BASIS OF DESIGN REPORT
(DRAFT)

FOR THE

TOWN OF EMPIRE

WATER TREATMENT PLANT IMPROVEMENTS

JUNE 2021

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FOR THE

TOWN OF EMPIRE
Water Treatment Plant Improvements

JVA, Inc.
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JVA Project No. 1085.2e

JUNE 2021

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SECTION 1 – BASIC PROJECT INFORMATION

This Basis of Design Report (BDR) was prepared following the Colorado Department of Public Health and Environment's (CDPHE) State of Colorado Design Criteria for Potable Water System. As an existing system before October 1, 1999, this system is exempt from the requirements of the New Public Water System Capacity Planning and Manual and does not require demonstration of technical, managerial and financial capacity.

WATER SYSTEM INFORMATION

The Town of Empire (Town) operates a community water system under PWSID No. CO0110010 with approximately 194 taps. The Water Treatment Facility (WTF) treats surface water from Mad Creek. The Town also maintains a groundwater source for backup and emergency conditions. The WTF consists of a filter building containing the slow sand filtration process (two filters) and a treatment building containing bag filtration, UV disinfection, and chlorine disinfection processes. The Town area and treatment locations are depicted in Figure 1.

PROJECT LOCATION

The Town's service area is located off U.S. Highway 40. The mailing address for the Town Hall is P.O. Box 100, Empire, CO 80438. The location of the filter building and the treatment building and growth boundary are shown in Figure 1.

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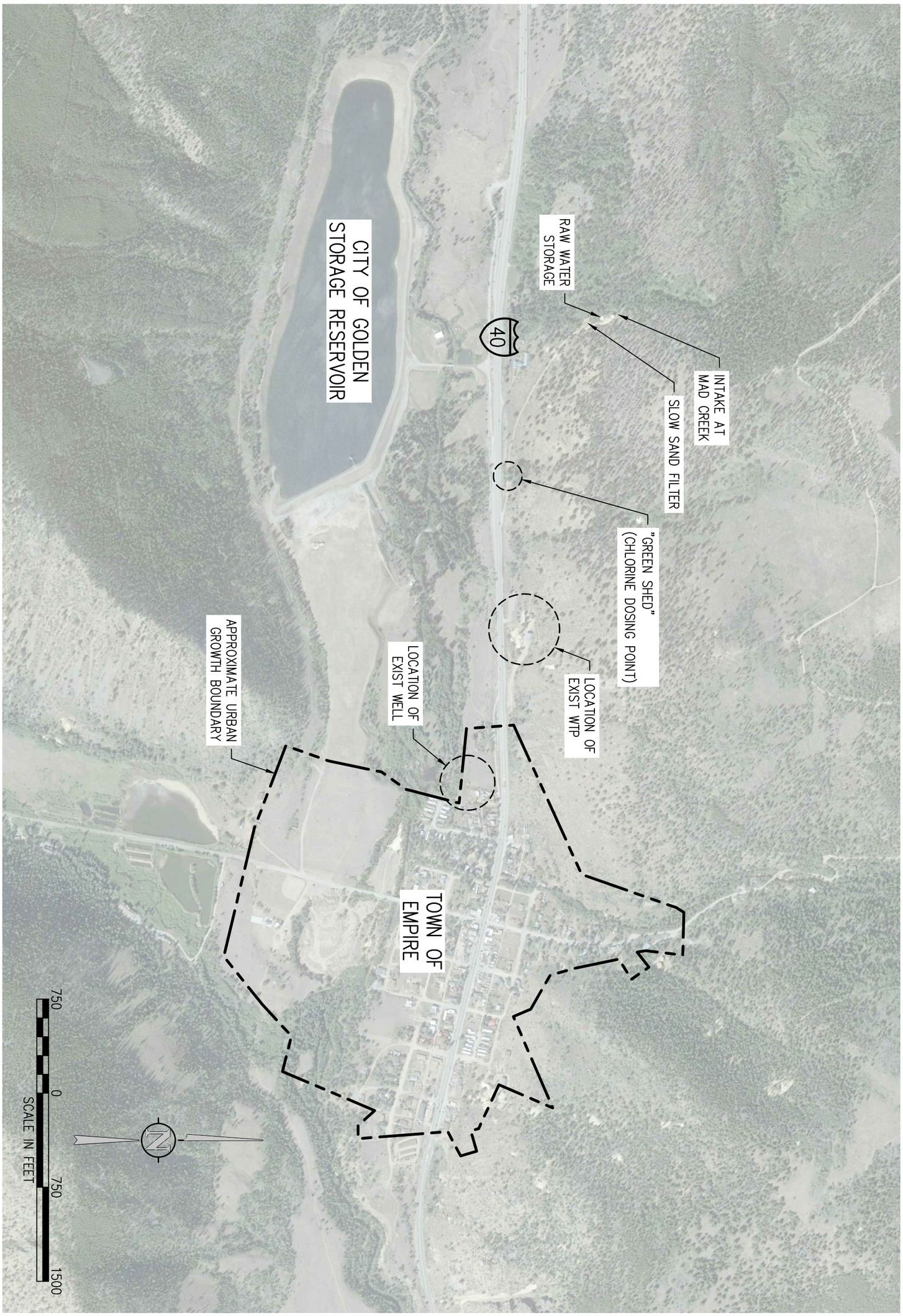

FIGURE 1 - EXIST WATER SYSTEM
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PROJECT PURPOSE AND SCOPE

EXISTING FACILITIES

The Town's current water treatment facilities are located at two separate buildings, the filter building and the disinfection building. The existing process consists of slow sand filtration, bag filtration, UV disinfection, and chlorine disinfection. Raw water from Mad Creek is stored in a 100,000-gallon raw water storage tank. Raw water then flows by gravity to one of two slow sand filters. Filtrate flows by gravity from the slow sand filters to the treatment building. The treatment building includes a multi-bag filter followed by two UV disinfection units. After UV disinfection, the water is dosed with chlorine and soda ash before going to the distribution system. The existing process flow diagram is depicted in Figure 2. In addition, the existing water treatment site and floor plan is presented in Figure 3.

PROJECT DESCRIPTION

The Town's current water treatment facilities are located at two separate buildings, the filter building and the treatment building. The treatment building includes a multi-bag filter followed by two UV disinfection units. The filter building is new and was constructed in 2017, primarily to achieve additional log inactivation credits with the new UV system. The bag filtration units were added for polishing and to remove potential sand carryover. The Slow Sand Filter Building is over 30 years old and approaching its useful life. A 2019 sanitary survey documented current deficiencies including:

1.) Concerns with slow sand filter clear well water tightness
2.) Cross connection potential in overhead space between slow sand filter and the clear well
3.) Valve stem roof penetrations at the clear well – potential contamination
4.) UV system was inactive – needing bulb replacement
5.) Upgradient original design disinfection injection point was inactive and current dosing in the WTP building was non-compliant.

The UV system operational issue has been corrected, the new "Green Shed" chlorine injection point was installed, and the valve stems have been resealed. In addition to the documented deficiencies, the slow sand filter location is isolated and difficult to access. Routine maintenance can be a challenge. The slow sand filter building is over 30 years old and approaching its useful life and alternate treatment schemes are being explored.

ALTERNATIVES EVALUATION – WATER TREATMENT IMPROVEMENTS

The following three treatment alternatives are being considered.

1.) No action,
2.) Rehabilitate Existing Treatment System
3.) Addition of Membrane Filtration

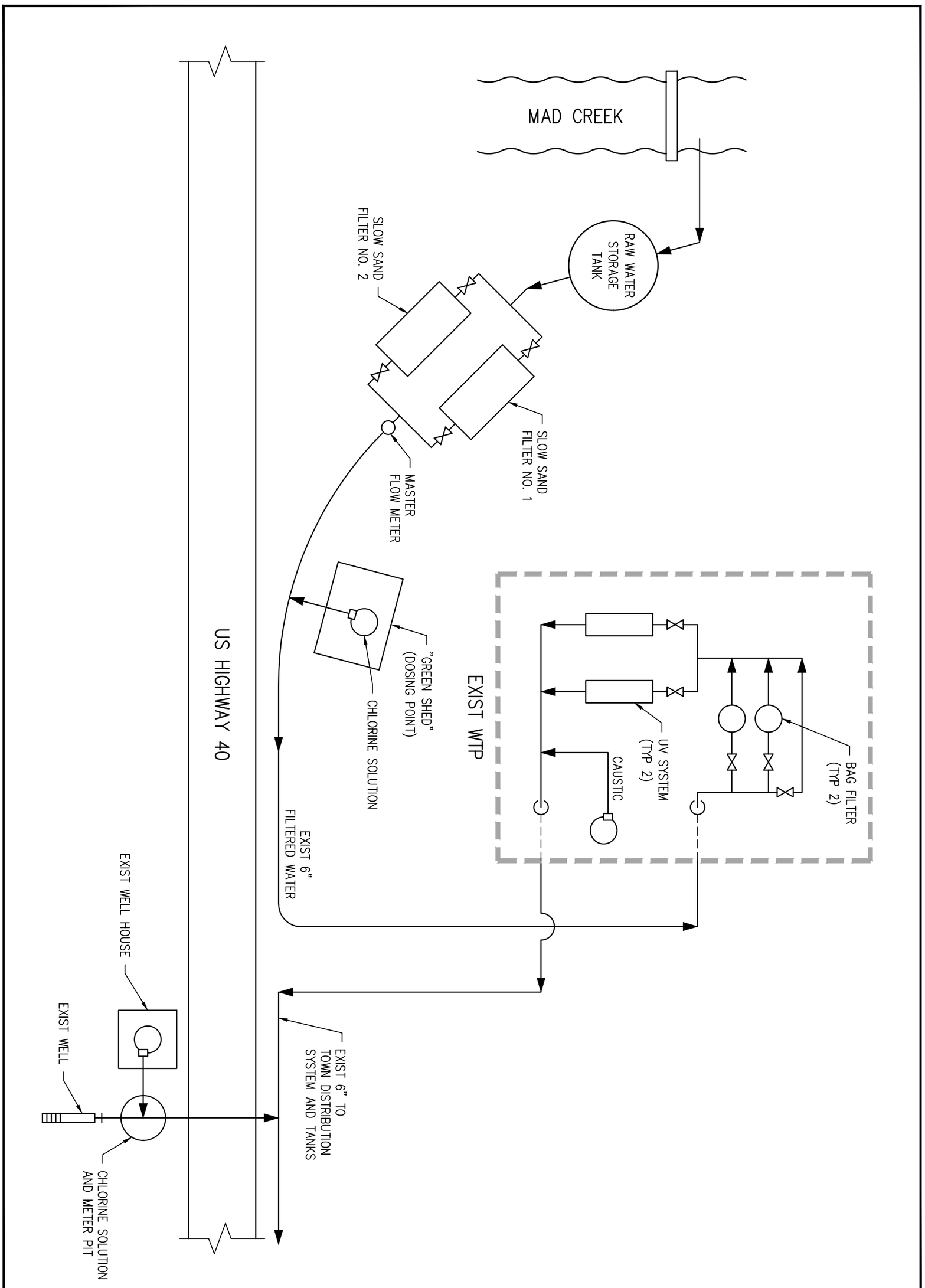

FIGURE 2 - EXIST WATER SYS. PROCESS FLOW DIAGRAM

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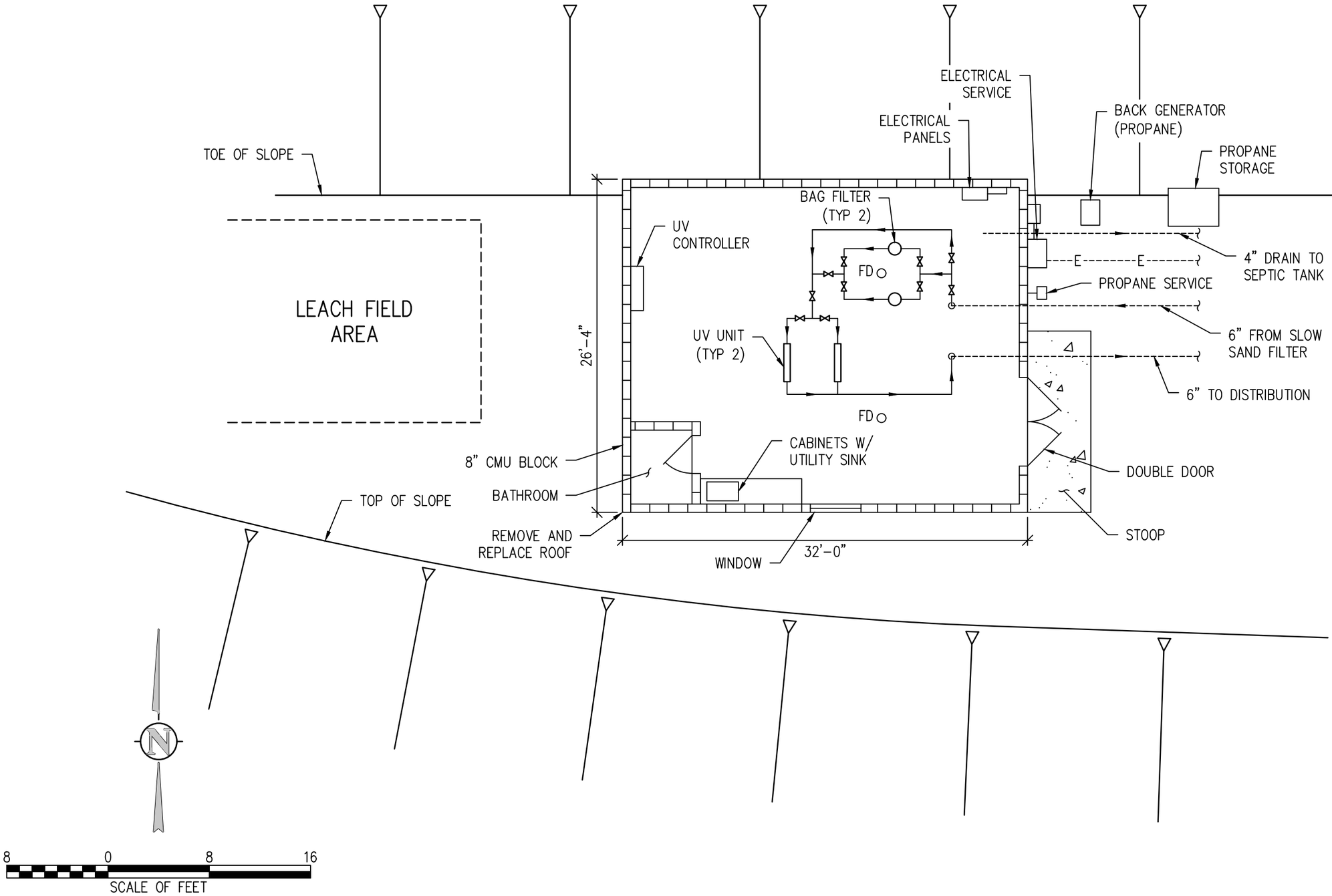

FIGURE 3 - EXIST WTP BUILDING SITE / FLOOR PLAN

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Other filtration options such as mixed media pressure filters could also be explored. But given the current building constraints and the proven technology and high-quality filtrate of microfiltration, membranes were selected for evaluation. The buildout maximum day demand is estimated 75 gpm.

Alternative 1: No Action

Overview

In this alternative the Town would continue to use the water system in its current condition. Improvements to the slow sand filter would not be completed.

Life Cycle Cost

There would be no capital expenditures and operation and maintenance costs would be unchanged.

Advantages

- No capital cost

Disadvantages

- Continued poor access
- Will require continued corrective actions to stay compliant with CDPHE

Alternative 2: Rehabilitate Existing Treatment System

Overview

In this alternative, the slow sand filtration process would remain, and the water treatment building bag filtration and UV system would continue to operate. The remaining items of the current corrective action plan would be implemented, most notably the construction of walls to isolate the filter overhead space from the clear well. Other ancillary improvements are also needed, including valve replacements at the Mad Creek intake and miscellaneous building rehab to extend the facility life.

Life Cycle Cost

The construction cost is estimated at $205,000. Comparative annual O&M is estimated at $3,400 annually with a 20 yr present worth of $70,000.

Advantages

- Lower capital cost
- ORC familiarity with current treatment system

DISADVANTAGES

- Slow sand filter is old, and replacement is most likely required in next 20 yrs.
- Slow sand filter is isolated and emergency visits can be difficult in inclement weather
- The steep graded dirt road access increases maintenance time for visits to the slow sand filters
- Having treatment components in three locations; slow sand filter, Green Shed disinfection and UV building adds maintenance complexity.

ALTERNATIVE 3: ADDITION OF MEMBRANE FILTRATION

OVERVIEW

In this alternative the slow sand filters would be abandoned, and the UV building would be retrofitted with the installation of membrane filtration. There are several microfiltration manufactures that could provide equipment meeting the 75 gpm maximum day production and footprint constraints of the existing treatment building.

The Town currently serves its customers with an all-gravity treatment system (no pumping), only using power for lighting and UV disinfection operation. Maintaining this unique gravity feed system is desired, however the incoming pressure at the building is about 90 psi. The feed pressure for most polymeric membranes is normally reduced to 50 psi or less, requiring pumping to deliver the filtrate to the distribution system. However, ceramic membranes housed in steel modules can accommodate the higher pressure and can be used in the gravity condition of Empire. In addition, the ceramic flux rate is three times higher and the backwash waste is $1/6^{th}$ that of a polymeric system. Backwashes and pneumatic valve operation would be controlled with a duplex ¾ hp compressor. For this comparison the ceramic membranes manufactured by Aqua-Aerobics Systems, Inc. were used with the following characteristics. The membranes are preapproved by CDPHE. A more detailed evaluation and comparison of microfiltration manufactures is currently underway.

Table 1 – Ceramic Membrane System

Parameters	Design Criteria
Flux rate	120 gfd
Two racks - 3 modules each	(redundancy) 3 modules exceeds 70 gpm production
Single skid with control panel	12 ft long x 5 ft wide
Backwash tank	150 gallons (3 ft diameter)
Air compressor receiver	200 gallons (3 ft diameter)
CIP tank	250 gallons (3.5 ft diameter

A proposed process flow diagram and potential floor plan for the membrane option is presented in Figures 4 & 5. The layout includes a serpentine piping system to achieve the appropriate chlorine contact time in the building. The reinstallation of the UV system is shown as optional, because the improved membrane system does not require the UV giardia/cryptosporidium log reduction. For the comparison, we have assumed the UV is not reinstalled to provide more operational space and reduce power consumption.

A small polymer dose (ACH) is recommended as a filter aid. Chemicals for CEBs (Chemically Enhanced Backwash) and CIPs (Clean-In-Place) are required, with the proposed drum locations depicted on Figure 5. The treatment building is currently served with an on-site septic and leach field system and therefore the reduced waste volume of the ceramic system is ideal. However, due to the high flow rates of the backwash and the need to attenuate waste flows the construction of two (3,000 gallon) buried tanks is included. We have assumed the small, equalized waste flow from the new tanks can be connected to the exiting leach field. A potential sewer connection is also being considered.

Life Cycle Cost

Electrical costs to operate the UV has been removed and replaced with the required power for the ¾ hp compressor. A CEB is estimated to occur every 3 days with a total chemical use of 70 gallons per year. A CIP is estimated at a 6-month frequency with a chemical use of 8 gallons per year. The manufacture indicates that the ceramic membranes have a life in excess of 20 yrs. We have assumed the replacement of two modules ($8,000) at the 10 yr mark. The construction cost is estimated at $1,071,000. Comparative annual O&M is estimated at $1,000 annually with a 20 yr present worth of $30,000 (including module replacement).

Advantages

- New system mostly automated
- Fits in existing building footprint (new vaulted roof required)
- Reliable treatment technology
- Consolidated treatment operations into single building
- Easier and safer access for operations and emergencies

Disadvantages

- Highest capital cost
- New technology for ORC
- Must manage disposal of treatment residuals

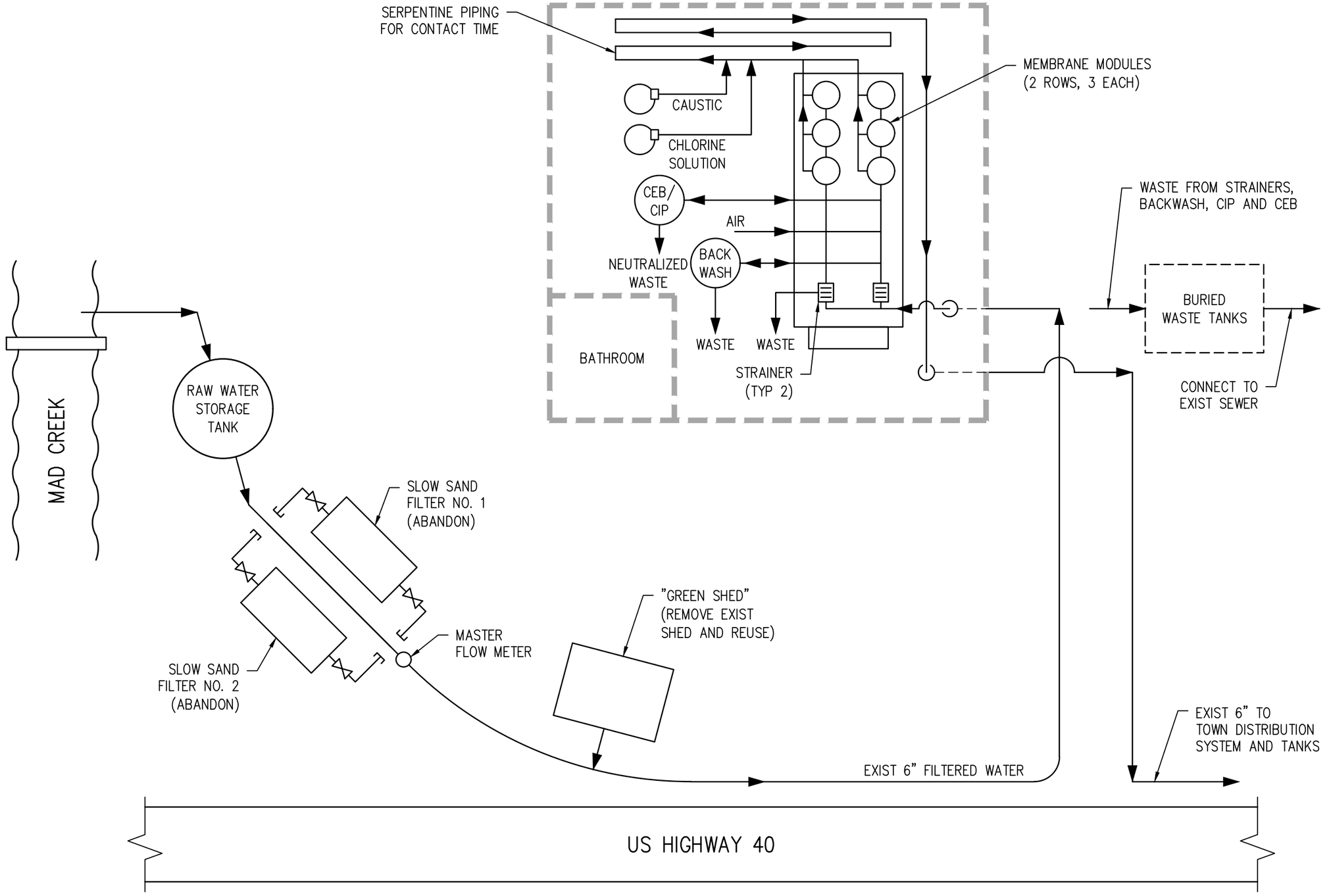

FIGURE 4 - PROPOSED WATER SYS. PROCESS FLOW DIAGRAM
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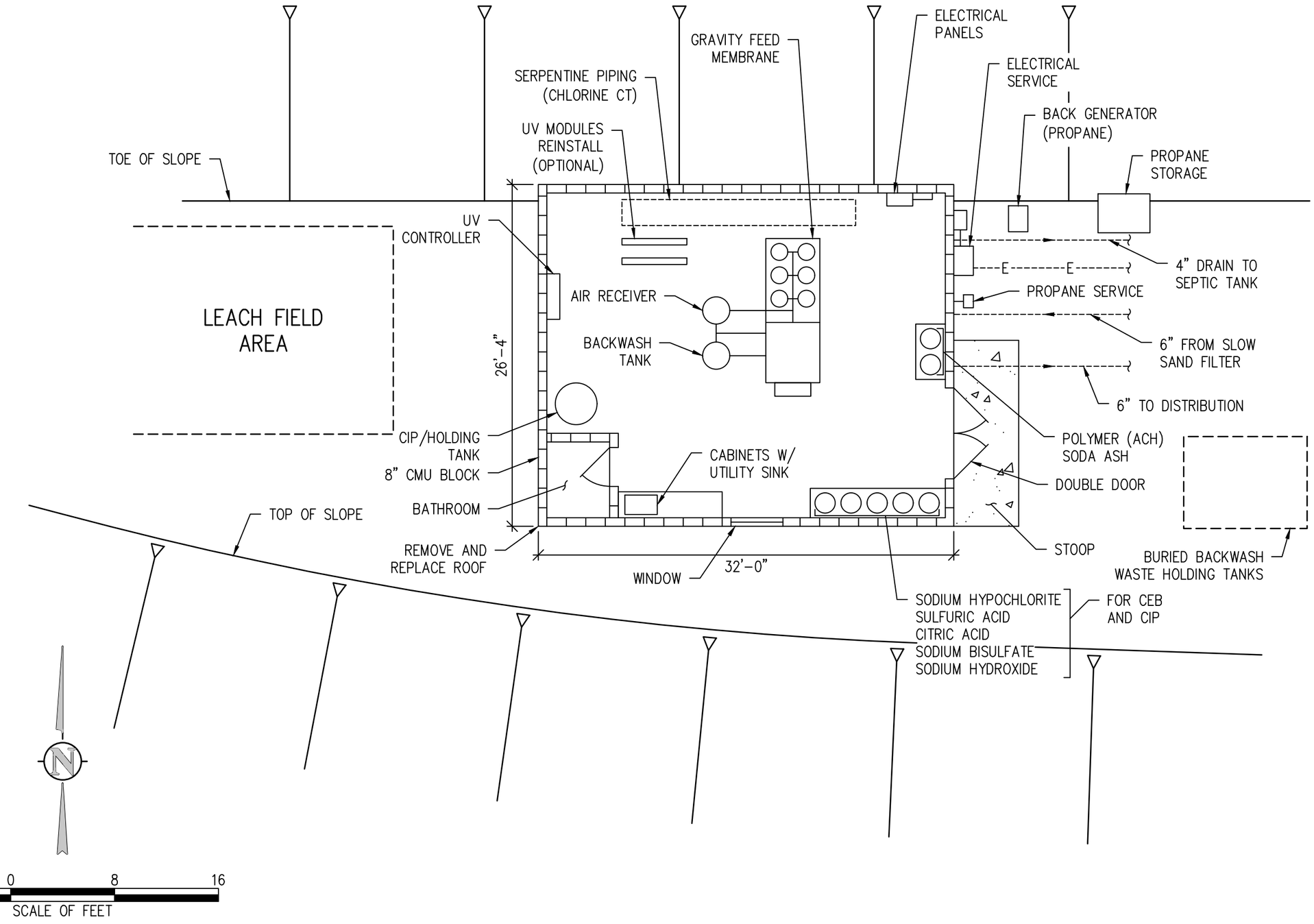

FIGURE 5 - WTP BUILDING IMPROVEMENTS SITE / FLOOR PLAN

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PROJECT COST

The estimated construction cost for the water treatment improvements totals $1,071,000.

PROPOSED DEVIATIONS

No deviations from the CDPHE DCPWS are proposed at this time.

IMPLEMENTATION PLAN AND SCHEDULE

The schematic design presented in this BDR will be used to finalize the bidding documents for the project. The anticipated implementation schedule is provided in Table 1.

Table 2- Anticipated Implementation Schedule

Task	Anticipated Date
CDPHE BDR Submittal	August 6, 2021
CDPHE Approval	October, 2021
Commence Construction	November, 2021
Completion Improvements – Start-up	May, 2022

SECTION 2 – SOURCES OF POTENTIAL CONTAMINATION

FLOODPLAIN INFORMATION

Based on the Federal Emergency Management Agency (FEMA) Flood Insurance Rate Map (FIRM) Panel 0480C, the proposed project site is not located in the 100-year flood plain.

POTENTIAL CONTAMINATION SOURCES

Mad Creek is a pristine water supply. Potential contamination would be from high stream flow related to a storm event and the resulting high turbidity.

RISK MITIGATION

Raw water is continuously monitored at Mad Creek. High turbidity water can be detected and diverted. The Town has the option of using the new well.

SECTION 3 – WATER QUALITY DATA

RAW WATER SOURCE

In accordance with CDPHE, a grab sample of the Mad Creek raw water supply was collected and tested for standard constituents. The water quality summary is presented in Table 1.

Table 1 – Mad Creek Raw Water Intake - Water Quality Results

Constituent	Value	Suggested Maximum
Total Alkalinity (as CaCO3)	17.1 mg/L	250 mg/L
Bicarbonate (as CaCO3)	17.1 mg/L	250 mg/L
Carbonate (as CaCO3)	< 4 mg/L	-
Hydroxide (as CaCO3)	< 4 mg/L	-
Chloride	1.1 mg/L	250 mg/L
Iron	0.42 mg/L	0.3 mg/L
Manganese	0.0014 mg/L	0..05 mg/L
Fluoride	< 0.1 mg/L	4.0 mg/L
Potassium	0.6 mg/L	50 mg/L
Nitrate Nitrogen	0.05 mg/L	10 mg/L
pH	7.13	8.5
Calcium	4.5 mg/L	200 mg/L
Magnesium	0.87 mg/L	125 mg/L
Sodium	2.8 mg/L	100 mg/L
Sodium Adsorption Ratio	0.3	4
Total Hardness (as CaCO3)	14.9 mg/L	500 mg/L
Sulfate	3.6 mg/L	250 mg/L
Total Dissolved Solids	27 mg/L	500 mg/L

IMPACTS TO CORROSIVITY

The Mad Creek water supply has a low alkalinity and is aggressive. The Town recently completed an Optimal Corrosion Control Treatment Recommendation (OCCTR). Based on the evaluation of the water quality the recommended treatment is to continue to add caustic soda to raise the entry point pH to minimize the corrosion of residential plumbing.

SECTION 4 – PROCESS FLOW DIAGRAM AND HYDRAULIC PROFILE

PROCESS FLOW DIAGRAM

The Town's current water treatment facilities are located at two separate buildings, the filter building and the treatment building. The existing process consists of slow sand filtration, bag filtration, UV disinfection, and chlorine disinfection. The proposed membrane treatment system is to be installed in the existing treatment building, consolidating facilities. See Figures 4 & 5.

HYDRAULIC DESCRIPTION

Raw water from Mad Creek is stored in a 100,000-gallon raw water storage tank. Raw water then flows by gravity to one of two slow sand filters. Filtrate then flows by gravity from the slow sand filters to the new "Green Shed" chlorine injection point and then to the treatment building. The treatment building includes a multi-bag filter followed by two UV disinfection units. After UV disinfection, the water is dosed with soda ash for pH control prior to the distribution system which includes two (2) 100,000-gallon potable water storage tanks. The all-gravity feed system is proposed to remain with the improved membrane treatment.

SECTION 5 – CAPACITY EVALUATION AND DESIGN CALCULATIONS

WATER SOURCES

The Town has water rights on Mad Creek which are sufficient to meet Town demands. Mad Creek is the Towns primary water source. The basin has no development, and the surface water is pristine. When available the Town prefers to use the Mad Creek supply. The Town also has rights in Clear Creek, via Henderson Mine. The alluvial Clear Creek water is pumped directly to the distribution system via an in-town well. The Town has sufficient water rights to meet existing maximum day demands in the summer. However, in the winter months, Mad Creek can freeze, requiring the Town to rely on poor quality alluvial groundwater. The Town purchased water storage rights in Golden Reservoir in 2019.

Table 4 – Town of Empire Water Rights Summary

Source Name	Source Classification	Source Description
Mad Creek	Surface	1.82 cfs (3.61 ac-ft/day) of water rights
Guanella Reservoir	Surface	Town has 10 ac-ft of storage capacity that can be used to augment Mad Creek and alluvial well water rights. Can store water from Henderson Mine and other water sources that become available. Additional 6.3 ac-ft supply provided by Golden
Alluvial Wells	Groundwater	Water is from Henderson Mine 35863-F and 41458-F from Case No. 82CW227 May = 15.3 ac-ft June = 10.8 ac-ft July = 11.9 ac-ft August = 13.1 ac-ft September = 16.7 ac-ft
Henderson Mine Water		Leased for 20 gpm (2.65 ac-ft/month)

The Town has very senior water rights and sufficient water rights for the Town's current and future projected water demand.

The storage rights were purchased to augment the existing water rights from Mad Creek. The Town can use the stored water when Mad Creek water is unavailable.

Demand Projections

The DOLA population estimates from 2010 through 2018 were used with the Clear Creek County estimated growth rate to project the population during the 20-year planning period. The number of taps was estimated using 1.73 persons per tap from DOLA. The number of taps in 2019 was then divided by the maximum daily flow per day in 2019 to get 2.4 (units). The number of tap projections were then divided by 2.4 to estimate the water demand. Based on the estimated population, persons per household, growth rate, and number of taps from DOLA the town is expected to grow from 305 people to 361 people in 20 years. This is equivalent to 176 taps to 209 taps.

According to the Town the system serves 194 taps and a population of approximately 410. Based on these initial values in 2019, projections were made using 2.11 persons per tap and the DOLA Clear Creek County estimated growth rate, a population of 486 and 230 taps is projected in 2040.

Based on 63 gallons per day (gpd) from 176 taps, this results in a peak day flow of approximately 75 gpd in 20 years.

Treatment

The Town of Empire treatment process is proposed to be improved with membrane filtration. The new "Green Shed" and point of chlorine dosing will be moved back to the treatment building.

Table 5 shows the log inactivation credits the Town's current treatment process receives for giardia, viruses, and cryptosporidium. Chlorine Contact Time (CT) will be achieved prior to distribution.

Table 5 – Log Inactivation Credits

Treatment Process	Giardia Credits	Virus Credits	Cryptosporidium Credits
Slow Sand Filtration	2 log	2 log	3 log
Bag Filtration	2 log	0 log	2 log
UV Disinfection	1 log	0 log	1 log
Required Inactivation	0 log	2 log	0 log
Chlorine Disinfection Required	0 min*mg/L	12 min*mg/L	0 min*mg/L

Based on Table 5, the Town is required to achieve two additional log removals of virus inactivation. At a pH of 8 and a temperature of 0.5 degrees Celsius, the required CT for two log virus removal is 12 minutes - milligrams per liter (min*mg/L).

The process goals for disinfection improvements are based on the regulatory compliance requirements set for the State of Colorado Design Criteria for Potable Water Systems as presented in Table 6.

Table 6 – Disinfection & Chemical Application Design Criteria

Criteria	CDPHE	Empire WTF
DISINFECTION		
Maximum free chlorine residual	5 mg/L	2.0 mg/L
Automatic proportioning chlorinators provided	Yes	Yes
3-Log removal of Giardia lamblia, 4-Log removal of viruses	Yes	Yes
Continuous chlorine residual monitor	Yes	Yes
Chlorine Room Ventilation[1]	1 air change per 2 minutes	Tuff shed ventilated
Heater provide to maintain min 60 F	Yes	Tuff shed heated
Sufficient capacity to replace largest unit/ spare parts available	Yes	Yes
CHEMICAL APPLICATION		
Backflow prevention devices provided	Yes	Yes
Redundant feeder provided	Yes	Will use old feeder as spare
Means must be provided to measure liquid level in liquid storage tank	Yes	Visual
Tanks must be vented	Yes	55-gal drum
Automatic or manual control options	Yes	Both
Feed rate proportional to flow	Yes	Yes
Sufficient storage for 30 day supply	Yes	Yes
Secondary containment provided	Not required for 55-gal drums	No

[1] Design for chlorine ventilation is based on the Ten States Standards guideline of 1 air change per minute

SECTION 6 – MONITORING AND SAMPLING EVALUATION

PROPOSED FLOW METERING

The Town will continue to use the flow metering device at the treatment building. The meter will be integrated into the new treatment scheme.

WATER QUALITY SAMPLING

SAMPLING LOCATIONS

The Town will sample for residual chlorine at the first customer. The Town will continue to sample at all other required locations.

WATER QUALITY PARAMETERS

Water quality parameters set forth by CDPHE for sources classified as groundwater will continue to be monitored.

SECTION 7 – GEOTECHNICAL REPORT

Based on Appendix A Table A.1 ES DW Design Review Matrix, Section 7 – Geotechnical Report, is not applicable.

SECTION 8 – RESIDUALS HANDLING PLAN

The membrane filters will require backwashing and chemical cleaning. The residual solids will be metered and disposed in the local sewer system or on-site leach field.

SECTION 9 – IMPACT TO CORROSIVITY

The Mad Creek water supply has a low alkalinity and is aggressive. The Town recently completed an Optimal Corrosion Control Treatment Recommendation (OCCTR). Based on the evaluation of the water quality the recommended treatment is to continue to add caustic soda to raise the entry point pH to minimize the corrosion of residential plumbing.

SECTION 10 - PRELIMINARY PLAN OF OPERATION

STAFFING AND OPERATOR CERTIFICATION

The Town's Operator in Responsible Charge (ORC) is Robert Wayne Ramey (Lic #5225). The ORC has a Class A Water Treatment Operator certification that will expire in September 22, 2022. The proposed water treatment improvements will not change the operating license needed by the ORC.

OPERATING CONSIDERATIONS

OPERATING CONFIGURATION AND PROCESS CONTROL PROCEDURES

The ORC operating procedures are unchanged.

PHASED OPERATION DURING CONSTRUCTION

During construction, the contractor will be required to coordinate with the Town in using the well supply or set up temporary facilities. The slow sand filter process can remain active, but the UV and bag filtration will be removed during installation.

EMERGENCY RESPONSE AND PROCEDURES

The current emergency response plans will be unchanged.

OPERATIONAL SAFETY

Current safety procedures will be unchanged

SECURITY PROVISIONS

The existing building security will be unchanged.