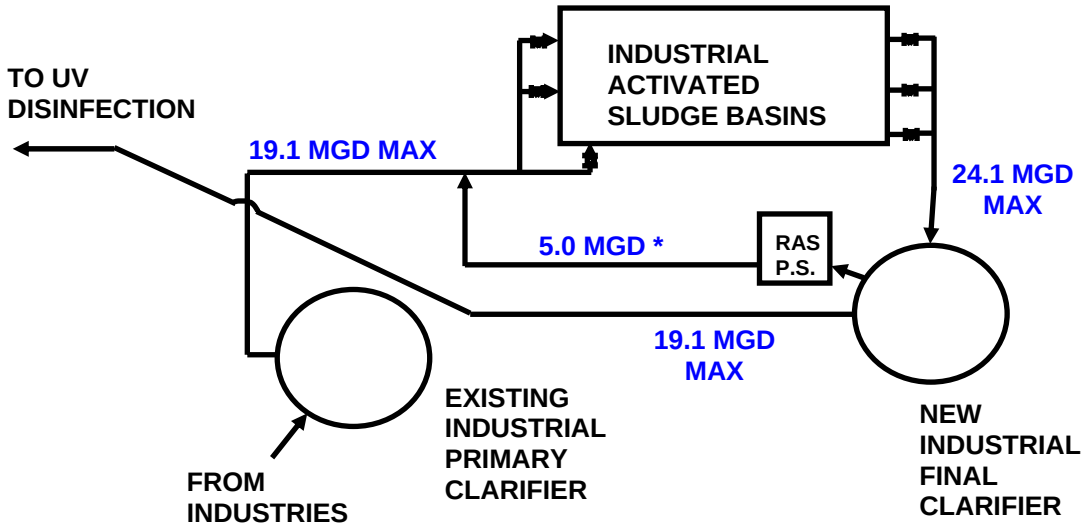


Figure 4 – Phase III – Industrial Total Nitrogen Removal Facilities

4.0 Hydraulic Analysis of Proposed Facilities

4.1 Disinfection Facilities and Effluent Pump Station

The analysis of the Disinfection Facilities and Effluent Pump Station as shown on Figure 1 indicates that there is sufficient hydraulic head available provided that the following modifications are made to existing structures:

- The existing 60 inch pipe from the Final Clarifiers is either replaced with a larger pipe or a new parallel pipe is added in order to reduce headloss.

In addition, the following issues represent less than ideal hydraulic conditions in order to provide sufficient hydraulic head:

- Velocity in the piping from the Final Clarifiers to the Effluent Pump Station is low (0.9 feet per second at average flow). However, this piping should not carry significant solids.

4.2 High Rate Treatment Facility

The analysis of the High Rate Treatment Facility as shown on Figure 2 indicates that there is sufficient hydraulic head available provided that the following modifications are made to existing structures:

- Pump capacity and pressure is increased at the Whitehead Pump Station as described in TM-CSO-9 – Whitehead Pump Station Improvements.

4.3 Phase I – Industrial Ammonia Removal (Nitrification)

The analysis of the Phase I – Industrial Ammonia Removal Facilities as shown on Figure 3 indicates that there is sufficient hydraulic head available provided that the following modifications are made to existing structures:

- The walls in the existing Aerobic Digester Basins must be raised 2 feet in order to provide sufficient wall height for the hydraulic gradeline within the basins. The hydraulics for Phase I only require the basin walls to be raised 2 feet, but the walls will be raised 4 feet in Phase I to accommodate future Phase III hydraulics (construction efficiency).

In addition, the following issues represent less than ideal hydraulic conditions in order to provide sufficient hydraulic head:

- Velocity in the pipe from the Industrial Activated Sludge Basins to the Industrial Final Clarifier is low (1.2 feet per second at average flow). This pipe will carry significant solids from the Industrial Activated Sludge Basins to the Industrial Final Clarifier.
- Velocity in pipes from the Industrial Primary Clarifier to the Industrial Activated Sludge Basins is low (0.4 feet per second at average flow in 60 inch pipe). This piping will carry significant solids from the Industrial Primary Clarifier to the Industrial Activated Sludge Basins. Much of this pipe already exists.
- Weirs in the existing Industrial Primary Clarifier will be submerged at peak day flow. However, weirs at this location would be submerged at the peak flow regardless of the downstream hydraulics. The clarifier wall will not be overtopped at the peak day flow.

4.4 Phase III – Industrial Total Nitrogen Removal (Nitrification/ Denitrification)

The analysis of the Phase III – Industrial Total Nitrogen Removal Facilities as shown on Figure 4 indicates that there is sufficient hydraulic head available provided that the following modifications are made to existing structures:

- The walls in the existing Aerobic Digester Basins must be raised 4 feet in order to provide sufficient wall height for the hydraulic gradeline within the basins. The walls will be raised 4 feet during Phase I construction to accommodate Phase III hydraulics (construction efficiency).

In addition, the following issues represent less than ideal hydraulic conditions in order to provide sufficient hydraulic head:

- Velocity in the pipes from the Industrial Final Clarifier to the junction box upstream of the UV Disinfection Facility is low (0.6 feet per second at average flow). This piping should not carry significant solids.
- Velocity in the pipe from the Industrial Activated Sludge Basins to the Industrial Final Clarifier is low (0.7 feet per second at average flow). This pipe will carry significant solids from the Industrial Activated Sludge Basins to the Industrial Final Clarifier.
- Velocity in pipes from the Industrial Primary Clarifier to the Industrial Activated Sludge Basins is low (0.4 feet per second at average flow in 60 inch pipe). This piping will carry significant solids from the Industrial Primary Clarifier to the Industrial Activated Sludge Basins. Much of this piping already exists.
- Weirs in the existing Industrial Primary Clarifier will be submerged at peak day flow. However, weirs at this location would be submerged at the peak day flow regardless of downstream hydraulics. The Industrial Primary Clarifier wall will not be overtopped at the peak day flow.

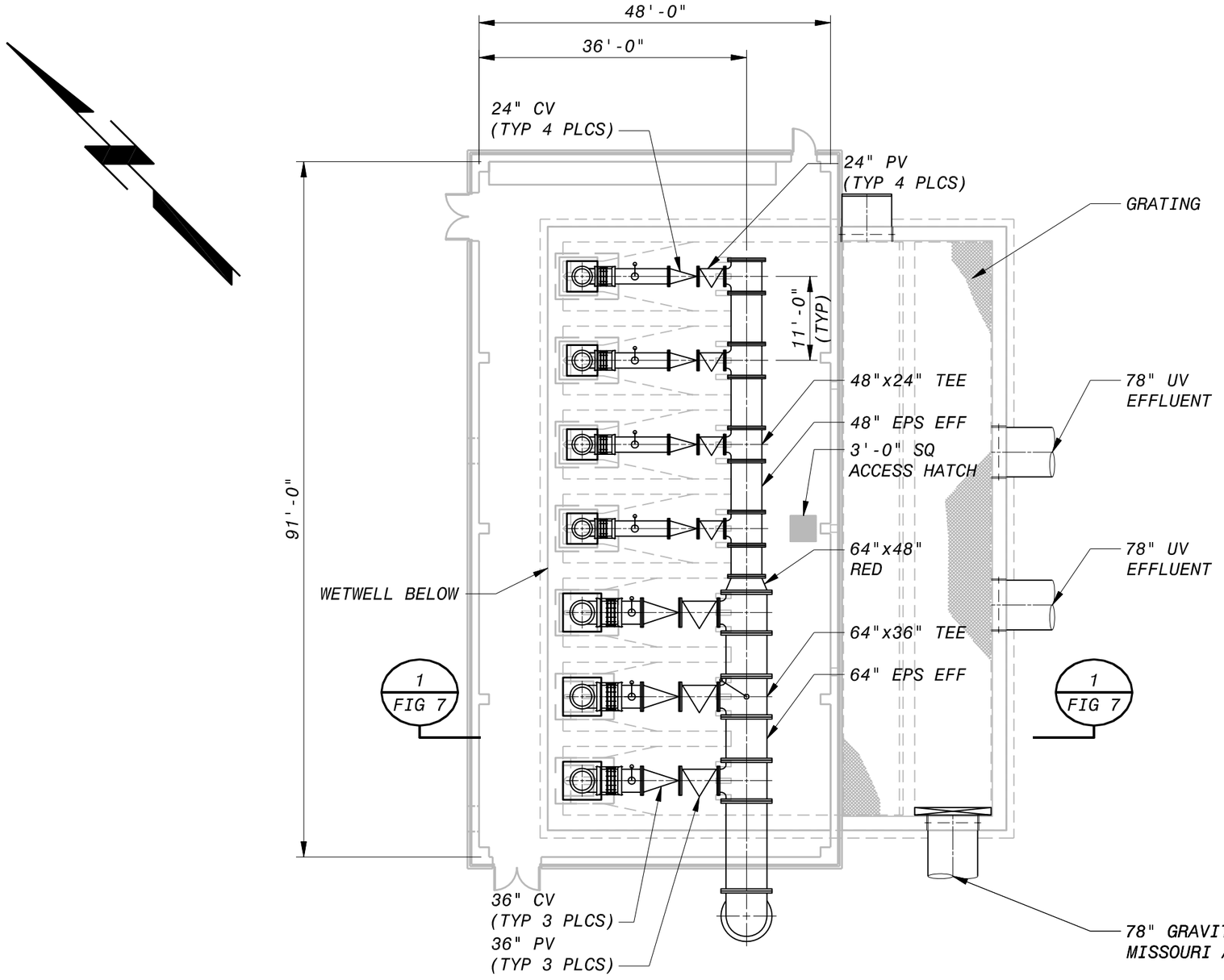
5.0 Effluent Pump Station

5.1 Description

The Effluent Pump Station would be sized for an ultimate firm capacity of 108 mgd with an initial firm capacity of 54 mgd. Preliminary sizing of the pump station includes four 14 mgd pumps and three 26 mgd pumps for the ultimate firm capacity. Figure 5 presents a plan view of the proposed Effluent Pump Station. Figure 6 is a sectional plan showing the wetwell of the pump station, and Figure 7 shows a section through the pump station. The pump station would use vertical diffusion vane pumps with a wetwell located below the pumps. The pumps, valves, and discharge piping would be located in a superstructure above the wetwell. All pumps would be provided with eddy current drives to allow variable speed operation.

The Effluent Pump Station discharge pipeline to the Missouri River is planned as a 66 inch pipe. Several alignments are possible for the discharge pipeline. One

163509-2000-GENUP-C-N0001FCJQ



16' 12' 8' 4' 0 16' 32'

1/16"=1'-0"

NOTE: LAYOUT SHOWS ALL FUTURE PUMPS.

BLACK & VEATCH
Building a world of difference.

ST. JOSEPH, MISSOURI
FACILITIES PLAN

PN 163509

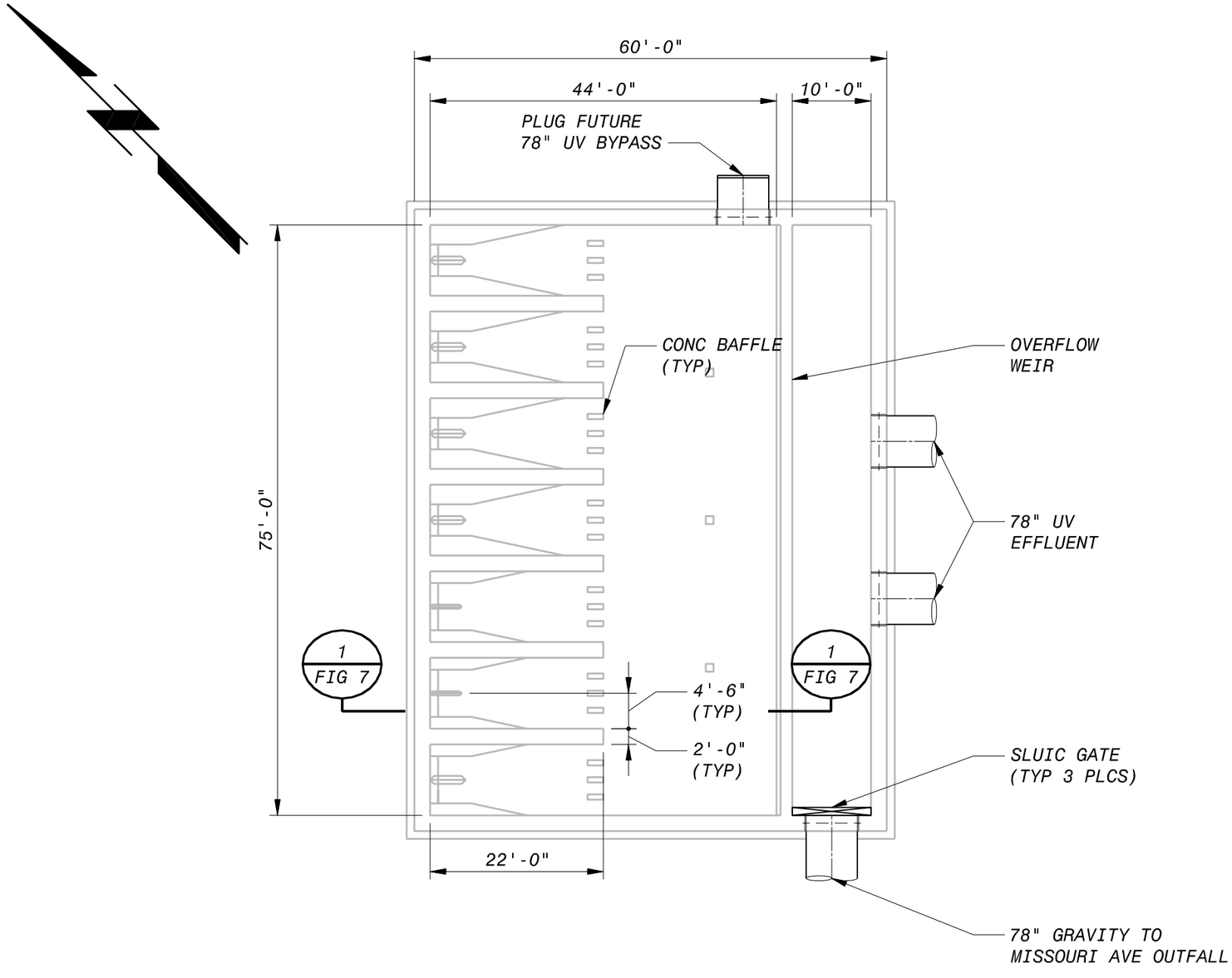
EFFLUENT PUMP STATION - OPERATING FLOOR PLAN

MAY 2010

FIGURE 5

BFIGBORD
FBFIGBORD

163509-2000-GENUP-C-N0001FCJR



16' 12' 8' 4' 0 16' 32'

1/16"=1'-0"

BLACK & VEATCH
Building a world of difference.

ST. JOSEPH, MISSOURI
FACILITIES PLAN

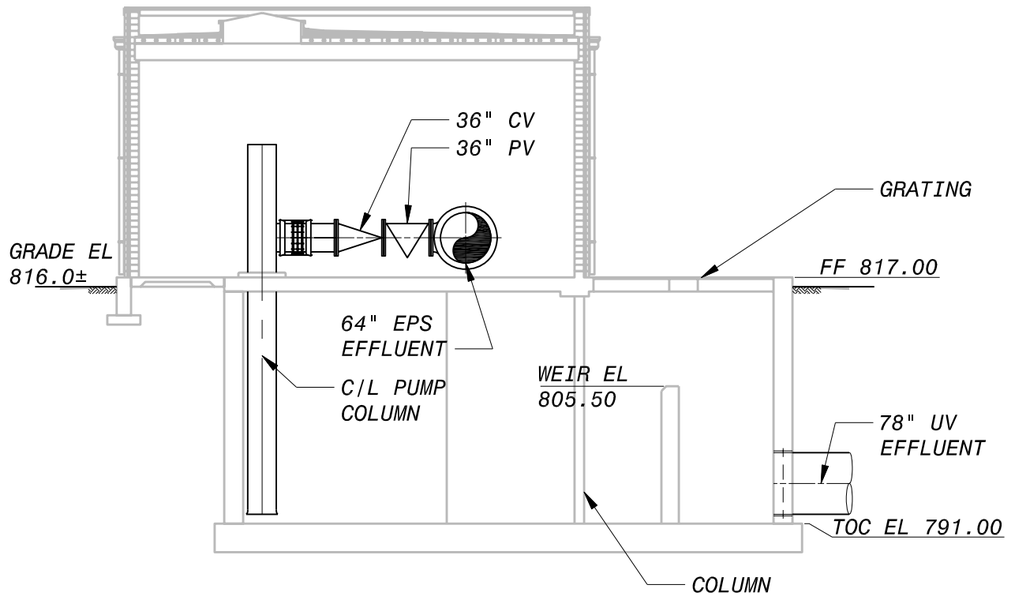
PN 163509

EFFLUENT PUMP STATION - SECTIONAL PLAN

MAY 2010

FIGURE 6

BFIGBORD
FBFIGBORD



NOTE:
PILING NOT SHOWN

ST. JOSEPH, MISSOURI
FACILITIES PLAN

PN 163509

EFFLUENT PUMP STATION - SECTION 1

MAY 2010

FIGURE 7

BLACK & VEATCH
Building a world of difference.

alignment of the pipeline could extend from the proposed Effluent Pump Station location south of the adjacent grain bins and west to and over the top of the Missouri River levee. Tunneling would be required for portions of the alignment that cross existing railways. A shorter alignment may be possible through or under the round grain bins. The final decision on alignment will be made during detailed design when survey information is available.

5.2 Frequency of Operation

To determine the frequency of operation of the proposed Effluent Pump Station, two independent variables must be considered. They are the Missouri River stage (water surface elevation) and the frequency of rainfall events in western Missouri. The stage in the Missouri River can create backwater conditions in the WPF effluent pipe which would cause the Effluent Pump Station to operate. A review of the proposed WPF hydraulics was performed to determine the critical river stage which would trigger the Effluent Pump Station to operate. It was determined that in the future during dry weather (once the UV Disinfection Facilities are in service), the pump station would need to operate when the Missouri River reaches a stage (elevation) of approximately 806 feet (equivalent to USGS gauge 06818000 stage of approximately 18 feet) at the WPF outfall. Upon review of the data from USGS gauge 06818000, an elevation of 806 feet has an approximately 4.3 percent chance of occurring on any given day. Figure 8 presents the exceedance probability of Missouri River stages at USGS gauge 06818000.

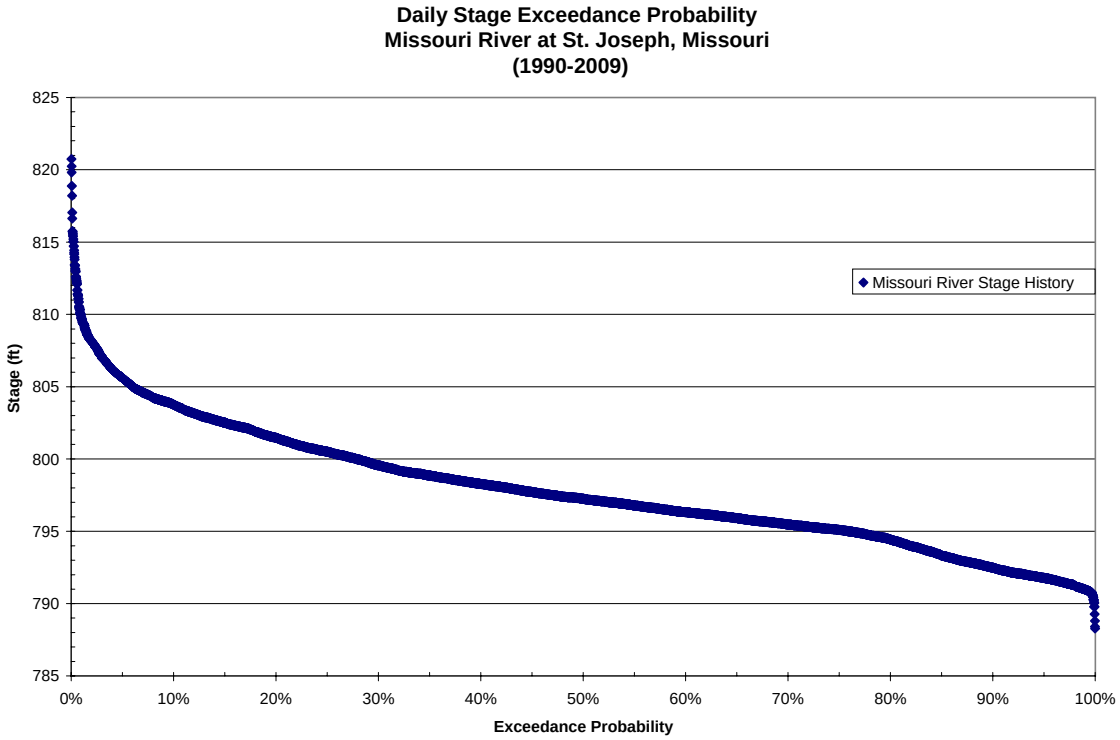


Figure 8 – Missouri River Stage Exceedance Probability at St. Joseph, Missouri

A rainfall event can also cause the Effluent Pump Station to operate. Since the WPF treats flow from a combined sewer system, inflows to the WPF are increased significantly once a rain event commences. At its peak, the WPF is sized to pass 54 mgd of effluent. Based upon a review of the proposed WPF hydraulics, a peak effluent flow of 54 mgd, in and of itself, will not cause the Effluent Pump Station to operate. Fifty-four mgd is the peak flow that will occur during the interim period before the proposed HRT Facility is in service (approximately 2029). Once the HRT Facility is in service, the peak flow from the combined WPF and HRT will be 108 mgd which will cause the Effluent Pump Station to operate.

The WPF gravity outfall is (and will continue to be) directed to the Missouri Avenue combined sewer. A rainfall event causes combined sewer overflows (CSOs) from the upstream Missouri Avenue Basin to pass through the Missouri Avenue trunk sewer thus affecting the gravity outflows from the WPF. If the Missouri Avenue trunk sewer has CSOs passing through, it can cause the Effluent Pump Station to operate.

Based upon a review of model simulated runoff flow rates resulting from the wet weather design storms (Design Events A through H as defined in TM-CSO-2 – CSS Model Calibration and Existing Conditions), a storm event of approximately Design Event D size (1.4 inch, 17 hours long) will cause the Effluent Pump Station to operate during the interim period. This correlates to a frequency of six times a year or a 1.6 percent chance that the Effluent Pump Station will operate on any given day.

During the interim period, the Effluent Pump Station has a 4.3 percent chance of operating on any given day due to high river stage and a 1.6 percent chance of occurring on any given day due to a rainfall event of Design Event D size. Therefore, the overall probability of the Effluent Pump Station operating on any given day during the interim period is approximately equal to 5.9 percent (4.3 percent plus 1.6 percent). The joint probability of having both a high river stage and a rainfall event of 1.4 inches is equal to 0.09 percent (5.9 percent times 1.6 percent) and is therefore considered negligible in determining the overall daily probability of the Effluent Pump Station operation during the interim period.

Based upon a review of runoff flow rates resulting from the design storms (Design Events A through H), a storm event of Design Event A size (0.28 inch, 6 hours long) will cause the Effluent Pump Station to operate after completion of the proposed HRT Facility in approximately 2029. This correlates to a frequency of 36 times a year or a 9.9 percent chance that the Effluent Pump Station will operate on any given day.

Once the HRT Facility is in service, the Effluent Pump Station has a 4.3 percent chance of operating on any given day due to high river stage and a 9.9 percent chance of occurring on any given day due to a rainfall event. Therefore, the overall probability of the Effluent Pump Station operating on any given day is approximately equal to 14.2 percent (9.9 percent plus 4.3 percent) once the HRT Facility is in service. This operation frequency assumes no dry weather flow through the proposed HRT Facility for tertiary treatment/nutrient polishing. The joint probability of having both a high river stage and a rainfall event of 0.28 inches is equal to 0.4 percent (9.9 percent times 4.3 percent) and is therefore considered negligible in determining the overall daily probability of the Effluent Pump Station operation upon completion of the proposed HRT Facility.

6.0 Conclusions and Recommendations

Hydraulic analyses were performed for the following proposed facilities:

- Disinfection Facilities and Effluent Pump Station
- High Rate Treatment Facility
- Phase I – Industrial Ammonia Removal Facilities
- Phase III – Industrial Total Nitrogen Removal Facilities

Phase II of the nutrient removal plan was not included in the evaluation as the addition of chemical for phosphorous removal does not have any significant impact on hydraulics.

There appears to be sufficient hydraulic head available for the proposed facility improvements provided that modifications identified within this technical memorandum are constructed. Low pipe velocities will occur at several locations, and the weirs at the existing Industrial Primary Clarifier will be submerged during peak day industrial flow.

The recommended layout for the Effluent Pump Station is shown on Figures 5 through 7. The Effluent Pump Station will need to operate approximately 6 percent of the time for the interim period. In the future, when the HRT is operating, the Effluent Pump Station will operate approximately 14 percent of the time with no dry weather treatment through the future HRT facility. The Effluent Pump Station will begin pumping when the Missouri River reaches an approximate stage of 18 feet (based on no more than 8 mgd upstream flow in the Missouri River Outfall and a maximum of 54 mgd effluent flow from the WPF). The opinion of probable project cost for the Effluent Pump Station will be developed as part of the design memorandum for the Disinfection Facilities and Effluent Pump Station project.

7.0 References

The following references were utilized in the preparation of this memorandum:

- TM-CSO-2 – CSS Model Calibration and Existing Conditions (Black & Veatch, May 19, 2009).

- TM-CSO-9 – Whitehead Pump Station Improvements (Black & Veatch, September 4, 2009).
- TM-CSO-10 – Wet Weather Treatment Facilities (Black & Veatch, November 17, 2009).
- TM-WW-4 – Nutrient Removal Facilities (Black & Veatch, March 19, 2010).
- Geotechnical Engineering Report (L. Robert Kimball, 1973).
- KCMO Overflow Control Program, Design Year for CSS Analyses, September 2006.