Document ID: EDF-10041
Revision ID: 0
Effective Date: 05/11/11

Engineering Design File

New Pump and Treat Facility Flushing Calculations

Idaho Cleanup Project

ENGINEERING DESIGN FILE

EDF No.: EDF-10041 EDF Rev. No.: 0 Project No.: 23339 FCF and/or FDC No.: N/A

1. Title: New Pump and Treat Facility Flushing Calculations			
2. Index Codes: Building/Type TAN-1611	SSC ID T-300	Site Area TAN	
3. Formal Calculation? ☐ Yes (MCP-2374) ☒ No (MCP-2059)	Quality Level: 3	QLD Number: 3807	
Formal analyses and calculations require engineering management approval.			
*4. NPH PC or SDC: or ☒ N/A		SSC Safety Category: or ☒ N/A	
*5. (a) Affects Safety Basis: ☐ Yes ☒ No		(b) Affects SNF/HLW: ☐ Yes ☒ No	

6. Summary:

The New Pump and Treat Facility (NPTF) at the Test Area North (TAN) pumps contaminated groundwater into a surge tank (T-300) prior to treatment using air strippers. Because the groundwater within the TAN trichloroethene plume is F001 listed waste, the NPTF requires daily inspections when it is operating. The NPTF is shut down on a routine basis (e.g., on the weekends). If the system is flushed with potable water to remove contaminated water from the process system, the daily inspections can be curtailed. The purpose of this Engineering Design File is to determine the processing time required to flush the system of contaminated water.

7. Signatures: (See instructions for significance of signatures. Add or delete signatories as needed.)

Name (typed or printed) / Signature and Date	Signatory Role	Organization / Discipline
Lorie S. Cahn Lorie S Cahn 5-11-11	Author	Design Agent
Michael C. Swensen Michael Swensen 5-12-11	Technical Checker	Technical Checker
	Reviewer	* Independent Peer Reviewer (see instructions, Item 7, Note 2)
	Reviewer	Requestor (if applicable)
	Reviewer	* Design Authority (if applicable)
	Reviewer	* Quality Assurance (only if 5(b) is "Yes")
	Reviewer	* Nuclear Safety (only if 5(a) is "Yes")

ENGINEERING DESIGN FILE

EDF No.: EDF-10041 EDF Rev. No.: 0 Project No.: 23339 FCF and/or FDC No.: N/A

Howard S. Forsythe Howard Forsythe 5/11/11	Document Owner	Document Owner

8. Does document contain sensitive unclassified information? ☐ Yes ☒ No
   If Yes, what category:

9. Will document be externally distributed? ☒ Yes ☐ No

10. Registered Professional Engineer's Stamp (if required) ☒ N/A

Registered Professional Engineer Stamp		
		This Engineering Design File was prepared under the direction of the Registered Professional Engineer as indicated by the stamp and signature provided on this page. The Professional Engineer is registered in the State of Idaho to practice ___________ Engineering.

* Not required for commercial level calculations.

New Pump and Treat Flushing Calculations

1. BACKGROUND

The New Pump and Treat Facility (NPTF) at the Test Area North (TAN) pumps contaminated groundwater into a surge tank (T-300) prior to treatment using air strippers. Because the groundwater within the TAN trichloroethene (TCE) plume is F001 listed waste, the NPTF requires daily inspections when it is operating. The NPTF is shut down routinely (e.g., on the weekends). If the system is flushed with potable water to remove contaminated water from the process system, the daily inspections can be curtailed. The purpose of this Engineering Design File is to determine the processing time required to flush the system of contaminated water.

During flushing, potable water is pumped into the surge tank at an average rate of 155 gpm, as shown in Figure 1. The system is designed to equalize the inflow and outflow. At the rate of 155 gpm, the height of water in the tank is about 35 in. Using the volume of the mixture in the tank, the initial mass of TCE in the tank, and the desired concentration, the time needed to flush the system of contaminated water can be calculated using a first-order separable differential equation.

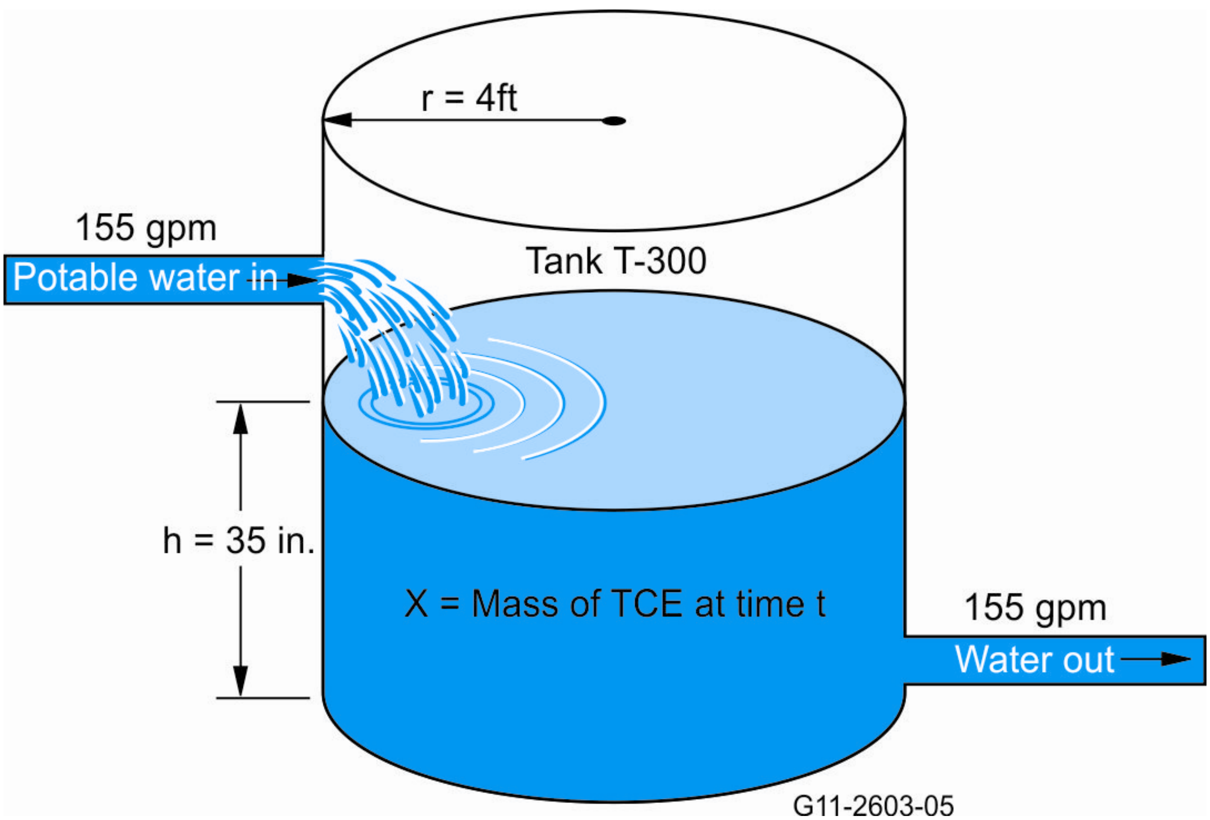

Figure 1. Conceptual diagram of the T-300 surge tank.

The TCE concentrations in the influent (SP-1) over time are shown in Figure 2. The TCE concentrations ranged from a low of 64 µg/L when the NPTF was operating 24/7 to a high of 380 µg/L when the NPTF had been on standby for over 2 years, and averaged 78 µg/L. The maximum concentration of 380 µg/L will be used in this calculation to be conservative. In order for the tank to no-longer-contain listed waste, the TCE must be below the maximum contaminant level of 5 µg/L. Data from the last 3 years (2008–2010) indicate that TCE concentrations have been nondetect in the potable water (Environmental Data Warehouse [EDW]).

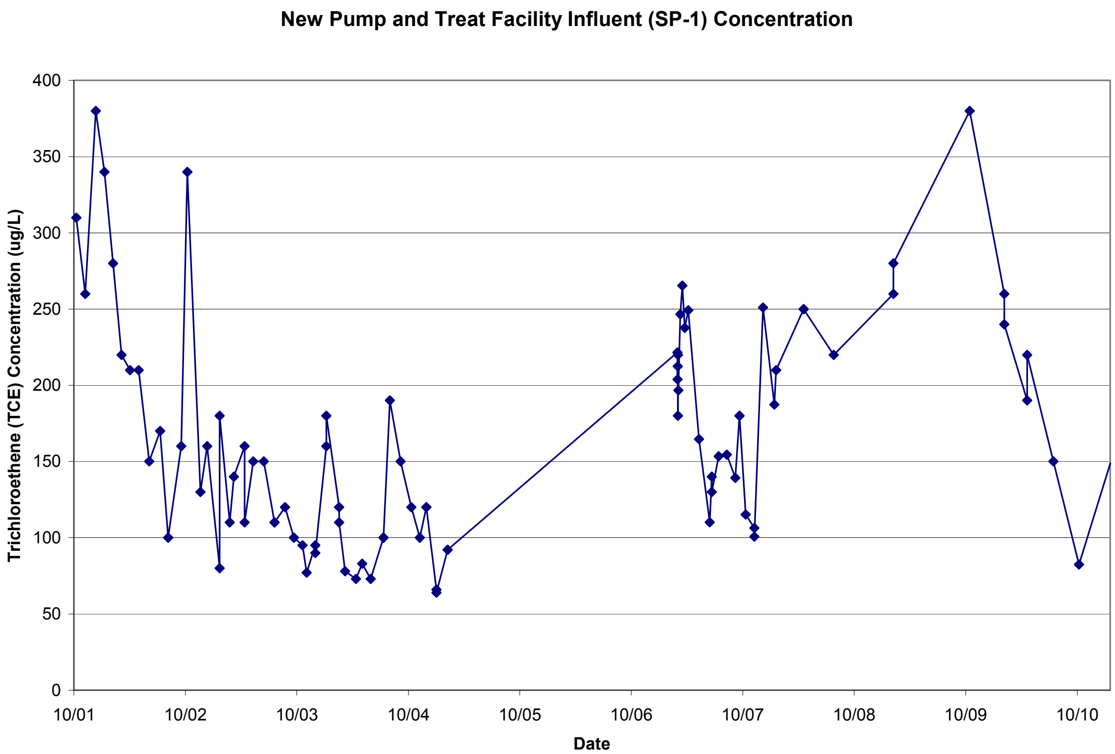

Figure 2. TCE concentrations at the NPTF influent sample port (SP-1).

Information on the dimensions of the tank is available from the manufacturer (Central California Mfg.) in the NPTF Operations and Maintenance Manual. The tank is a nominal 3,000-gal, 8-ft-diameter tank (Model #08VCT03K).

2. CALCULATIONS

To convert height in the tank (h) to the volume (V)

$$V = \pi r^2 h$$

$$V \text{ [gal]} = \pi \times (r \text{ [ft]})^2 \times h \text{ [in.]} \times 1 \text{ [ft]}/12 \text{ [in.]} \times 7.481 \text{ [gal]}/[\text{ft}^3]$$

Substituting $r = 4$ ft and $h = 35$ in.:

$V = 1{,}097$ gal.

We will assume that the solution in the tank is mixed, which is a conservative assumption because the water exiting the bottom of the tank is more concentrated than the clean water flowing into the top. Given that the potable water is pumped in at 155 gpm, and the outflow is the same, we can use a first-order separable differential equation to determine the time necessary to drop the concentration from 380 µg/L to 5 µg/L, or a dilution of 76 (380/5).

Let X be the number of grams of TCE in the tank at any time t (min). Using conservation of mass, the change in the amount of TCE with respect to time is

dX/dt = (rate in of TCE) – (rate out of TCE)

$dX/dt = [\mathrm{TCE}]_{in}$ × (rate of water flowing in) – $[\mathrm{TCE}]_{out}$ × (rate of water flowing out).

Where [TCE] is the concentration of TCE in the tank or X/1,097 gal.

dX/dt = (0)(155 [gpm]) – (X/1,097 [gal]) × 155 gpm.

Therefore,

dX/dt = – (X/1,097 [gal]) × 155 [gpm]

Dividing, we get:

dX/dt = – X/7.08

Rearranging, we get:

$$\frac{1}{X}dX = -\frac{1}{7.08}dt$$

Integrating yields

$$\int \frac{1}{X}dX = \int -\frac{1}{7.08}dt$$

$$\ln|X| = -\frac{1}{7.08}t + C \qquad (1)$$

The initial condition (g TCE in 1,097 gal in the tank) is

X_0 = 380 µg/L × 1097 gal × 3.785 L/gal × g/10^6 µg

X_0 = 1.58 g TCE

Substituting X = 1.58 and t = 0 into Equation (1) yields

$$\ln 1.58 = C$$

Equation 1 becomes:

$$\ln|X| = -\frac{1}{7.08}t + \ln 1.58$$

$$e^{\ln X} = e^{\left(-\frac{1}{7.08}t + \ln 1.58\right)}$$

$$X = e^{\left(-\frac{t}{7.08} + \ln 1.58\right)}$$

$$X = e^{\left(-\frac{t}{7.08}\right)} \times e^{\ln 1.58}$$

$$X = e^{-\left(\frac{t}{7.08}\right)} \times e^{\ln 1.58}$$

$$X = 1.58e^{-\left(\frac{t}{7.08}\right)} \text{ or } X = X_0 e^{-\left(\frac{t}{7.08}\right)}$$

The tank must be mixed until [TCE] is 5 µg/L, which is when the mass of TCE is:

5 µg/L × 1,097 gal × 3.785 L/gal × g/10^6 µg = 0.0208 g TCE.

When X = 0.0208 g TCE, then:

$0.0208 = 1.58\ e^{-(t/7.08)}$

$0.0208/1.58 = 1/76 = e^{-(t/7.08)}$

Taking the ln of both sides yields

$$\ln\frac{1}{76} = \frac{t}{-7.08}$$

$$\ln 1 - \ln 76 = \frac{t}{-7.08}$$

$$-\ln 76 = \frac{t}{-7.08}$$

Solving for t yields:

t = 7.08 ln 76 = 30.3 min.

Therefore, if the tank is flushed for 30.3 minutes, the concentration of the water remaining in the tank will be less than the maximum contaminant levels.