Water Protection Bureau
P.O. Box 200901
Helena, MT 59620-0901

# PERMIT FACT SHEET

## MONTANA GROUND WATER POLLUTION CONTROL SYSTEM (MGWPCS)

| | |
|---|---|
| Permittee: | Genesis Partners LLC |
| Permit Number: | MTX000223 |
| Permit Type: | Domestic wastewater |
| Application Type: | Renewal |
| Facility Name: | Genesis Business Park |
| Facility Location: | Gallatin County, MT<br>PLSS; T2SR5E, NE,NE,NE Section 23 |
| Facility Address: | 855 Technology Boulevard Suite 101 |
| Facility Contact: | Terry Threlkeld (operator), Clair Daines (owner) |
| Treatment Type: | Level II, Septic, Trickling Sand Filter |
| Receiving Water: | Class I Ground Water |
| Number of Outfalls: | 1 |
| Outfall / Type: | SWTS<br>Latitude: 45.656344° Longitude: -111.068417° |
| Effluent Type: | Domestic in nature wastewater |
| Mixing Zone: | Standard |
| Effluent Limit Type: | DBEL |
| Effluent Limits: | Total nitrogen: DBEL (60 percent removal) |
| Flow Rate: | Design maximum: 10,240 gpd<br>Design average: 10,240 gpd |
| Effluent sampling: | Monthly at EFF-001 (see **Figure 3**.). |
| Ground water sampling: | Quarterly upgradient and monthly down gradient monitoring wells (see special conditions) |
| Fact Sheet Date: | October 30, 2018 |
| Prepared By: | Rich Morse |

# 1.0 PERMIT INFORMATION

DEQ issues MGWPCS permits for a period of five years. The permit may be reissued at the end of the period, subject to reevaluation of the receiving water quality and permit limitations. This fact sheet provides the basis for DEQ's decision to renew a MGWPCS wastewater discharge permit for Genesis Business Park LLC (applicant) for the Genesis Business Park wastewater treatment system.

## 1.1 APPLICATION

DEQ received an application for renewal of the permit on August 3, 2016. Renewal fees accompanied the application. DEQ reviewed the submittal and issued a completeness letter on August 26, 2016.

## 1.2 PERMIT HISTORY

This facility was originally constructed prior to 1998. The facility at that time was exempted from the requirement for permit coverage. The facility applied for a modification of the treatment system in 2011. In 2011 a permit was issued for the facility for a single outfall, Level II treatment with maximum daily flow of 10,240 gpd and a Definition Based Effluent Limit (DBEL) of 24 mg/L Total Nitrogen (TN). On July 28, 2016 the applicant applied for a renewal of the discharge permit for this facility. DEQ issued a letter of completeness for the application on August 26, 2016.

The facility is currently running with a quarterly average flow of approximately 7,000 gpd. The facility has a maximum design flow of 10,240 gpd. Records for the period of 2015 to 2018 indicate that the facility is not meeting the 24mg/L effluent limit. Quarterly average Total Nitrogen is reported in Discharge Monitoring Reports (DMRs) as 47.3 mg/L for the period of March 31, 2015 to the first quarter of March 31, 2018. The quarterly average for the last two years (January 2016 to March 2018) as reported by the applicant, has been 50.6 mg/L which is 50.79% percent removal of TN.

Prior to 2015 the applicant installed an additional 20,000 gallon septic tank at the head end of the treatment system. The current permit requires carbon injection and UV disinfection at the rear end of the treatment system. There is no downgradient monitoring for this facility. The applicant is interested in bringing this facility into compliance. In order to get a better idea of the local hydrogeology, the applicant performed a local drawdown pump test in February of 2016. The pump test provided a new K factor for the site. Transmissivity was increased from 29 feet per day to 74.5 feet per day. This factor was used to compute a new Water Quality Based Effluent Limit (WQBEL) for the facility (see appendix A).

## 1.3 CHANGES TO THIS PERMIT

This facility is currently not in compliance with its 2011 effluent limits.

Definition Based Effluent Limits for Level II treatment facilities require the removal of 60 percent TN or to reach 24mg/L TN effluent concentration. Currently the Genesis Business Park facility is removing an average of 50.79 percent of TN, and the average effluent concentration is 50.6 mg/L (applicant supplied analysis, 1/8/16 – 3/21/18). Based on the applicant influent sampling, 60 percent removal of the current TN would result in effluent concentrations of 44.8 mg/L. The 2018 recalculated Water Quality Based Effluent Limit (WQBEL) for the

facility, using current ambient monitoring data, and the updated transmissivity data is 44.3 mg/L TN effluent concentration (see calculations Appendix A).

To bring this facility into compliance with its current DBEL effluent limit, special conditions are attached to this permit renewal (Section 5.3). DEQ is requiring a plan from the applicant for treatment changes that will improve the performance of the facility allowing it to meet the permit limits. These special conditions also include the installation of downgradient monitoring wells. The current DBEL of 60% removal for TN will remain in effect (see **Table 9.**).

# 2.0 FACILITY INFORMATION

The applicant reports that the treatment facility serves a business park which has 560 non-resident workers. The maximum design capacity is for 10,240 gallons per day (gpd). The system is currently averaging approximately 7,000 gpd. Waste water flows into the system from non-residential, educational and office facilities which occupy approximately 15 buildings on the site.

Wastewater is delivered to one 20,000 gallon septic tank then on to one 9,000 gallon septic tank. Wastewater moves to four 4,000 gallon recirculation tanks, then through a recirculating sand filter. 80% of the volume is diverted back into the sand filter system and 20% of the wastewater will be diverted to a series of dosing tanks. Prior to discharge, wastewater passes through a Megatron ultraviolet disinfection unit. Wastewater is distributed to four pressure dosed, subsurface drainfields for discharge to ground water. Wastewater treatment plans submitted to the Department as part of the 2011 permit application materials indicate that there is an option for adding additional treatment consisting of either a denitrification catalyst (carbon source) or a polishing filter.

## 2.1 LOCATION

The Genesis Business Park wastewater treatment system is located south of Bozeman on South 19th Ave. (see **Figure 1. and Figure 2.**).

**Figure 1**. Location of the Genesis Business Park

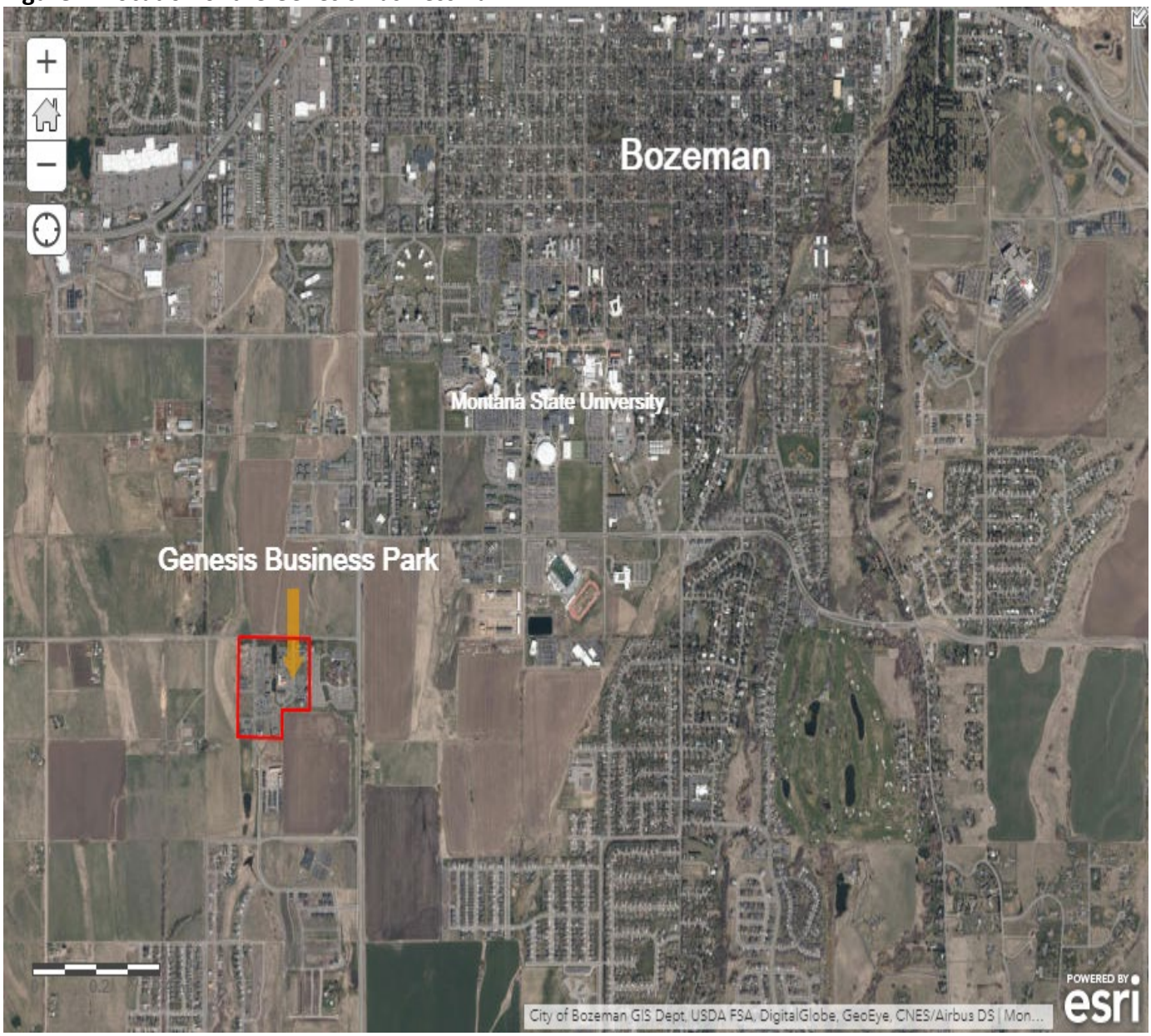


**Figure 2.** Site Map

## 2.2 OPERATIONS

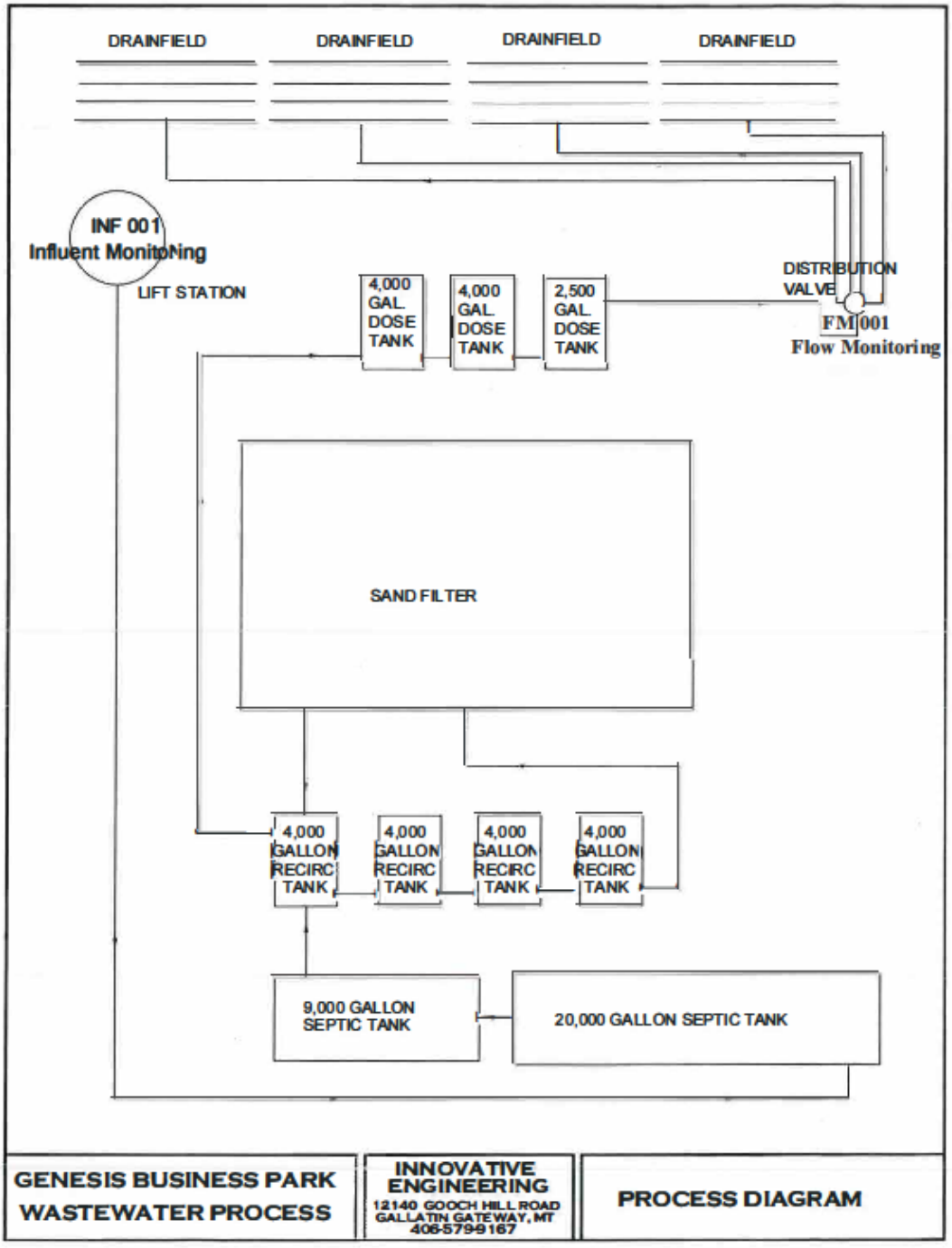
System operations are summarized below in **Table 1.** Components of the Genesis wastewater treatment facility are illustrated in **Figure 3.**.

**Table 1. Collection, Treatment, and Disposal Summary**

| | |
|---|---|
| **Collection** | |
| Contributing sources: | 15 business buildings (non-industrial) with 560 non-residential workers<br>SIC Code: 221320 |
| Collection method: | Gravity sewer lines to lift station to 20,000 gallon septic tank |
| Flow volume: | Average daily design flow: 10,240 gallons per day<br>Maximum daily design flow: 10,240 gallons per day |
| **Treatment** | |
| Treatment level: | Level 2 |
| Treatment location: | Latitude: 45.6563972, Longitude: -111.066666 |
| Treatment technology: | Recirculating sand filter, to four pressure-dosed drainfields. |
| **Disposal** | |
| Method of disposal: | Infiltration to ground water |
| Disposal structure: | Subsurface drainfield (Outfall 001) |
| Outfall location: | Latitude: 45.656344, Longitude: -111.068417<br>PLSS; 2SR5E, NE,NE,NE Section 23 |

Monitoring and sampling requirements are further discussed in **Section 6**.

**Figure 3.** Line diagram of Genesis Business Park wastewater facility (2018).



## 2.3 EFFLUENT AND INFLUENT CHARACTERISTICS

DEQ requires a permit applicant to disclose the quality of the effluent so that DEQ may evaluate the potential for pollution of state water. During the previous permit cycle, the facility sampled and reported effluent quality criteria to DEQ in the form of discharge monitoring reports (DMRs). The applicant supplied supplemental data for TN which is included with the DMR data. Analytical results are summarized in **Table 2**. The majority of the concentrations are reported in units of milligrams per liter (mg/L), which is equivalent to one part per million. Additional influent and effluent data for Nitrogen is contained in **Table 6.**.

**Table 2.**

**Effluent and Influent Quality – Outfall 001.**

| Parameter[1] | Location | Units | Reported Minimum Value[2] | Reported Average Value[3] | Reported Maximum[2] Value | # of Samples | Source of Data |
|---|---|---|---|---|---|---|---|
| Biochemical Oxygen Demand ($BOD_5$) | EFF-001 | mg/L | 1.00 | 6.70 | 23.00 | 13 | DMR |
| Chloride (as Cl) | EFF-001 | mg/L | 1.00 | 85.30 | 135.00 | 13 | DMR |
| Flow rate, Discharge | FM-001 | gpd | 6265.00 | 6973.00 | 7635.00 | 13 | DMR |
| Nitrogen, Nitrate + Nitrite (as N) | EFF-001 | mg/L | 0.03 | 16.41 | 57.60 | 25 | APP |
| | INF-001 | | 0.11 | 1.28 | 1.75 | 25 | APP |
| Nitrogen, Total Kjeldahl (as N ) | EFF-001 | mg/L | 16.00 | 34.21 | 53.80 | 25 | APP |
| | INF-001 | | 50.10 | 110.64 | 151.00 | 25 | APP |
| Nitrogen, Total (as N) | EFF-001 | mg/L | 27.58 | 50.61 | 88.40 | 25 | APP |
| | INF-001 | mg/L | 51.80 | 111.10 | 151.16 | 25 | APP |
| | % REMOVAL | Percent | 5.02 | 50.79 | 80.59 | 25 | APP |
| Phosphorus, Total (as P) | EFF-001 | mg/L | 1.00 | 8.39 | 10.80 | 13 | DMR |
| Specific Conductivity | EFF-001 | µS/cm | 1050.00 | 1180.00 | 1340.00 | 13 | DMR |
| Total Dissolved Solids (TDS) | EFF-001 | mg/L | 0.00 | 629.15 | 1080.00 | 13 | DMR |
| Total Suspended Solids (TSS) | EFF-001 | mg/L | 0.00 | 3.38 | 16.00 | 13 | DMR |

Footnotes:

APP = Applicant supplemental materials.

DMR = Self Reported Discharge Monitoring Reports

EFF-001: Effluent sample site located at dose tank prior to drainfield

FM-001 = Effluent flow meter located in control building prior to discharge

INF-001 = Influent sample site located at lift station prior to treatment.

Period of Record: **DRM**= 3/31/15-6/30/18, **APP**= 1/18/16-12/20/17.

(1) Conventional and nonconventional pollutants only, table does not include all possible toxics.

(2) Minimum and Maximum value recorded of all quarterly reported values.

(3) Average of reported quarterly averages.

## 2.4 GEOLOGY

The valley is an east-tilted graben (a down dropped fault block). The floor of the basin is composed of Precambrian bedrock that is overlain by thick sequences of Tertiary-aged sediments and Quaternary alluvial and glacial sediments. Quaternary sediments are the source of water for the Genesis Business Park PWS. The inventory region shown in blue in **Figure 4** below includes the wells located at the Genesis Business Park (in red). Geologic information in this permit is from the Source Water Delineation and Assessment Report for these wells (DEQ 2006).

**Figure 4.**

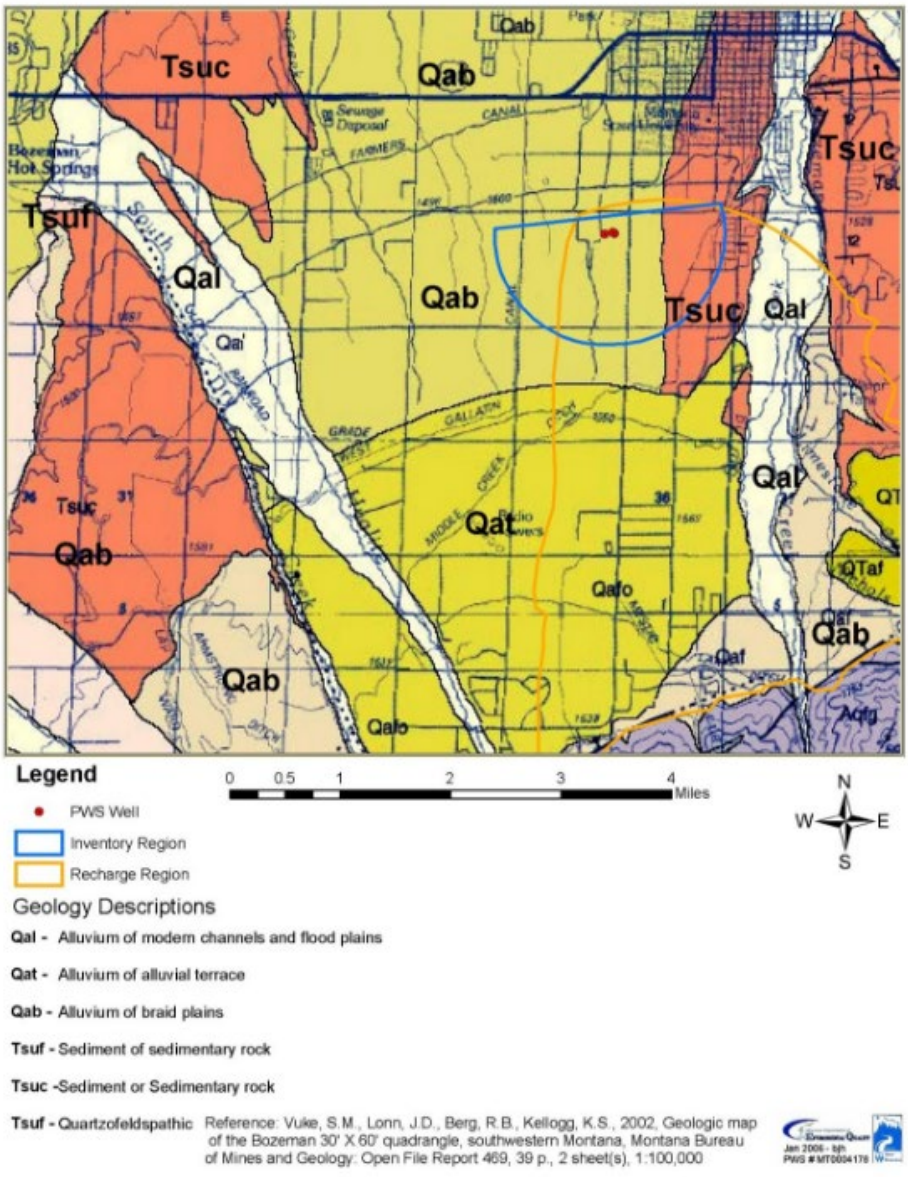



**Figure 4.** Geologic Map for the area around the Genesis Business Park (Genesis Park PWS wells marked in red).

## 2.5 HYDROGEOLOGY

The Genesis Business Park facility sits on Quaternary alluvial fan deposits (see **Figure 3.**) that occupy the south east portion of the Gallatin Valley. Quaternary flood-plain alluvium generally is the most permeable material in the basin, and the most reliable source of ground water. Transmissivity values range from 5,100 to 90,000 ft2/day, and average 27,000 ft2 /day for alluvium of the Gallatin River. Quaternary and Tertiary alluvial-fan deposits have a wide range of hydraulic characteristics, indicating that they can provide significant supplies for many water uses.

Genesis Business Park drainfields number 1-4 are located on the northern boundary of the facility, along the south side of Stucky Road. Each drainfield is located approximately 1-2 feet below ground surface. Due to the closeness in proximity, the four drainfields are considered a single Outfall 001. The total drainfield area is approximately 6,528 $ft^2$. Each drainfield has approximately 1,632 $ft^2$. Six test pits were dug in the area of the drainfield. Test pits excavated in the area of the drainfield indicate silt loam in the first 16 inches of the test pit. From approximately 14 inches to 40 inches test pits indicate brown sandy loam. From approximately 32-120 inches test pits indicate brown sandy gravel with cobbles. All but one test pit indicates the presence of shallow ground water occurring at approximately 6 to 9 feet below ground surface. The receiving ground water in the area of the facility has been classified as Class I ground water.

**Table 3.** Hydrogeologic Summary (applicant supplied information)

| | |
|---|---|
| Average depth to ground water | 15 feet |
| General ground water flow direction | N00°E |
| Hydraulic conductivity | 75 feet per day |
| Hydraulic gradient | 0.016 feet/feet |
| Nearest downgradient surface water | Farmer's Canal |

## 2.6 GROUND WATER MONITORING WELLS

There were no downgradient monitoring wells associated with the 2011 permit for this facility. There is one upgradient ambient well (MW1) that is monitored quarterly. This well location is plotted on **Figure 2**. Monitoring well information is provided below in **Table 4**. Two downgradient monitoring wells (MW-2 and MW-3) are required to be installed for this permit renewal.

**Table 4.** Monitoring Well Summary

| | |
|---|---|
| **Monitoring Well MW-1** | |
| MBMG GWIC ID: | none |
| Location: Latitude: | 45.654045° Longitude: -111.06719° |
| Rationale: | Ambient receiving water quality |
| Notes: | Applicant suspects nitrogen is influenced in this well by adjacent agricultural applications. |
| **Monitoring Well MW-2** | |
| MBGWIC ID: | none |
| Location: | Downgradient end of the permitted mixing zone (east end of the center 1/3 of the mixing zone). |
| Rationale: | Downgradient monitoring |
| Notes: | To be installed as a special condition of this renewal. |
| **Monitoring Well MW-3** | |
| MBWIC ID: | none |
| Location: | Downgradient end of the permitted mixing zone (west end of the center 1/3 of the mixing zone). |
| Rationale: | Downgradient monitoring |
| Notes: | To be installed as a special condition of this renewal. |

If a DEQ-approved monitoring well is abandoned, destroyed or decommissioned, or is no longer able to be sampled due to fluctuations in the ground water table, the permittee must install or designate a new well to replace the abandoned, destroyed, decommissioned, or non-viable well.

## 2.7 GROUND WATER QUALITY CHARACTERISTICS

Water sampling results from MW-1 are provided in **Table 5.** and **Table 6.**. Based on the 432microsiemens per centimeter (µS/cm) specific conductance, the receiving water is Class I ground water.

**Table 5.**

| Ambient Water Quality Reported From Monitoring Well MW-1 | | | | | | |
|---|---|---|---|---|---|---|
| **Parameter** | **Units** | **Reported values** | | | **Reporting Limit** | **# of Samples** |
| | | **Minimum** | **Maximum** | **Average** | | |
| Chloride (as Cl) | mg/L | 3 | 4 | 3.3 | 1 | 3 |
| Total dissolved solids | mg/L | 245 | 285 | 263 | - | 4 |
| *Escherichia coli* bacteria | CFU/100mL | <1 | <1 | <1 | 1 | 4 |
| Nitrogen, nitrate+nitrite (as N)* | mg/L | 1.28 | 2.81 | 1.85 | NR | 21 |
| Nitrogen, total Kjeldahl (as N)* | mg/L | 1.4 | 10.1 | 3.5 | NR | 21 |
| Total Nitrogen * | Mg/L | 2.79 | 12.91 | 5.34 | NR | 21 |
| Organic carbon | mg/L | 0.8 | 1.0 | 0.88 | - | 4 |
| pH | Standard units | 7.5 | 7.6 | 7.52 | 0.1 | 4 |
| Specific conductivity (@25°C) | µS/cm | 413 | 444 | 432 | - | 4 |

*Values provided by applicant as supplemental information 8/2/18 (**Table 6.**)

**Table 6.** Data supplied by applicant 8/02/2018

**Genesis Sand Filter Performance**
**2015 2016**

| Sample Date | Monitoring Well | | | Lift Station | | | Dose Tank | | | Percent Removal |
|---|---|---|---|---|---|---|---|---|---|---|
| | TKN | $NO_2$+$NO_3$ | Total N | TKN | $NO_2$+$NO_3$ | Total N | TKN | $NO_2$+$NO_3$ | Total N | |
| | (mg/L) | (mg/L) | (mg/L) | (mg/L) | (mg/L) | (mg/L) | (mg/L) | (mg/L) | (mg/L) | % |
| 1/18/2016 | 3.90 | 1.28 | 5.18 | | | | | | | |
| 1/25/2016 | | | | 50.10 | 1.70 | 51.80 | 29.70 | 19.50 | 49.20 | 5.02 |
| 2/1/2016 | 1.70 | 1.38 | 3.08 | 115.00 | 1.18 | 116.18 | 24.90 | 20.30 | 45.20 | 61.09 |
| 2/16/2016 | 2.80 | 1.32 | 4.12 | 111.00 | 1.44 | 112.44 | 26.60 | 25.50 | 52.10 | 53.66 |
| 3/16/2016 | 1.70 | 1.39 | 3.09 | | | | | | | |
| 1st Quarter Avg | 2.53 | 1.34 | 3.87 | 92.03 | 1.44 | 93.47 | 27.07 | 21.77 | 48.83 | 39.93 |
| 5/23/2016 | 10.10 | 2.81 | 12.91 | 139.00 | 1.38 | 140.38 | 18.20 | 26.00 | 44.20 | 68.51 |
| 5/31/2016 | 2.00 | 2.34 | 4.34 | 101.00 | 1.75 | 102.75 | 25.20 | 27.40 | 52.60 | 48.81 |
| 6/8/2016 | 1.70 | 1.95 | 3.65 | 127.00 | 1.00 | 128.00 | 20.40 | 24.60 | 45.00 | 64.84 |
| 6/20/2016 | 2.80 | 2.14 | 4.94 | 142.00 | 1.26 | 143.26 | 28.00 | 25.40 | 53.40 | 62.73 |
| 6/29/2016 | 1.70 | 1.71 | 3.41 | 105.00 | 1.01 | 106.01 | 20.40 | 25.80 | 46.20 | 56.42 |
| 2nd Quarter Avg | 3.66 | 2.19 | 5.85 | 122.80 | 1.28 | 124.08 | 22.44 | 25.84 | 48.28 | 60.26 |
| 9/27/2016 | 2.80 | 1.41 | 4.21 | 105.00 | 1.30 | 106.30 | 30.80 | 0.88 | 31.68 | 70.20 |
| 3rd Quarter Average | 2.80 | 1.41 | 4.21 | 105.00 | 1.30 | 106.30 | 30.80 | 0.88 | 31.68 | 70.20 |
| 10/26/2016 | 2.00 | 1.52 | 3.52 | 99.10 | 1.31 | 100.41 | 38.60 | 10.10 | 48.70 | 51.50 |
| 11/15/2016 | 1.40 | 1.39 | 2.79 | 62.20 | 1.57 | 63.77 | 25.20 | 26.30 | 51.50 | 19.24 |
| 4th Quarter Avg | 1.70 | 1.46 | 3.16 | 80.65 | 1.44 | 82.09 | 31.90 | 18.20 | 50.10 | 35.37 |
| 3/27/2017 | 1.70 | 1.63 | 3.33 | 118.00 | 1.60 | 119.60 | 52.10 | 0.03 | 52.13 | 56.41 |
| 1st Quarter Avg | 1.70 | 1.63 | 3.33 | 118.00 | 1.60 | 119.60 | 52.10 | 0.03 | 52.13 | 56.41 |
| 5/23/2017 | 2.20 | 2.58 | 4.78 | 142.00 | 0.11 | 142.11 | 25.20 | 2.38 | 27.58 | 80.59 |
| 6/5/2017 | 5.60 | 2.35 | 7.95 | 151.00 | 0.87 | 151.87 | 50.40 | 2.75 | 53.15 | 65.00 |
| 6/27/2017 | 2.00 | 2.06 | 4.06 | 130.00 | 1.04 | 131.04 | 53.20 | 1.94 | 55.14 | 57.92 |
| 2nd Quarter Avg | 3.27 | 2.33 | 5.60 | 141.00 | 0.67 | 141.67 | 42.93 | 2.36 | 45.29 | 67.84 |
| 8/1/2017 | 3.4 | 1.96 | 5.36 | 107 | 1.45 | 108.45 | 48.2 | 18.6 | 66.80 | 38.40 |
| 8/21/2017 | 5.6 | 1.82 | 7.42 | 76.2 | 1.54 | 77.74 | 50.4 | 31.9 | 82.3 | -5.87 |
| 9/12/2017 | 7.8 | 1.89 | 9.69 | 73.6 | 0.78 | 74.38 | 16 | 35.1 | 51.1 | 31.30 |
| 3rd Quarter Average | 5.60 | 1.89 | 7.49 | 85.60 | 1.26 | 86.86 | 38.20 | 28.53 | 66.73 | 21.28 |
| 10/25/2017 | 8.7 | 1.99 | 10.69 | 143 | 1.03 | 144.03 | 30.8 | 5.4 | 36.2 | 74.87 |
| 11/8/2017 | 1.7 | 1.99 | 3.69 | 152 | 1.16 | 153.16 | 23 | 38.2 | 61.2 | 60.04 |
| 12/20/2017 | | | | 127 | 1.53 | 128.53 | 30.8 | 57.6 | 88.4 | 31.22 |
| 4th Quarter Avg | 5.20 | 1.99 | 7.19 | 140.67 | 1.24 | 141.91 | 28.20 | 33.73 | 61.93 | 55.38 |
| 3/14/2018 | | | | 93.5 | 1.75 | 95.25 | 53.8 | 10.9 | 64.7 | 32.07 |
| 3/21/2018 | | | | 96.6 | 1.64 | 98.24 | 49.3 | 15.4 | 64.7 | 34.14 |
| | | | | 95.05 | 1.70 | 96.75 | 51.55 | 13.15 | 64.70 | 33.11 |

# 3.0 WATER QUALITY STANDARDS AND NONDEGRADATION

Ground water is a water of the state. The State of Montana uses several water quality measures to protect, sustain, and improve the quality of state waters. These water quality limitations provide the basis for effluent limits that DEQ applies to discharge permits (**Section 5**). DEQ protects all designated uses of state water by basing effluent limits on the most restrictive water quality limitations, intended to protect the most sensitive uses.

## 3.1 BENEFICIAL USES

With a specific conductivity of 432 µS/cm (**Table 5** above), the receiving water is Class I ground water and therefore a high-quality water of the State. Class I ground waters must be maintained suitable for the following uses with little or no treatment:

- Public and private drinking water supplies
- Culinary and food processing purposes
- Irrigation
- Drinking water for livestock and wildlife
- Commercial and industrial purposes

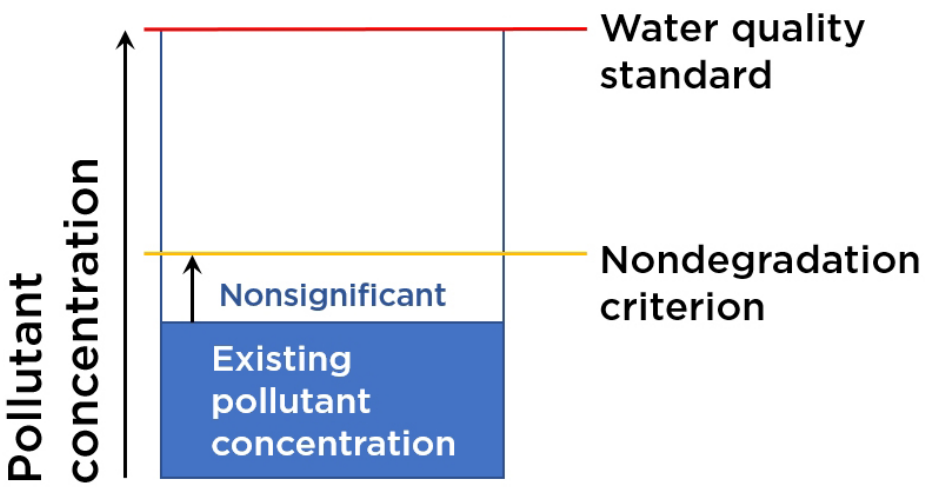
DEQ protects all the assigned beneficial uses by protecting the most sensitive. Drinking water is the most sensitive use of this receiving water.

## 3.2 WATER QUALITY STANDARDS

DEQ's ground water standard for nitrate is 10.0 mg/L, as is the standard for nitrate + nitrite (as nitrogen). Class I ground water must be maintained suitable for use as a drinking water supply with little or no treatment, and therefore must meet the corresponding human health standard of 10.0 mg/L total nitrogen. These water quality standards may not be exceeded outside a designated mixing zone (**Section 4**).

## 3.3 NONDEGRADATION

Montana's nondegradation policy is intended to preserve high-quality state waters. Any water whose existing condition is better than the water quality standards must be maintained in that high quality. Nondegradation policy states that certain types of common activities cause nonsignificant changes in water quality, and also provides criteria for determining whether changes in water quality are significant.




Nonsignificant changes do not require further nondegradation review. Therefore, DEQ must determine whether the proposed discharge will result in significant changes in water quality.

## 3.4 NONSIGNIFICANCE

When developing the initial permit (DEQ, 2011), the Department determined that discharges in compliance with this permit result in nonsignificant changes in water quality. This discharge has not increased since this determination, and therefore DEQ did not perform a new significance determination for this permit renewal. DEQ determined that the discharge will continue to meet ground water nonsignificance/nondegradation criteria (described below) at the end of the mixing zone (**Section 4**). DEQ used these criteria and updated ground water quality data to establish effluent limits (discussed below in **Section 5**).

### 3.4.1 Ground Water Nonsignificance Criteria

For this discharge to ground water, the following nonsignificance criteria are relevant:

#### *Nitrogen*

Under Montana statute, ground water total nitrogen at or below 7.5 mg/L at the downgradient end of the mixing zone (see **Section 4**) is a nonsignificant change in water quality, so long as the discharge does not cause degradation of surface water. Evaluation of the effects to surface water are discussed below in **Section 3.4.2**. Using the nonsignificance criterion of 7.5 mg/L, DEQ established effluent limits that cause the discharge to comply with ground water nonsignificance/nondegradation criteria at the end of the mixing zone. This is discussed in detail in **Section 5.1**.

#### *Phosphorus*

A total phosphorus surface water breakthrough time of greater than 50 years is a nonsignificant change in water quality. The phosphorus criterion requires an analysis to determine a breakthrough time. Breakthrough occurs when the subsurface soils lose their capability to adsorb any more phosphorus, and it reaches surface water.

A phosphorus breakthrough analysis conducted by DEQ in 2011 (DEQ, 2011) estimated the phosphorus breakthrough to occur in 191 (*i.e.* >50) years. Phosphorus breakthrough time of greater than 50 years is

considered nonsignificant. The 2011 permit established that a phosphorus effluent limit for this facility was not required. This 2011 phosphorus determination is maintained within this proposed permit renewal.

Ground water discharges meeting these criteria are nonsignificant, so long as they do not cause degradation of surface waters (see **Section 3.4.2**).

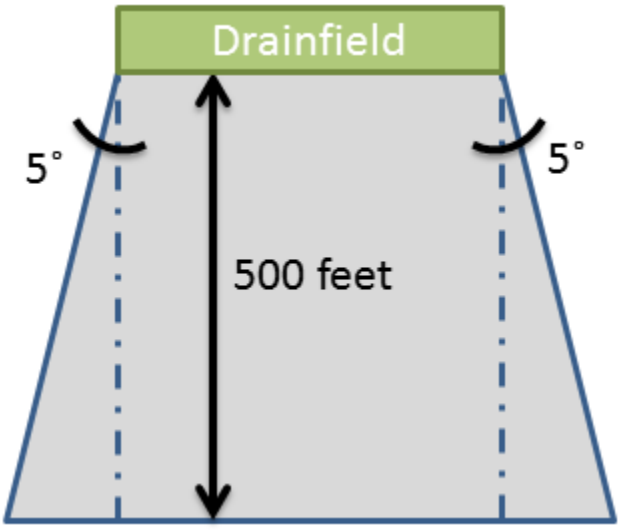
### 3.4.2 Surface Water Nondegradation

This source has not changed since the last permitting cycle. DEQ determined (2011) the source is not a significant source and does not cause degradation of surface water.

## 4.0 MIXING ZONE

A mixing zone is a specifically defined area of the receiving water where water quality standards may be exceeded. DEQ evaluates the suitability according to criteria established in the Administrative Rules of Montana. The mixing zone is then defined in the permit. The applicant requested a standard mixing zone for this discharge, consistent with previous permit cycles.

A standard mixing zone extends 500 feet downgradient from the source. The upgradient boundary is equal to the width of the source (measured perpendicular to the of ground water flow direction). The mixing zone widens in the downgradient direction by 5° on either side. The width of the downgradient boundary is calculated by adding the increased width for each side (the tangent of 5° (0.0875) times the mixing zone length) to the width of the upgradient boundary. Standard mixing zones extend 15 feet below the ground water table.




The volume of ground water ($Q_{GW}$) available to mix with the effluent is calculated using Darcy's Equation: $Q_{GW} = KIA$

Where:
$Q_{GW}$ = ground water flow volume (feet$^3$/day)
K = hydraulic conductivity (feet/day)
I = hydraulic gradient (feet/feet)
A = cross-sectional area (feet$^2$) at the downgradient boundary of the mixing zone.

**Table 7.** summarizes the variables used in Darcy's equation and the resulting volume of ground water available to mix at Outfall 001. These values are drawn from the previous fact sheet, and recent analyses.

**Table 7.**

| Hydrogeologic and Mixing Zone Information - Outfall 001 | | |
|---|---|---|
| **Parameter** | **Units** | **Value** |
| Mixing Zone Type | - | Standard |
| Authorized Parameters | - | Total Nitrogen |
| Ambient Ground Water Concentrations, Nitrate + Nitrite | mg/L | 5.07 |
| Ground Water Flow Direction | azimuth/bearing | North |
| Length of Mixing Zone | feet | 500 |
| Thickness of Mixing Zone | feet | 15 |
| Outfall Width, Perpendicular to Ground Water Flow Direction | feet | 1078 |
| Width of Mixing Zone at Down Gradient Boundary | feet | 1165.5 |
| Cross Sectional Area of Mixing Zone (A) | $ft^2$ | 17482.5 |
| Hydraulic Conductivity (K) | feet/day | 75 |
| Hydraulic Gradient (I) | ft/ft | 0.016 |
| Volume of Ground Water Available for Mixing ($Q_{gw}$) | $ft^3$/day | 20,979 |

In order to determine whether a mixing zone is allowable, DEQ calculates a predicted concentration at the downgradient end of the mixing zone. This mixing calculation follows the following procedure:

- Volume of ground water times the concentration of the parameter = existing load;
- Volume of discharge times the concentration of the parameter = waste load; and
- (Existing load + waste load) / total volume = predicted concentration.

Because the predicted concentration must satisfy the most stringent nonsignificance criterion (**Section 3**), DEQ can calculate water quality based effluent limits (WQBELs) by rearranging the equation and solving for the effluent concentration (**Section 5**).

# 5.0 PERMIT CONDITIONS

Discharge permits include conditions that ensure compliance with the Montana Water Quality Act and the regulations used to implement it. These conditions include effluent limits as well as any special conditions that DEQ deems necessary to protect the quality of the receiving water.

Montana's numeric water quality standards are published in Circular DEQ-7. Water quality criteria applicable to this permit are summarized below in **Table 8**. The permit establishes effluent limits that will meet water quality standards and nondegradation criteria, thereby protecting beneficial uses and existing high quality waters. The most restrictive criteria in **Table 8** provide the basis for the effluent limits.

**Table 8.** Applicable Ground Water Quality Criteria

| Parameter | Human Health Standard | Beneficial Use Support | Nondegradation Criteria |
|---|---|---|---|
| Nitrate plus nitrite (as Nitrogen[N]) | 10 mg/L | - | - |
| Total Nitrogen | - | 10 mg/L | **7.5 mg/L** |

## 5.1 TOTAL NITROGEN EFFLUENT LIMIT

This permit renewal reestablishes the previous Definition Based Effluent Limit. Based on the information and analyses presented above, DEQ proposes the following numerical effluent limitations in **Table 9**.

**Table 9.**

| **Proposed Final Effluent Limits – Outfall 001, Genesis Business Park** | | | |
|---|---|---|---|
| **Parameter** | **Units** | **Minimum Percent Removal**(1) | **Rationale** |
| Nitrogen, Total (as N) | % | 60 | DBEL |
| Footnotes: | | | |
| Beneficial Uses: ARM 17.30.1006 | | | |
| (1) See definition in Part V of permit. | | | |

## 5.2 TOTAL PHOSPHORUS EFFLUENT LIMIT

DEQ previously determined (2011) that phosphorous discharged to ground water would reach the surface water, (Farmer's Canal) in 197 years. A phosphorous breakthrough time of less than 50 years is considered significant. As discussed above, there is no phosphorus limit associated with this permit.

## 5.3 SPECIAL CONDITIONS

The following special conditions will be included in the permit (see **Table 12**. for compliance schedule).

**I. Monitoring**

1. Ground Water Monitoring Well Installation Plan
   a. Within 6 months of the effective date of this permit, the permittee will submit to the Department for approval a plan for ground water monitoring well installation as well as a brief summary of a monitoring, sampling and analysis plan for monitoring wells to be installed onsite. The plan is to include the location, conceptual design and construction methods of the planned ground water monitoring wells, and the monitoring, sampling and analysis methods that will be used to meet the monitoring required in the permit.

This plan should include but not be limited to the requirements of Part I.E.2. and Part I.E.3. of this permit.

b. All monitoring wells shall be located on land owned, or controlled by the permittee. If monitoring wells are to be installed on land not owned by the permittee, the permittee shall demonstrate legal access to the proposed monitoring well locations for duration of the permit cycle.

2. Ground Water Monitoring Well Installation.

   a. The permittee shall install the approved monitoring wells by within 12 months of the effective date of this permit.
   b. Two downgradient monitoring wells will be installed near the down gradient edge, and centered on, the standard mixing zone for outfall 001. These wells will be finished on the east and west edge of the center 1/3 of the downgradient edge of the mixing zone. The wells will be completed in the first 15-20 feet of the shallow perched aquifer. These wells will be called MW-2 and MW-3.
   c. All ground water monitoring wells must be constructed by a licensed monitoring well constructor pursuant to monitoring well construction standards so as to obtain representative static water level data and ground water quality samples.
   d. The permittee will submit to the Department well logs for all wells used in the above mentioned analysis. See Appendix B and C for additional monitoring well information.

3. Ground Water Monitoring Well Installation Report.
   a. Within 12 months of the effective date of this permit, the permittee shall submit to the Department a report documenting the installation of the down gradient monitoring wells. The report shall document the results of the monitoring well installation, including the final location of the installed monitoring well, construction details, and or well log for the installed well.

4. Ground Water Monitoring Well Sampling Reports.
   a. In supplement to Part I.D., sampling reports shall include water quality analytical results as described in **Table 11**.

5. If any monitoring well(s) are abandoned, destroyed or decommissioned during any activities at the facility or are no longer able to be sampled due to fluctuations in the ground water table, the applicant shall install a new well to replace the abandoned, destroyed, decommissioned or the non-viable well(s). The applicant may use existing monitoring wells provided that ground water quality data collected from them are representative of the aquifer conditions and ground water quality.

II. **Operational Changes**

1. Operational Plan.
   a. Within 12 months of the effective date of this permit, the permittee will submit to the Department for approval a plan for operational changes in the treatment facility. Current treatment and operations of the facility result in exceedances of the 2011 concentration limit for the facility. Operational and treatment changes included in the plans should address existing noncompliance issues. The plan is to include the location, conceptual

design and construction methods of the changes in operation or treatment proposed by the permittee.

2. Plan Implementation Report.
   a. Within 18 months of the effective date of this permit, the permittee shall submit to the Department a report documenting the implementation of operational changes and treatment changes at the facility. The report is to document the results of the changes, including the final location, construction details, and changes in the Operation and Management (O&M) of the facility. This report shall include an updated O&M plan for the facility.

III. **Monitoring and Sampling Report**

1. Status Report
   a. Within 24 months of the effective date of this permit, the Permittee will submit a report to the Department documenting, the viability of the changes implemented to bring the facility into compliance, or, provide the Department with a plan for additional changes in operations and treatment at the facility to bring the facility into compliance.

# 6.0 MONITORING AND REPORTING REQUIREMENTS

DEQ requires effluent and ground water monitoring to assure compliance with the effluent limitations and therefore water quality standards. Effluent and influent monitoring and ground water monitoring are required as a condition of this permit. All monitoring and sampling required by this permit must be representative; therefore the permit identifies specific monitoring locations. Monitoring requirements and rationale are summarized in **Table 10.** and **Table 11.**

## 6.1 EFFLUENT MONITORING

This permit includes numeric effluent limitations with specific magnitudes and durations to ensure the discharge will not cause or contribute to an exceedance of an applicable water quality standard (see **Section 5.2**). Accordingly, the permittee is required to monitor and report at a specified frequency in order to demonstrate compliance with these limitations.

Effluent samples and discharge flow measurements must be representative of the nature and volume of the effluent. The effluent sample location (EFF-001) is located at the final dose tank before discharge to drainfields as shown in **Figure 3**. The permittee is required to maintain and report flow measurements using a flow-measuring device capable of measurements that are within 10 percent of the actual flow. The flow measuring device (FM-001) is located at the discharge vault prior to discharge to drainfields (**Figure 3**). Effluent and Influent monitoring and reporting requirements are summarized in **Table 10**.

**Table 10.**

**Influent and Effluent Monitoring and Reporting Requirements – Outfall 001**

| Analyte/Measurement | Monitor Location | Units | Sample Type[1] | Minimum Sample Frequency | Reporting Requirements[1][2][3] | Report Freq |
|---|---|---|---|---|---|---|
| Flow Rate, Effluent[4] | FM-001 | gpd | Contin-uous | Contin-uous | Daily Maximum Quarterly Average | Quarterly |
| Nitrogen, Nitrite+Nitrate (as N) | EFF-001 INF-001 | mg/L | Grab | 1/Quarter | Daily Maximum Quarterly Average | Quarterly |
| Nitrogen, Total Ammonia (as N) | EFF-001 INF-001 | mg/L | Grab | 1/Quarter | Daily Maximum Quarterly Average | Quarterly |
| Nitrogen, Total Kjeldahl (TKN)(as N) | EFF-001 INF-001 | mg/L | Grab | 1/Quarter | Daily Maximum Quarterly Average | Quarterly |
| Nitrogen, Total (as N)[8] | EFF-001 INF-001 | mg/L | Calculate | 1/Quarter | Daily Maximum Quarterly Average | Quarterly |
| Nitrogen Percent Removal [5][6][7] | EFF-001 | % | Calculate | 1/Quarter | Daily Minimum Quarterly Average | Quarterly |
| Phosphorus, Total (as P) | EFF-001 INF-001 | mg/L | Grab | 1/Quarter | Quarterly Average | Quarterly |

Footnotes:

EFF-001: located at effluent collection tank just prior to release of wastewater to drainfields.

INF-001: located at first septic tank in the treatment.

FM-001: located in control building prior to discharge to drainfields.

If no discharge occurs during the reporting period, "no discharge" shall be recorded on the effluent Discharge Monitoring Report (DMR) report forms.

Grab sample will represent concentration for a 24 hour period.

Parameter analytical methods shall be in accordance with the Code of Federal Regulations, 40 CFR Part 136, unless specified above.

(1) See definitions in Part V of the permit.

(2) Daily Maximum: Report highest measured daily value for the reporting period on Discharge Monitoring Report (DMR) form.

(3) Daily Minimum: Report lowest measured daily value for the reporting period on Discharge Monitoring Report (DMR).

(4) Requires recording device or totalizing meter, must be capable of recording daily effluent volume.

(5) Percent Removal will be based on daily minimum.

(6) At least 60% removal of total nitrogen from the raw influent.

(7) Calculated as {[(Influent TN - Effluent TN)/Influent TN]*100} using the corresponding quarterly average values as reported on the Discharge Monitoring Report (DMR) form for the reporting period.

(8) Total Nitrogen is the sum of Nitrate + Nitrite and Total Kjeldahl Nitrogen.

## 6.2 GROUND WATER MONITORING

There is currently no Ground Water Monitoring associated with this facility. As a special condition of this permit renewal, two new downgradient ground water monitoring wells will need to be established. These wells will be labeled MW-2 and MW3. They will be located at the down gradient end of the permitted 500 foot mixing zone as described in Monitoring Well Summary **Table 4**. . They will be located, installed, and will begin reporting analyses within 11 months of the effective date of this permit. Monitoring schedules are included in **Table 11**.

**Table 11.**

| **Ground Water Monitoring and Reporting Requirements MW-1, MW-2 and MW-3 Reported Separately** | | | | | | |
|---|---|---|---|---|---|---|
| **Analyte/Measurement** | **Monitor Location(1)** | **Units** | **Sample Type(2)** | **Minimum Sampling Frequency** | **Reporting(2)(3)(4) Requirements** | **Reporting Frequency** |
| Chloride (as Cl) | MW-2<br>MW-3 | mg/L | Grab | Quarterly | Quarterly Average | Quarterly |
| *Escherichia coli* Bacteria | MW-2<br>MW-3 | CFU/100ml | Grab | Quarterly | Daily MaximumQuarterly Average(5) | Quarterly |
| Nitrogen, Nitrate + Nitrite (as N) | MW-1<br>MW-2<br>MW-3 | mg/L | Grab | Quarterly | Daily Maximum<br>Quarterly Average | Quarterly |
| Nitrogen, Total Ammonia (as N) | MW-1<br>MW-2<br>MW-3 | mg/L | Grab | Quarterly | Daily Maximum<br>Quarterly Average | Quarterly |
| Nitrogen, Total Kjeldahl (TKN)(as N) | MW-1<br>MW-2<br>MW-3 | mg/L | Grab | Quarterly | Daily Maximum<br>Quarterly Average | Quarterly |
| Static Water Level (SWL)(6) | MW-2<br>MW-3 | ft-bmp | Instant-aneous | Quarterly | Quarterly Average | Quarterly |

| Footnotes: |
|---|
| CFU = Colony Forming Units |
| ft-bmp = feet below measuring point |
| At no time shall the permittee mark or state "no discharge" on any monitoring well DMR form. |
| Each monitor well to be individually sampled and analyzed for each respective parameter listed above. |
| If any monitoring well(s) are abandoned, destroyed or decommissioned, or are no longer able to be sampled due to fluctuations in the ground water table; the permittee shall install a new well to replace the abandoned, destroyed, decommissioned, or non-viable well(s). |
| Monitoring for the proposed monitoring wells MW-2 and MW-3 shall commence upon installation (Compliance Schedule). |
| Parameter analytical methods shall be in accordance with the Code of Federal Regulations, 40 CFR Part 136, unless specified above. |
| (1) Refer to Section 2.6 and Section 6.2 of the Fact Sheet for the proposed location of the monitoring wells. |
| (2) See definitions in Part V of the permit. |
| (3) Submittal of DMRs will be required, regardless of the installation status of each individual monitoring well. If the monitoring well(s) is not installed for an individual monitoring period, the following shall be stated upon each applicable DMR: "monitoring well has not been installed". |
| (4) Daily Maximum: Report highest measured daily value for the reporting period on Discharge Monitoring Report (DMR). |
| (5) The geometric mean must be reported if more than one sample is taken during a reporting period. |
| (6) Measuring point (point of reference) for SWL measurements shall be from top of casing and measured to within 1/100th of one foot. |

## 6.3. COMPLIANCE SCHEDULE

The actions listed in **Table 12.** below must be completed on or before the respective scheduled completion date. A report documenting each respective action must be received by DEQ on or before the scheduled reporting date. Completion of all actions or deliverables must be reported to DEQ in accordance with Part II.D and Part IV.G of the permit.

**Table 12.**

| Authority | Action | Scheduled Completion Date (1) |
|---|---|---|
| 17.30.1031 | Submit Plan to install monitoring wells. | 6 months |
| | Install monitoring wells. | 12 months |
| | Begin ground water monitoring and reporting of new monitoring wells. (4) | 12 months |
| | Submit report documenting the installation of monitoring wells. (2)(3) | 12 months |
| | Submit plan for operational and treatment changes to Department for approval. | 12 months |
| | Implement operational and treatment changes at the facility. | 18 months |
| | Report to the Department the status of compliance efforts and the effects of operational changes.(2) | 24 months |

Foot notes:
(1) The actions must be completed on or before the scheduled completion dates. Completion dates are "within months of effective date of permit".
(2) Reports must be received by DEQ within 28 days of completion date. The reports must include all information required for each applicable action as listed in Section 5.3 (Special Conditions).
(3) The written report documenting monitoring well installation, must include final location, drilling methods used, borehole lithologic log, well construction details, elevation of measuring point, and the depth to the top contact of the first ground water bearing zone. This information must be included for each respective monitoring well.
(4) Sampling parameters required for each respective monitoring well are listed within Table 3 of the permit.

# PUBLIC NOTICE

Legal notice information for water quality discharge permits are listed at the following website: http://deq.mt.gov/Public/notices/wqnotices. Public comments on this proposal are invited any time prior to close of business on **January 4, 2019**. Comments may be directed to:

DEQWPBPublicComments@mt.gov

or to:

Montana Department of Environmental Quality
Water Protection Bureau
PO Box 200901
Helena, MT 59620

All comments received or postmarked prior to the close of the public comment period will be considered in the formulation of the final permit. DEQ will respond to all substantive comments pertinent to this permitting action and may issue a final decision within thirty days of the close of the public comment period.

All persons, including the applicant, who believe any condition of the draft permit is inappropriate, or that DEQ's tentative decision to deny an application, terminate a permit, or prepare a draft permit is inappropriate, shall raise all reasonably ascertainable issues and submit all reasonably available arguments supporting their position by the close of the public comment period (including any public hearing). All public comments received for this draft permit will be included in the administrative record and will be available for public viewing during normal business hours.

Copies of the public notice are mailed to the applicant, state and federal agencies, and interested persons who have expressed interest in being notified of permit actions. A copy of the distribution list is available in the administrative record for this draft permit. Electronic copies of the public notice, draft permit, fact sheet, and draft environmental assessment are available at the following website: http://deq.mt.gov/Public/notices/wqnotices.

Any person interested in being placed on the mailing list for information regarding this permit may contact the DEQ Water Protection Bureau at (406) 444-5546 or email DEQWPBPublicComments@mt.gov. All inquiries will need to reference the permit number (MTX000223), and include the following information: name, address, and phone number.

During the public comment period provided by the notice, DEQ will accept requests for a public hearing. A request for a public hearing must be in writing and must state the nature of the issue proposed to be raised in the hearing.

# Appendix A- WQBEL Calculation

**MASS BALANCE EQUATION**

**ALLOWABLE DISCHARGE CONCENTRATION DETERMINATION**

$$C_2 = \frac{C_3(Q_1 + Q_2) - C_1 Q_1}{Q_2}$$

| | | |
|---|---|---|
| C1 | Ambient ground water (background) concentration (mg/L) | 5.1 |
| **C2** | **Allowable discharge concentration (mg/L)** | **44.06** |
| C3 | Ground water concentration limit for pollutant (from Circular WQB-7) at the end of the mixing zone. | 7.50 |
| Q1 | Ground water volume ( $ft^3$ / day) | 20839 |
| Q2 | Maximum flow of discharge (design capacity of system in $ft^3$ / day) | 1368 |

The volume of ground water that will mix with the discharge ($Q_s$) is estimated using Darcy's equation: Q1=K I A

| | | |
|---|---|---|
| **Q1** | **Ground water flow volume ( $ft^3$ / day)** | **20839** |
| K | hydraulic conductivity (ft/day) | 74.5 |
| I | hydraulic gradient (ft/ft) | 0.0160 |
| A | cross-sectional area ($ft^2$) of flow at the down-gradient boundary of a standard 500-foot mixing zone. | 17482 |

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# Appendix B– Monitoring Well Installation Requirements

Monitoring well MW-2 and MW-3 will be installed so that all collected samples will be representative of the shallow portion of the water bearing zone (mixing zone). The monitoring well must be constructed so that the perforated casing and filter pack is only representative of ground water occurring from the top contact of the seasonal high ground water down to twenty feet below the top contact of the seasonal high ground water. The monitoring well must be secured, maintained, labeled, and monitored for long-term viability.

Upon completion, a monitoring well installation report must be received by DEQ due on or before the 28th day of the month following the completion date. The report must include final location, drilling methods used, borehole lithologic log, well construction details, well identification, elevation of measuring points, and the depth to the top contact of the first ground water bearing zone. The respective completion and reporting dates are listed in Section VII.. The commencement date for monitoring well sampling and reporting is listed in **Table 12.**.

# Appendix C. - Ground Water Quality Monitoring

As a special condition (ARM 17.30.1031), ground water monitoring will be established in this permit to provide for long term ambient and downgradient monitoring of the aquifer. Ground water monitoring will be required at monitoring wells MW-1, MW-2 and MW-3. Ground water monitoring will be used for mixing zone determination, aquifer characterization, and in collection of data that is required for future permit renewal (Part III.A., Duty to Reapply). Ground water monitoring and reporting requirements are summarized in Table 9. All analytical methods must be in accordance with the Code of Federal Regulations, 40 CFR Part 136 for each monitored parameter.

# Appendix D. - References Cited

40 CFR § 136 – Guidelines Establishing Test Procedures for the Analysis of Pollutants. 2011.

Administrative Rules of Montana, Title 17, Chapter 30, Water Quality:

- Subchapter 2 - Water Quality Permit Fees.
- Subchapter 5 – Mixing Zones in Surface and Ground Water.
- Subchapter 7 – Nondegradation of Water Quality.
- Subchapter 10 – Montana Ground Water Pollution Control System.
- Subchapter 13 – Montana Pollutant Discharge Elimination System.

Crowley et al., 2017. Montana Bureau of Mines and Geology (MBMG), Principal Aquifers of Montana, MBMG Hydrogeologic Map 11.

Department of Environmental Quality, Water Quality Circulars:

- Circular DEQ-2 – Design Standards for Wastewater Facilities.
- Circular DEQ-4 – Montana Standards for On-Site Subsurface Sewage Treatment Systems.
- Circular DEQ-7 – Montana Numeric Water Quality Standards, Required Reporting Values, and Trigger Values.

Department of Environmental Quality. 2011 Administrative Record of Montana Ground Water Pollution Control System (MGWPCS) permit application and supplemental materials, Genesis Business Park MTX000223.

Fetter, C.W., Applied Hydrogeology, 1994.

Freeze, R., and Cherry, J., Groundwater, 1979.

Montana Bureau of Mines and Geology, Ground-Water Information Center, Retrieved November, 2014, from the GWIC database, http://mbmggwic.mtech.edu.

Montana Code Annotated, Title 75, Chapter 5, *Montana Water Quality Act*, 2011.

U.S. Environmental Protection Agency, Effluent Limitation Guidelines, http://water.epa.gov/scitech/wastetech/guide/, 2013.

U.S. Environmental Protection Agency, NPDES Permit Writers' Manual, 833-K-10-001, September 2010.

U.S. Environmental Protection Agency, *Onsite Wastewater Treatment Systems Manual*, 625/R-00/008, Office of Research and Development and Office of Water. 2002b.

U.S. Geological Survey, Basic Ground Water Hydrology, http://pubs.usgs.gov/wsp/2220/report.pdf, 2016.

Woessner, W., Troy, T., Ball, P. and D.C. DeBorde. 1998. Virus Transport in the Capture Zone of a Well Penetrating a High Hydraulic Conductivity Aquifer Containing a Preferential

Slagel, E., Steven. Geohydrologic Conditions and land use in the Gallatin Valley, Southwestern Montana, Montana Bureau of Mines and Geology, 1993