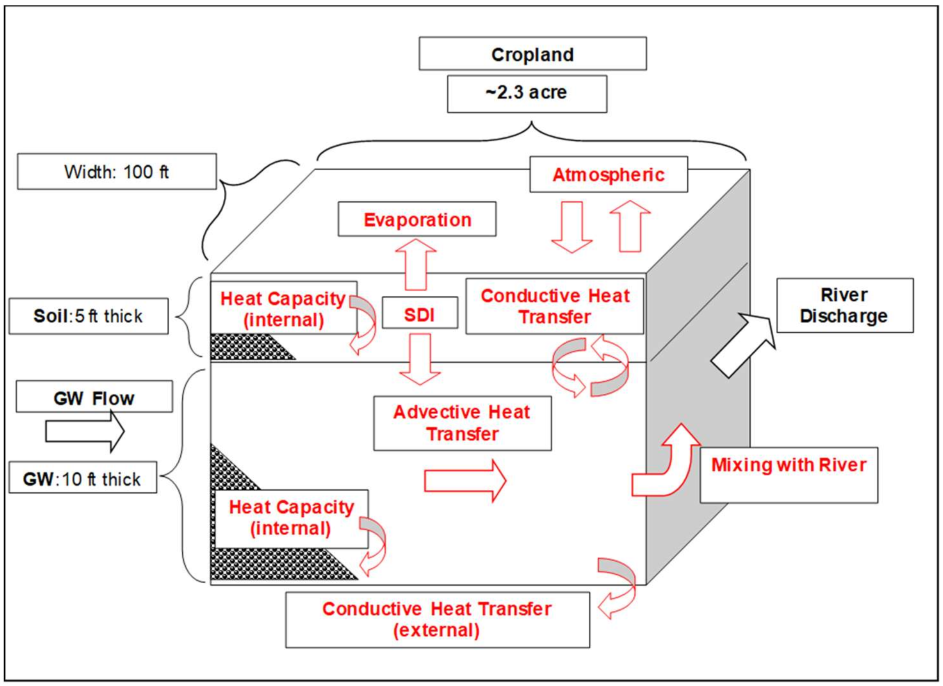
City of Middleton

Natural Treatment System

Reuse Pilot Study

2022 Annual Report



Prepared for: City of Middleton

Prepared by: Jack Harrison, PhD, P.E.

Mike Martin, P.E., Civil Dynamics

Date: April 28, 2023 v2

Diagram: conceptual thermal process model for Pilot Study showing heat loading, transfer, and loss.

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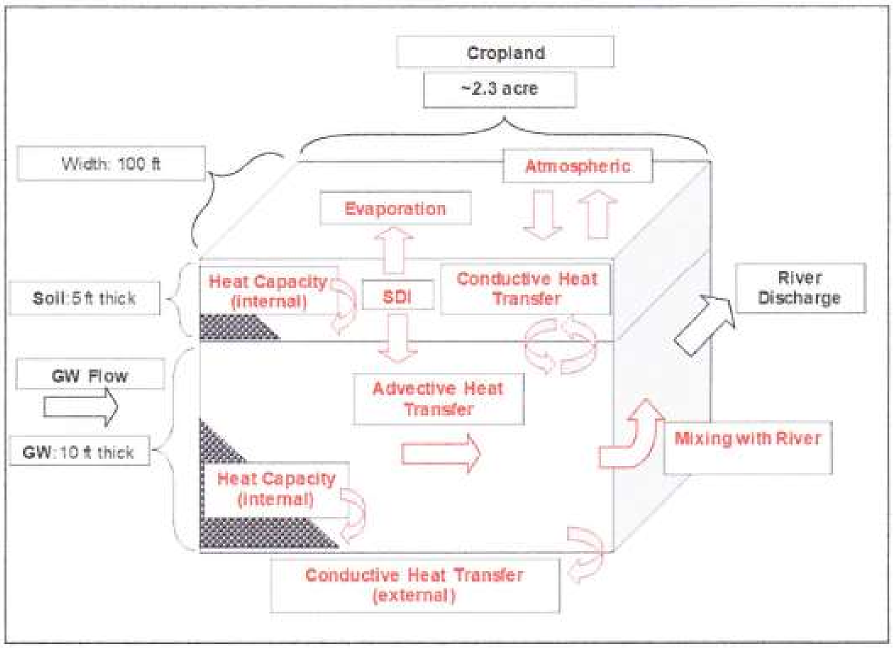

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Acknowledgements

This 3rd annual report was prepared under the direction of Jason Van Gilder (Public Works Director) and Nate Bryan (Wastewater Treatment Plant Manager). Supporting information and input was provided by Middleton city staff including Rodger Hawker, and Jay Irby with OMCS. Kirby Cook with Civil Dynamics provided supporting analyses. Without all their ongoing support and efforts, this study would not be possible.

Purpose

This pilot study is intended to demonstrate use and assess feasibility of a subsurface drip irrigation (SDI) system for agronomic and high-rate reuse on an alfalfa crop. The intent of this second Pilot Study Annual Report is to provide DEQ information on 2022 operations, 2023 planned 2023 operations, and a general assessment of 2020 through 2022 monitoring results.

If this study project is successful, this natural treatment system (NTS) would be part of the final wastewater treatment system. The City is hopeful that with continued operation, monitoring and reporting, DEQ will fully accept the use of a subsurface drip reuse application system and the proposed non-growing season (NGS) operations.

Introduction

The City of Middleton is anticipating an IPDES permit with new phosphorus limits consistent with the Lower Boise River TMDL (IDEQ 2015). It is also expected that the next permit will include requirements to address temperature (IDEQ 2019). To help determine a long-term and economical approach for meeting these future discharge limits, the City is conducting this pilot study (Harrison and Martin 2020) on crop land located to the east of their wastewater treatment facility and north of the Mill Slough (Figure 1).

The pilot study is intended to:

1. Demonstrate the use of subsurface drip irrigation (SDI) of reclaimed water on an alfalfa crop
2. Assess the environmental effectiveness of wintertime high rate reuse for storage of phosphorus
3. Collect data to assess possible future temperature management via reuse with the SDI system

The Idaho Department of Environmental Quality (DEQ) approved the Pilot Study Work Plan (Harrison and Martin 2020) on September 9, 2020. The approval was subject to conditions including environmental monitoring and annual reporting (Attachment – Regulatory Approvals). Additionally, the Idaho Department of Water Resources (IDWR) issued an Injection Well permit on July 12, 2021, which allows the use of the SDI system for reuse (Attachment – Regulatory Approvals).

As discussed in the 1st annual report, (Harrison and Martin 2021), the City installed most of the SDI system, established the alfalfa crop, and collected background environmental data. With the above regulatory approvals and final testing of the SDI, the City began applying reclaimed water to the cropland in July of 2021. This 2nd Pilot Study Annual Report provides DEQ with an update on the pilot study implementation, an environmental assessment based on the 2020 and 2021 monitoring results and analyses, and target loading rates for 2022 operations.

Study Area and Operational Zones

The study area (Figure 1) is located on City owned property north of the Mill Slough between the City's wastewater treatment facilities and other farm properties that the city owns. The fenced portion of the study area, approximately 14 acres in size, has been divided into 5 operational zones (OZ) and is authorized for reuse of the City's recycled water. Additionally, a sixth operational zone, which is 3 acres in size, is outside the fenced area and no reclaimed water will be applied on this zone.

Two of the operational zones (OZ 4 and OZ 5) are currently used to assess differing types of reuse (Table 1). Reclaimed water is applied at or below agronomic rates (e.g., 4 ft/yr) during the irrigation season on OZ 4. On OZ 5, reclaimed water is applied during the winter time at a hydraulic loading rate exceeding the agronomic rate. The annual phosphorus loading rate target for both of these zones is 20 lb/ac/yr.

Table 1 Types of Operational Zone Management during 2022

Operational Management	**Types**	**Control (Supplemental)**	**Agronomic Reuse**	**Winter Reuse**
Operational Zone	Zone #	6	4	5
Irrigation/Reuse Period	Season	Summer	Summer	Winter
Loading Targets	Hydraulic	Agronomic	Agronomic	High Rate
	TP (lb/ac)	2	20	20

Operational zone 6 is operated as a control with no reuse water applied. Supplemental irrigation water is applied at agronomic rates, which results in a phosphorus loading rate of about 2 lb/ac/yr. The other operational zones (OZ 1, 2 AND 3) have been managed similar to the control site (OZ 6) at this time. In 2023, new operations are proposed for OZ 1 and OZ 2, and discussed below and in Section – Planned 2023 Operations.

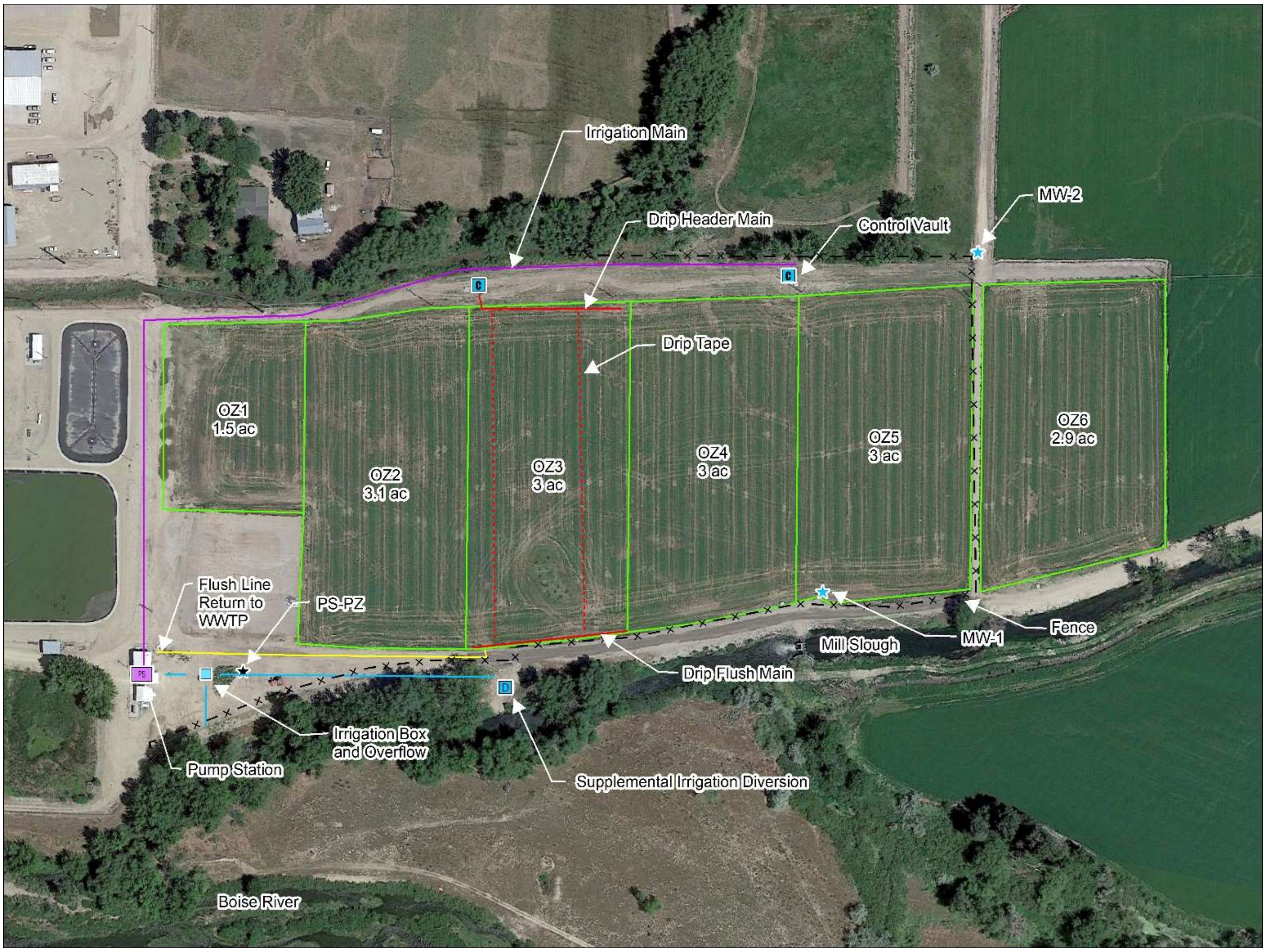

Figure 1 – Reuse pilot study area: reuse is approved within the fenced area on Operational Zone (OZ) 1 through 5; OZ 6, which is outside the fenced area, is used as a study control site

Pilot Study Status and Proposed 2023 Changes

Pilot Study Goals and Objectives

The primary goal of the study is to demonstrate the feasibility of subsurface drip irrigation (SDI) for a forage crop, to quantify the uptake of phosphorus applied to soils, and assess potential approaches to manage the thermal load. The objectives identified to meet these goals include:

- Obtain operational experience with system operations and management
- Demonstrate water application tracking methods that can be used to identify irrigation system problems with limited uncontrolled discharge of water (Phase 1)
- Collect environmental data to support DEQ acceptance of proposed NTS approaches
    - nutrient reduction with summertime agronomic applications (Phase 2)
    - nutrient reduction with fall and spring high rate applications (Phase 3)
    - temperature reduction (future phase)
- Provide information to support future planning decisions and permitting, and refinement of costs for full implementation of reuse and discharge.

Implementation Status

Major milestones that occurred in 2020 through 2022 with implementation of the Pilot Study are listed below:

- 2020
    - Collection of background environmental data began in June of 2020
    - SDI drip tape was installed and the alfalfa crop was planted in the fall of 2020
- 2021
    - 2020 Annual Report was submitted at the end of April 2021
    - SDI system was operational in June of 2021 and tested using supplemental water
    - First alfalfa crop harvest occurred in July of 2021
    - Final regulatory approvals were received in July of 2021
    - Application of reclaimed water began in July of 2021
    - Fall of 2022 improved SDI winterization by adding insulation and heaters to control vault
    - Winter time application of reuse in November of 2021
- 2022
    - Annual Report for 2021 was submitted at the end of April 2022
    - Added regular inspections of OZs to improve leak identification for prompt repair
    - Improved SCADA system operational control and monitoring of the SDI and pumping such as adding dual zone operations

Additional Project Specific Conditions

The following are conditions that must be met to continue operations past September 9, 2025:

- Obtain DEQ approval for any modifications to the Work Plan and QAPP
- Submit an annual report to DEQ by April 30 of each year
- Obtain either an approval of a revised Work Plan or a Reuse Permit
- To continue reuse via the SDI system IDWR has indicated a “Rules change” will be needed

2023 Proposed Operational Changes

The following are Work Plan operational changes proposed to improve or test anticipated future operation. The changes will only be implemented if approved by DEQ. More information about these changes is provided in Attachment – Proposed Operational Changes. Previously approved changes, which resulted in modifications to the Work Plan (or QAPP), are listed in Attachment – Regulatory Approvals.

- Increase the annual phosphorus loading targets for the reuse fields (OZ 4 and 5) from 20 lb/ac/yr to 25 lb/ac/yr; (or allow a target range of up to 25 lb/ac as long as previous year's crop removal exceeded this amount)

This change was initially proposed in the 2021 Annual Report. This loading increase seems justified considering crop removal was above 25 lb/ac and soils P levels are declining in reuse OZs (see Section – Loading and Removal, and Soil Phosphorus for more discussion).

- Test higher hydraulic loading rate (e.g., 15 ft/yr) on OZ 2

Wastewater treatment improvements that are now proposed will reduce future effluent TP to a much lower average concentration (e.g., from around 5 mg/L to lower than 1 mg/L). A higher hydraulic loading rate would then be needed to apply the annual TP target load. If approved reclaimed water will be used to meet TP target, and Mill Slough or domestic water would be used as supplemental irrigation water.

- Test crop rotation on OZ 1

Over the long term, regular re-establishment of alfalfa crop is needed to avoid excessive reduction in annual TP removal rates. This will also involve removal and re-installation of the dripline. Planning and testing a crop rotation will help determine annual average TP target loading and removal rates, versus annual operational target rate (e.g., 20 lb/ac/yr)

- Test drip irrigation during freezing weather for January/February reuse on OZ 3

Drip irrigation during freezing conditions may be needed to meet future permit conditions. Initially testing would occur on a limited based and as opportunity allows. This testing could occur in December, January or February, and source water used for testing could be domestic or wastewater effluent.

2022 Implemented QAPP /Monitoring Plan Changes

The following are changes (or adjustments) to the Work Plan that occurred during 2022

- Adjusted OZ acreages to address construction activity on OZ1 and increase accuracy on other zones
- Added water level monitoring locations to improve groundwater flow mapping:
    - Increased frequency of water level monitoring to monthly to improve GW mapping
    - Added water level monitoring locations (e.g., pump station and Boise river piezometer) to improve groundwater potentiometer surface mapping.
    - Increased frequency of temperature data download to monthly to reduce potential for lost data
    - Increased frequency of reuse total phosphorus sampling to weekly to improve phosphorus loading and tracking

SDI Operations

One of the stated goals of the pilot study is to demonstrate the effectiveness of the SDI system for growing alfalfa. The crop production data, as discussed below, show a relatively high level of annual alfalfa production of over 6 tons/ac for the six operational zones. The range of production reported in NRSC (2016) was 6 to 9 tons/ac. The crop production continues to meet expectations and thereby provides data to support the proposed long term use of the SDI system.

Another stated goal is to assess the environmental effectiveness of non-growing season (i.e., wintertime) high rate reuse for storage of phosphorus. At this point, the system has been successfully operated over two non-growing seasons. Still, while the SDI system has been shown to meet crop water demands, there have been operational issues and constraints first identified in 2021. As discussed below, most of these have been addressed.

- Pressure monitoring: system pressure was monitored to help identify leaks; in general it appears that regular field checks, which have been implemented, provide a better indication of smaller leaks caused by gophers; while pressure monitoring is most helpful for identifying relatively large leaks

- Leaks: caused by field operations, soils sampling, gophers, and construction; efforts are continuing to identify and manage these occasional problems through regular field checks (also see discussion on OZ1 below)

- Line flushing: needed when changing from reuse to supplemental water; this increases overall system management efforts; this has been addressed though changes in SCADA system programming

- Mill Slough intake: regular observation and intake screen cleaning was needed to avoid pump cavitation; to reduce intake screen clogging, the overflow return to the Mill Slough was closed for the supplemental irrigation gravity system (delivering water to the pump station): this eliminated the excess return flow thereby: 1) reducing the cleaning requirements at the intake screen, 2) reducing number of backwash cycles at the sand filters, and 3) eliminating pump cavitation problems

- Application duration: the original SCADA programing only allows for application on one zone at a time, which can limit loading rates below targets when relatively high application rates are desired; this limitation was reduced by modifying the SCADA programming to allow application on 2 zones at the same time, and by adding a start timer, which increased overall duration of application events;

As listed above, construction caused some of the SDI system leaks. In fact, wastewater treatment construction near OZ 1 required repair of 9 drip lines in that zone. When testing the system to find these leaks, much lower system pressure was observed. As stated above, this is an indication that pressure monitoring is most helpful for identifying relatively large leaks. After SDI repairs were made, the construction impacted area was leveled and reseeded. The alfalfa was not successfully established and additional actions are needed to resume full operation of OZ 1 (see section Proposed Operational Changes and Attachment – Proposed Operational Changes).

Environmental Characterization and Analyses

The Pilot Study monitoring was designed using available information on the characteristics of reclaimed water and the environmental conditions. As discussed in the Work Plan, the following are the key baseline conditions that were identified:

- The City's reclaimed water is currently discharged into the Boise River at the mouth of the Mill Slough under an NPDES permit. The reclaimed water to be applied in the study area will meet all the current permit conditions.
- The reclaimed water will be applied to crop land that was previously surface irrigated. The reuse through the SDI system can provide environmental benefits to both the surface and shallow groundwater, including reductions in sediment, nutrient and thermal loads.
- All available groundwater information indicates that the shallow groundwater in the Pilot Study area is not used as a potable water source and discharges into surface water. This would imply that any water that leaches into the shallow groundwater would then discharge into the Boise River.

Reuse Pilot Study Monitoring

The Pilot Study monitoring was designed to provide data and information on the recycled water, soils, crops, surface water and groundwater, along with data to determine phosphorus and thermal loading with and without reuse.

As discussed above, the pilot study monitoring approach was initially presented in the Work Plan and associated QAPP. These were then modified slightly in the first (2020) Annual Report. As part of the approval of the modifications, DEQ requested that a monitoring summary be prepared (Attachment – Reuse Pilot Study Monitoring Plan Summary).

Water quality constituents and sampling frequency vary by type of source, purpose, risk and need (Table 2). The constituents planned for monitoring were selected to allow annual phosphorus and thermal loading analyses, the primary focus of the study, and to establish and track environmental conditions around the study site. The monitoring summary And QAPP provide more details regarding frequency and monitoring locations. Water quality sampling and monitoring locations are shown in Figure 2.

Table 2 Constituents and Sampling Frequency

Type	#	Elev.	Temp	Flows	TP	DOP	NO3	NH3	TN/ TKN	TSS	TDS	Other
Water												
Reclaimed	1	--	**C**	**C**	**W**	**M**	**M**	**M**	**M**	**M**	**M**	
Irrigation	1	--	**C**	**C**	**M**	**M**	**M**	**M**	**M**	**M**	**M**	
Surface	4	**M**	**C**	**C**	**Q**	**Q**	**Q**	**Q**	--	**Q**	**--**	EC, pH
Groundwater	4	**M**	**C**	--	**Q**	--	**Q**	**Q**	--	--	**Q**	EC, pH
Replicate	1			--	**Q**	--	**Q**	**Q**	--	**Q**	**Q**	EC, pH

Notes: W= weekly, M = monthly (when applying), C = continuous, Q = quarterly

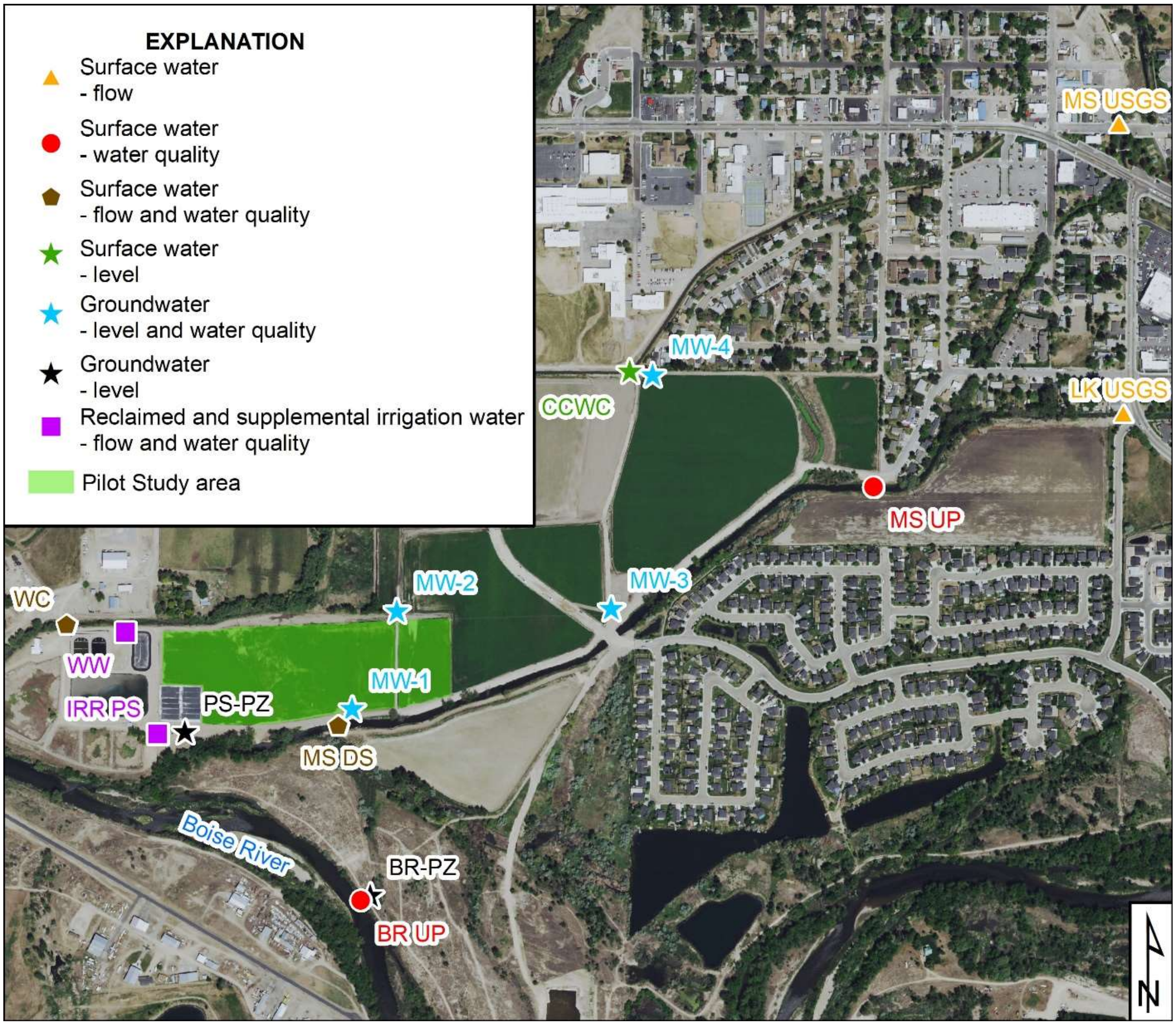

Figure 2 Monitoring locations for Pilot Study (includes new groundwater elevation monitoring locations)

Additionally, soil samples are collected bi-annually (in spring and fall), and crop tissue samples and crop weights will be collected after each harvest. Refer to the QAPP for a detailed list including soils and crop tissue parameters and procedures.

Key results of the monitoring and the analyses needed to support future permitting of the proposed reuse include phosphorus and thermal loading, crop phosphorus removal, changes in soil phosphorus, and changes in groundwater phosphorus and temperature in response to recycled water applied to the operational zones. Monitoring results from this study and analyses based on these data are summarized below. Quality assurance and quality control measures for the 2021 data are summarized in Attachment – QAQC Review.

Phosphorus Loading and Removal
A primary goal of the Pilot Study is to show that phosphorus in the reclaimed water applied at a relatively high rate, during non-growing season months (wintertime) is adsorbed by the soils and stored for use for crop production during the following summer. Demonstration of the SDI systems is also a

goal. The 2021 and 2022 data presented below has been collected and assessed to help determine if these goals are being met.

The phosphorus loading (via reuse and supplemental water) and crop phosphorus removal for the three types of operational management (Table 1) are shown in Table 3. A difference between the phosphorus loading and crop phosphorus removal should cause a change in soil phosphorus storage during 2021 as discussed in the next section. More detailed information on the loading and removal is provided in Attachment – Operational Data and Analyses.

Table 3 Crop Phosphorus Loading, Removal and Change in Storage

Phosphorus Load Balance (lb/ac)	**Control**	**Agronomic Reuse**	**Winter Reuse**
2022 Phosphorus Balance	OZ 6	OZ 4	OZ 5
Loading	1	20	19
Crop Removal	30	31	29
2022 Calculated Change	-29	-11	-10
2021 Phosphorus Balance			
Loading	1	10	2
Crop Removal	27	27	25
2021 Calculated Change	-26	-17	-23
2021-2022 Phosphorus Balance	OZ 6	OZ 4	OZ 5
P Added via Reuse and Irrigation	2	30	21
P Removed by Crop	57	58	54
2020-2021 Calculated Change	-55	-28	-33

The 2022 and 2021 loading and removal data show:

- The 2022 Reclaimed water application, along with supplemental irrigation, resulted in a phosphorus loading on the reuse sites (OZ 4 and OZ 5) that was close to the 20 lb/ac target.
- The 2021 Reclaimed water application, which began in July of 2021, and supplemental irrigation resulted in a phosphorus loading on the reuse sites that was well below the 20 lb/ac target. This was caused by a number of factors including:
    - Delayed SDI system testing and startup due to delayed construction
    - Delay in obtaining full regulatory approval
    - Limited initial availability of SCADA data during startup and subsequent delays in review of the data
    - Harvest shutdown periods that were not included during loading rate planning and were longer than anticipated
    - Late completion of the winterization of system components
- The 2021 and 2022 crop phosphorus data collected during harvests show that phosphorus removal was well above the target loading rate in each year (i.e., 20 lb/ac).

- The calculated change in soil P storage is considerably higher in OZ 6, which reflects the reuse loading on OZ 4 and 5.

The data show crop phosphorus removal exceeded loading on all operations zones. While this was planned for the control operation zone (OZ 6), it was hoped that loading on the reuse zones would be about the same as the crop removal, which was not the case. The resulting negative calculated change in soil storage (Table 3) is compared to the measured change in soil phosphorus in the section below.

Soils Phosphorus

Soils phosphorus (P) levels for 2020 through the fall of 2022 are reported below for OZ 4, 5 and 6. The soils P levels are based on the Olsen-P analyses of composited samples collected at 3 depths (0"- 12", 12"- 24", and 24"- 36"). Soils P results for OZ1, 2 and 3, are provided in Attachment – Environmental Monitoring Results and Analyses. The soils laboratory reports that include these and other results (e.g., EC, NO3, NH4, pH, and exchangeable Na percentage) are available upon request.

Note that crop production began in the spring of 2021, and therefore the soils P reported for the springs of 2020 and 2021 were prior to reuse and considered background. Agronomic (i.e., growing season) reuse (April through September) began in July of 2021 on OZ 4. High rate (i.e., non-growing season) reuse (Oct through March) began in October 2021 on OZ 5. There was no reuse (or fertilization) on the Control (OZ-6).

Soils P data for OZ 4, 5 and 6 (Figure 3 and Table 4) indicate a decrease in soil phosphorus as compared to the baseline (pre-reuse) data. This is consistent with crop uptake and removal rates, which for reuse sites have exceeded P application rates, and for all other operational zones where there has been no P application.

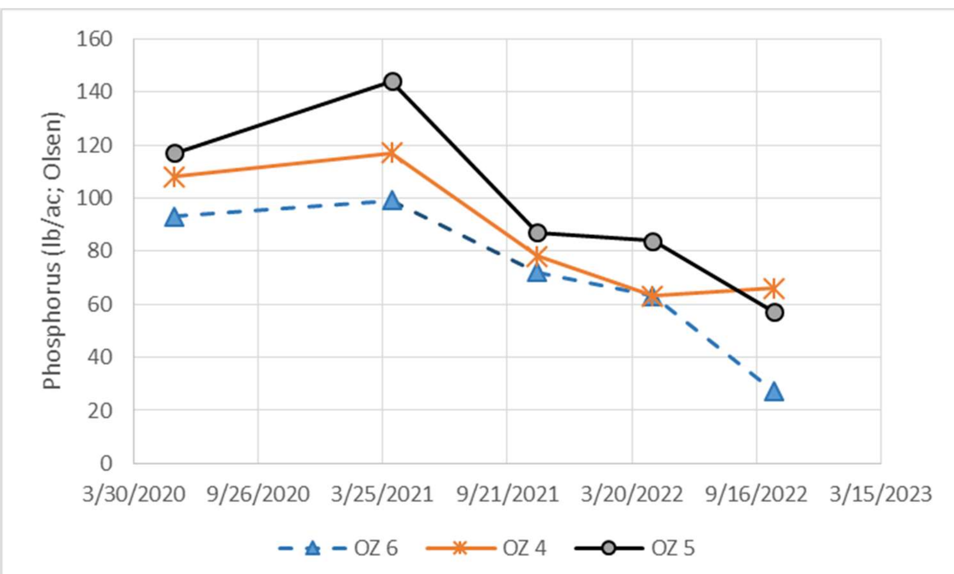

Figure 3 OZ 4, 5 and 6 Soil Monitoring Results for 2020 through spring 2022

Table 4 OZ 4, 5 and 6 Soil Monitoring Results for 2020 through fall 2022

Soil Phosphorus (lb/ac; Olsen)	Control	Agronomic Reuse	Winter Reuse
Date / Zone	OZ 6	OZ 4	OZ 5
5/28/2020	93	108	117
4/7/2021	99	117	144
Baseline (avg)	96	113	131
11/3/2021	72	78	87
Change from Baseline	-24	-35	-44
4/19/2022	63	63	84
Change from Baseline	-33	-50	-47
10/12/2022	27	66	57
Change from Baseline	-69	-47	-74

As stated above, the soils P data indicates a substaintial decrease in soil phosphorus from baseline for each operational zone (Table 4). Soil P loss can be caused by:

- Crop uptake for above ground foliage and subsequent harvest
- Root and soil biota growth occurring below sampling depth (i.e., 3 feet)
- Leaching of P into deeper soils and the shallow groundwater

Leaching of P, which is more likely to occur at OZ 5 with higher rate, non-growing season reuse applications, is a primary focus of this Pilot Study and will be discussed in the next section

The soil P levels measured in October 2022 also indicated the current soil P storage is sufficient for the continued crop production on reuse zones (OZ4 and 5). However, the measured soil P levels are slightly below annual removal rates on the control zone (OZ 6), indicating reduced crop production may occur on that zone.

Change in Soil P

The phosphorus load balance shows that more phosphorus was removed with the crop than added via reuse and supplemental irrigation loading (Table 3). The soils sampling results confirm this higher rate of removal from the soils (Table 4). Comparing these results for “Change in P” (Table 5) indicates a greater loss in “measured change” from baseline (based on soils data) compared to “calculated change” in P (based on loading and crop removal data).

Table 5 Phosphorus Deficits based on Load minus Removal, and Measured Change in Soil P

Change in P (lb/ac)	Control	Agronomic Reuse	Winter Reuse
2021-2022	OZ 6	OZ 4	OZ 5
Calculated Change in P (Loading-Removal)	-55	-28	-33
Measured Change in P (Soil)	-69	-47	-74
Difference (Calculated – Measured)	14	18	40

The difference between the calculated and measured changes in P can be caused by:

- Measurement error
- Difference in leaching rates
- Uptake of P from soils below measurement depth (measurement depth is 3 feet while alfalfa rooting depth can be much greater)

The difference between the calculated – measured "change in P" is noticeably higher for the high rate reuse zone (OZ 5), which suggests a higher leaching rate under the high rate operations or P uptake and removal from below the soils monitoring profile. Note that alfalfa can be deep rooted (greater than 5 feet) and soil monitoring extends to a depth of 3 feet. Either way, the crop removal has not decreased, which shows continued removal of P from the environment regardless of where the P is removed from.

Water Level Monitoring

Potentiometric surface contours (i.e., groundwater contour maps) were prepared using water level data collected in 2022 (Attachment – Environmental Monitoring Results and Analyses). The isopleths provide an indication of the local flow direction for the shallow (water table) groundwater. During the 2022 the flow appears to be generally south with a slight eastern component.

Water Quality Monitoring

The primary focus of this pilot study is the treatment of phosphorus consistent with the Lower Boise River TMDL allocations. To help assess treatment effectiveness, quarterly TP monitoring results from this study were plotted (Figure 4 and 5). The surface water and groundwater quality data collected in 2020 through spring of 2023 are provided in Attachment – Environmental Monitoring Results and Analyses, and sampling locations are presented in Attachment – Reuse Pilot Study Monitoring Plan Summary.

The quarterly Mill Slough TP concentrations (Figure 4) generally range from about 0.12 to 0.24 mg/L. These concentrations are consistent with the concentrations reported by USGS (Etheridge 2013) and then used by DEQ to develop the Lower Boise Phosphorus TMDL (IDEQ 2015).

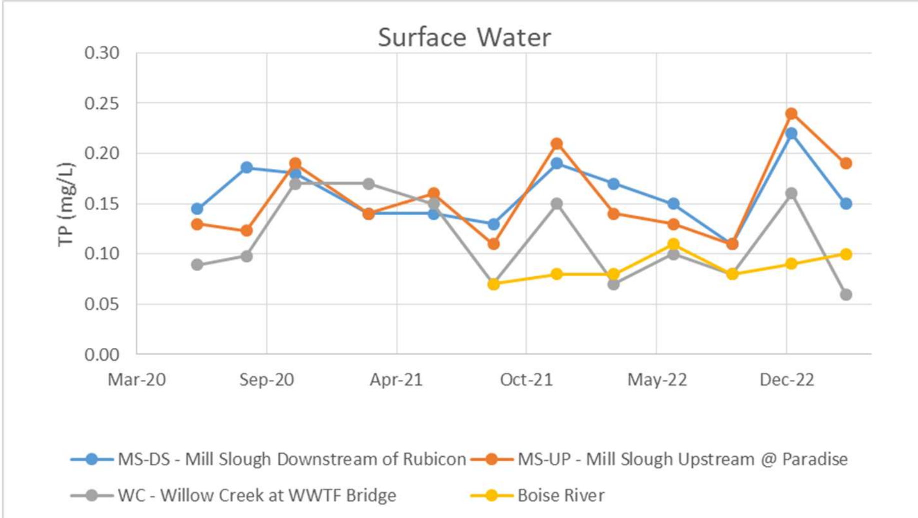

Figure 4 Quarterly Surface Water Phosphorus Monitoring Results for 2020 through spring of 2023

Note that TP concentrations for Mill Slough appear to be highest in fall (i.e., 0.16 to 0.21 mg/L). Because surface water flows in fall and early winter are primarily drainage from shallow upstream groundwater, the TP concentrations are somewhat representative of upstream groundwater TP concentrations. Also note that the Mill Slough TP is considerably higher than the Boise River, which is near the TMDL target of 0.07 mg/L

Quarterly groundwater TP concentrations (Figure 5) generally range from about 0.18 to 0.40 mg/L in the Pilot Study site (Figure 8). Note that the groundwater TP levels are generally higher than surface water (Figure 4). Also, TP levels reported for MW-3 and 4 are consistently higher than levels in MW-1 and 2, which are located downstream and upstream of the reuse operational zones, respectively.

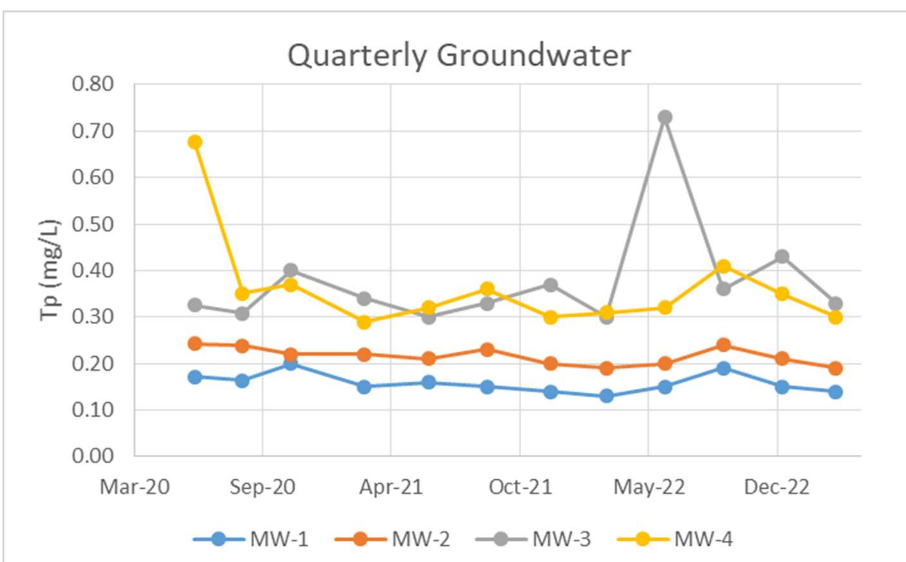

Figure 5 Quarterly Groundwater Phosphorus Monitoring Results for 2020 through spring of 2023

Note that TP in MW-3 is considerably elevated on 6-13-23 (i.e., a concentration over 0.70 mg/L) compared to other data. This level is similar to the TP reported for MW-4 in 2020. And, as occurred in 2020, there was standing surface water observed in the area around this well. Similar to MW-4, drainage will be rerouted (by buried pipe) to address this problem. Ignoring these surface water impacted TP results, the groundwater TP (Figure 5) has lower variability compared to surface water (Figure 4).

Based on groundwater mapping (Attachment – Environmental Monitoring Results and Analyses), MW-2 is located on upgradient perimeter of pilot study area, while MW-1 is located along the downgradient perimeter (Figure 1). Interestingly, MW-2 has consistently higher TP levels.

To the east, in the City's other alfalfa cropped land (Figure 2), MW-4 and MW-3 is located upgradient and downgradient, respectively. The TP concentrations reported for these wells are variable relative to each other, but consistently have higher TP compared to MW-1 and MW-2.

Temperature Monitoring

In the future, the city's wastewater discharge permit will likely include temperature limits. One of the goals of this study is to assess potential reuse approaches to manage the thermal load. If this study project is successful, reuse operations would be part of the final wastewater treatment system and allow for reuse throughout much of the year. Additionally, surface water discharge of the City's reclaimed water would still be planned during winter months when there is the likelihood for freezing weather that could increase difficulty with operations of SDI system.

To meet temperature management goal, the following objectives were identified:

- Demonstrate the use and assess feasibility of a subsurface drip irrigation (SDI) system for high-rate reuse on alfalfa cropland during the non-growing season
- Collect environmental data to support DEQ acceptance of non-growing season, high rate reuse including identification of time periods when temperature management via reuse may be most beneficial or limiting
- Provide information to support reuse and surface water discharge planning and permitting

Continuous temperature data have been collected at two irrigation water locations (reclaimed water and supplemental water), four surface water locations, and four groundwater monitoring locations. Additionally, daily (grab) temperature data of wastewater effluent are collected.

Selected temperature data collected beginning in July 2020 and through 2022 were plotted to provide a comparison of reclaimed water, surface water and groundwater temperatures (Figure 6). Also shown are the surface water temperature criteria that may be used to establish surface water discharge permit limits. Note that the wastewater (WW) effluent data was collected as a grab sample, while all other graphs show daily averages of 15-minute data. And, the groundwater average (GW Avg) is the daily average of the four Pilot Study monitoring wells. More detailed information on the temperature monitoring results are provided in Attachment – Temperature Monitoring Results

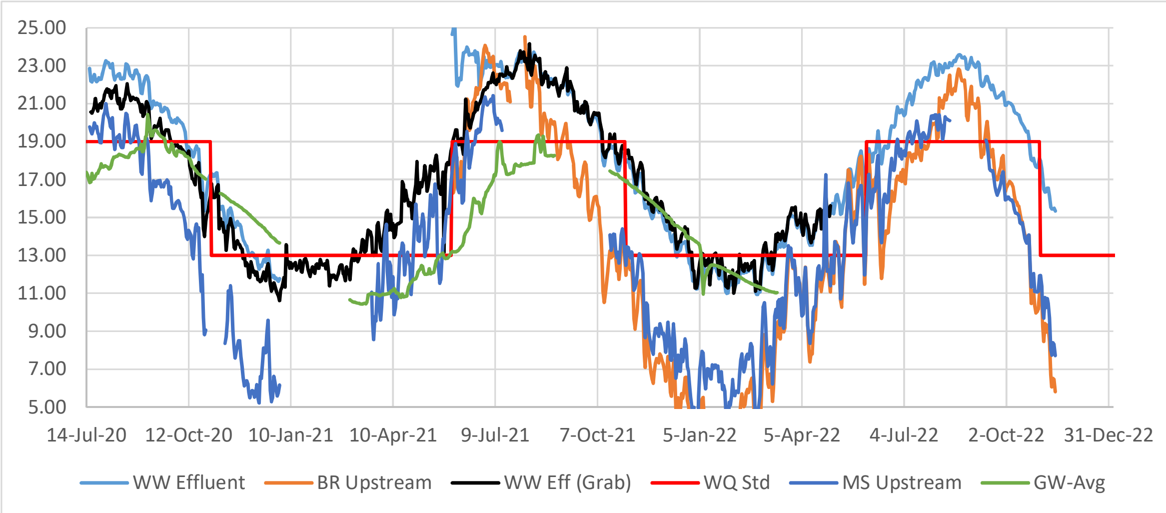

Figure 6 Selected temperature data (2020 through 2022) and WQ standards (units of °C)

The following are general observations based on a comparison of the temperature data with the surface water criteria:

- Reclaimed water temperatures (i.e., wastewater effluent) are above the criteria most of the year; periods below criteria include a few months during the coldest part of the winter and a few weeks in the fall
- Surface water temperatures are generally above criteria during spring and summer, but appear to be below criteria in the fall and winter
- Average ground water temperatures are above criteria in the late fall and early winter, but appear to be below criteria in other seasons

To begin the assessment needed to determine how reuse can affect the environment relative to temperature, a conceptual model was developed (see cover page). This was used to guide preliminary heat loading (and loss) analyses. The model and heat loading analyses are provided in Attachment – Pilot Study Heat Transfer Conceptual Model and Preliminary Heat Loading Analyses. The following are preliminary conclusions based on the heat loading analyses:

- Growing season agronomic reuse could add a thermal load to the soils but transfer of the heat load to shallow groundwater via convective transfer should be limited due to consumptive use. Additionally, conduction transfer would be low during months as thermal gradient would be low, and this would further reduce the potential for heat transfer to the groundwater.

- Non-growing season and higher rate reuse could add a thermal load to the soils that is transferred to the shallow groundwater via convection, which would then discharges to surface water.

- Soil evaporation could result in evaporative cooling (latent heat loss) that would substantially reduce reuse thermal loading to the groundwater (and the Boise River). This suggests that the land application system could act as a large evaporative cooling system.

- Groundwater thermal transfer and loss processes could attenuate the heat load transferred from the soils.

Planned Operations for 2023

It is anticipated that 2023 crop production and associated phosphorus removal will remain at or possibly above 2022 levels. The planned 2023 annual hydraulic and P target loading rates are shown in Table 6. The P loading rates shown in Table 5 are based on a projected reclaimed water TP concentration of 5 mg/L and a supplemental TP concentration of 0.2 mg/L. More details on loading rate targets are provided in Attachment – Monthly Loading Rate Targets.

Table 6 Planned and Proposed Loading Rate Targets for 2023

2023		Hydraulic Load (ft)			Phosphorus Load (lb/ac)		
Planned		Supp	Reuse	Total	Supp	Reuse	Total
Control	OZ 6	3.2	0.0	3.2	1.9	0.0	1.9
Agronomic Reuse	OZ 4	2.1	1.3	3.4	1.2	18.1	19.3
Winter HR Reuse	OZ 5	2.7	1.2	3.9	1.5	16.7	18.2
Proposed (Example Rates)							
Annual HR Reuse	OZ 2	13.2	1.2	14.4	3.7	16.7	20.3

The target total hydraulic loading rates are intended to meet or exceed growing season water demand on all operational zones. The growing season hydraulic loading rates are based on average monthly irrigation demand estimated using Allen, R. and C. Robison, 2017.

The planned hydraulic loading rates for the reuse zones (e.g., OZ 4 and 5) balance application of reclaimed water and supplemental irrigation such that the phosphorus load targets are met. The annual P loading rate target, as approved in the Work Plan, was conservatively set at 20 lb-P/ac/yr. An increase to 25 lb-P/ac/yr is proposed and 2023 loading rates will be adjusted if approved by DEQ.

Planned hydraulic loading rates for OZ 1 and 3 are similar to OZ 6 (Table 6). These target loading rates will also be used for OZ 2 unless alternative (e.g., proposed) rate targets are approved by DEQ. As previously stated, a higher hydraulic loading rate would be needed to apply the annual TP target load if future wastewater treatment improvements reduce effluent TP to a much lower average concentration (e.g., from around 5 mg/L to less than 1 mg/L). If higher rates are approved, the reclaimed water would be used to meet TP target, and Mill Slough or domestic water would be used as supplemental water to meet hydraulic loading targets.

On all zones the actual loading rates will vary depending on a number of operational and system design constraints, including weather, irrigation system limitations (e.g., pumping rates and scheduling), harvest shutdown periods and TP concentrations. As occurred in 2022, consistent effort will be needed during 2023 to ensure loading rates are near the phosphorus target levels for the reuse zones (i.e., 20 lb/ac, or if approved by DEQ 25 lb/ac).

Conclusions and Recommendations

The City has successfully operated the SDI system for reuse and supplemental irrigation of the alfalfa crop for two years. The crop production data showed that the system is effective for irrigation. Crop phosphorus loading and removal data showed that crop removal exceeded loading. This was generally consistent with the reduction in soil phosphorus levels as observed in the soils monitoring data.

The environmental data and analyses continue to support the following key baseline conditions that were identified during the pilot study design:

- Reclaimed water to be applied in the study area meets all the current NPDES permit conditions
- By reusing this reclaimed water for crop production, the SDI system provides environmental benefits to both the surface and shallow groundwater, including reductions in sediment, nutrient and thermal loads to surface water. Additionally, by farming without the use of fertilizer, nutrient loads to groundwater decrease. Due to limited data, changes in thermal loads have not been assessed.
- All available groundwater information indicates that the shallow groundwater in the Pilot Study area is not used as a potable water source and discharges into surface water. This would imply that any water that leaches into the shallow groundwater would then discharge into the Boise River.

The primary goals of the study are to demonstrate the feasibility of subsurface drip irrigation (SDI) for a forage crop, to quantify the uptake of phosphorus applied to soils, and to assess potential approaches to manage the thermal load. The status on meeting each of these goals is briefly discussed below.

Demonstrating SDI

Demonstration of the effectiveness of the SDI system is one of the stated goals of the pilot study. The crop removal data show a relatively high level of alfalfa production (e.g., over 6 tons/ac for OZs 4, 5 and 6). This was in the range of planned production levels and thereby provides data to support the continued use of the SDI system. In 2023, crop production is expected to remain at or above this level, and should continue until nutrients become limiting on some or all of the operational zones.

Wintertime, High-Rate Reuse

A primary goal of the pilot study is to show that phosphorus in the reclaimed water can be applied during non-growing season months (wintertime) and then stored in the soil for use by a crop. Operation of the SDI system in the late fall (e.g., November) demonstrates that this system can be used to apply reclaimed water during colder periods when some below freezing air temperatures occur.

The 2023 data show a reduction in the P available for 2023 crop production for OZ 4, 5 and 6. The "change in P" based on the soils data is noticeably higher for the high rate reuse zone (OZ 5), which suggests a higher leaching rate under the high rate operations or P uptake and removal from below the soils monitoring profile. Either way, the crop removal has not decreased, which shows continued removal of P from the environment regardless of where the P is removed from.

Thermal Load Management

Much of the lower Boise River has been listed as water quality limited due to elevated water temperature. In the near future, the City's wastewater discharge permit will likely include temperature limits. With this understanding, the third pilot study goal is to assess strategies for wastewater temperature management (i.e., non-growing season reuse via the SDI system).

The temperature data show that the reclaimed water temperatures are above the surface water temperature criteria most of the year except for a few months during the coldest part of winter and a few weeks in the fall. Surface water temperatures are above criteria during spring and summer, while the average ground water temperatures are above criteria in the late fall and early winter.

To begin the assessment needed to determine how reuse can affect the environment relative to temperature, a conceptual model was developed and preliminary heat loading (and losses) were estimated. While additional data and more rigorous analyses are needed, the preliminary analyses suggests that the land application system could act as a large evaporative cooling system.

Proposed Pilot Study Changes

The following proposed 2023 change, as discussed in this annual report (and its attachments), will be implemented if approved by DEQ:

- Increase the annual phosphorus loading target for the reuse fields from 20 lb/ac/yr to 25 lb/ac/yr ; this seems justified considering TP/crop removal has been above 25 lb/ac
- Test higher hydraulic loading rate (e.g., 15 ft/yr) on OZ 2; to assess likely future increased rates due to changes reclaimed water characteristics (i.e., low concentration of P)
- Test crop rotation on OZ 1: for long term planning
- Test OZ 3 drip irrigation system during freezing weather operations (January/February); to assess effectiveness freeze prevention design components

References

Allen, R. and C. Robison, 2017. Evapotranspiration and Consumptive Irrigation Water Requirements for Idaho: Supplement updating the Time Series through December 2016, Research Technical Completion Report, Kimberly Research and Extension Center, University of Idaho, Moscow, ID.

Etheridge, A.B. 2013. Evaluation of Total Phosphorus Mass Balance in the Lower Boise River, Southwestern Idaho. Reston, VA: US Geological Survey, Scientific Investigations Report 2013-5220. Available at http://pubs.usgs.gov/sir/2013/5220/.

Harrison, J. and M. Martin. 2021. Natural treatment system reuse pilot study 2020 annual report. Prepared for City of Middleton and submitted to DEQ April 2021.

Harrison, J. and M. Martin. 2020. Pilot study work plan. Prepared for City of Middleton and submitted to DEQ. August 25. 2020.

IDEQ. 2015. Lower Boise River Total Maximum Daily Load (TMDL) Total Phosphorus Addendum.

IDEQ. 2019. Personal communication from M. Snider.

Martin, M. and J. Harrison. 2020 dft. Quality assurance procedures plan (QAPP) for pilot study Sampling Project. Prepared for City of Middleton and submitted to DEQ. August 28, 2020.

Natural Resources Conservation Service (NRCS). 1972. Soils Survey for Canyon County. Internet accessed 2016.

List of Attachments

Attachment – Regulatory Approvals

Attachment – Proposed Operational Changes

Attachment – Reuse Pilot Study Monitoring Plan Summary

Attachment – QAQC Review

Attachment – Operational Data and Analyses

Attachment – Environmental Monitoring Results and Analyses

Attachment – Temperature Monitoring Results

Attachment – Pilot Study Heat Transfer Conceptual Model and Preliminary Loading Analyses

Attachment – Monthly Loading Rate Targets

(Available upon request)