Upper Granite Creek
Watershed Pollutant Reduction Plan

Prepared for

CITY OF PRESCOTT

Public Works Department
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Prescott, AZ 86301

Prepared by

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November 2020

Upper Granite Creek Watershed Pollutant Reduction Plan
City of Prescott
Public Works Department
Prescott, Arizona

Submitted to:

City of Prescott
Prescott, Arizona

Submitted by:

Wood Environment & Infrastructure Solutions, Inc.
Phoenix, Arizona

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City of Prescott
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Attn: Ben Burns, City of Prescott
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Section 303(d) of the Clean Water Act (CWA) requires that states compile a list of surface waters that do not meet applicable water quality standards (WQS). The Arizona Department of Environmental Quality (ADEQ) then must develop Total Maximum Daily Loads (TMDLs) for waterbodies on the 303(d) List. TMDLs set the amount of the given pollutant(s) that the waterbody can withstand without creating an impairment of that surface water's designated beneficial use(s). The City of Prescott (City) is named in two TMDLs, identified as:

- Watson Lake TMDL: Total Nitrogen, Dissolved Oxygen (DO), pH & Total Phosphorus Targets - Finalized February 2015 (Open File Report OFR-14-03)
- Final Upper Granite Creek Watershed *Escherichia coli (E. coli)* TMDL November 2015 (Open File Report 14-08)

Since 2015, Wood Environment & Infrastructure Solutions, Inc (Wood), has been supporting the City by performing a wide range of activities. The overall purpose of these activities was to evaluate and model pollutant reduction activities and present recommendations in the Upper Granite Creek Watershed Pollutant Reduction Plan (WPRP) and Watson Lake Reservoir Lake Management Plan (LMP). The objective of the WPRP is to identify scenarios and actions the City can take to achieve cost-effective reductions in the target pollutants. Significant activities performed to support this effort include:

- developing a TMDL Action Plan;
- planning and performing lake water, lake sediment, street dirt, and watershed *E.coli* sampling and analysis;
- developing a lake sediment profile;
- developing a Watershed Water Quality Model using Loading Simulation Program (LSPC) and the SIMplified Particulate Transport Model (SIMPTM);
- developing a hydrodynamic and water quality model of Watson Lake Reservoir using CE-QUAL-W2 Version 3.72 computer program (W2); and
- delivering a series of Technical Memos documenting the progress of activities performed.

The culminating effort of the aforementioned activities (as well as several others not listed above), is the development of this WPRP and the LMP. These Plans do not seek to re-present previous work efforts, but rather provide guidance to the City as a result of previous activities.

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Respectfully submitted,

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ABBREVIATIONS

2012 WIP	2012 Improvement Plan for the Upper Granite Creek Watershed
A&Wc	Aquatic and Wildlife (Cold Water)
A&We	Aquatic and Wildlife (Ephemeral)
A&Wedw	Aquatic and Wildlife (Effluent-Dependent Water)
A&Ww	Aquatic and Wildlife (Warm Water)
AAC	Arizona Administrative Code
ADEQ	Arizona Department of Environmental Quality
AgI	Agricultural Irrigation
AgL	Agricultural Livestock Watering
AZPDES	Arizona Discharge Pollution Elimination System
BMP	Best Management Practice
cfs	cubic feet per second
cfu	colony forming units
CGP	Construction General Permit
COD	Chemical Oxygen Demand
CWA	Clean Water Act
DO	Dissolved Oxygen
DWS	Domestic Water Source
E. coli	*Escherichia coli*
EC	Emergent Contaminant
FBC	Full-body Contact
FC	Fish Consumption
G-cfu	Giga-cfu = 1 billion cfu
HUC	Hydrologic Unit Code
L	Liter
LA	Load Allocation
LC	Loading Capacity
LR	Load Reduction
mg	milligram
mL	milliliter
MOS	Margin of Safety
MS4	Municipal Separate Storm Sewer System
MSGP	Multi-Sector General Permit
MST	Microbial Source Tracking
NB	Natural Background
NPS	Non-Point Source
PBC	Partial-Body Contact
PNF	Prescott National Forest
PS	Point Source
SSM	Single Sample Maximum
SU	Standard Unit
TMDL	Total Maximum Daily Load

TN	Total Nitrogen
TP	Total Phosphorus
UCL	Upper Confidence Level
USGS	United States Geological Service
WIP	Watershed Improvement Plan
WLA	Waste Load Allocation
WPRP	Watershed Pollutant Reduction Plan
WQS	Water Quality Standards
YPIT	Yavapai-Prescott Indian Tribe

1.0 BACKGROUND INFORMATION

Section 303(d) of the Clean Water Act (CWA) requires that states compile a list of surface waterbodies that do not meet applicable water quality standards (WQS). Total Maximum Daily Loads (TMDLs) must be developed for waterbodies on this list (the 303(d) List). TMDLs set the amount of the given pollutant(s) that the waterbody can withstand without creating an impairment of that surface water's designated beneficial use(s).

Twelve waterbodies within the Upper Granite Creek Watershed have been listed as water quality impaired. In 2004, Watson Lake Reservoir was listed for high nitrogen, low dissolved oxygen (DO), and high pH; subsequent TMDL development added phosphorus loading to the reservoir's pollutants of concern. Granite Creek was likewise listed for low DO in 2004 and was additionally listed for *Escherichia coli* (*E. coli)* bacteria in 2010. Miller Creek was also listed for *E. coli* at that time. Butte Creek and Manzanita Creek have since been added in the 2012/14 303(d) list, also for *E. coli*. Aspen Creek, North Fork Miller of Creek, Banning Creek, Government Canyon, Slaughterhouse Gulch, and two unnamed tributaries (AZ15060202-3333 [known locally as the Virginia St Wash], and AZ15060202-3313 [known locally as Ackers East]) were listed on 303(d) also for *E. coli* in 2016.

The Arizona Department of Environmental Quality (ADEQ) has finalized TMDL documents addressing pollutants within Watson Lake Reservoir and the Granite Creek watershed. As a stakeholder in these TMDLs, the City of Prescott (City) is required to implement measures to reduce the amount of these pollutants of concern entering these waterbodies from the City's stormwater discharges.

This Watershed Pollutant Reduction Plan (WPRP) is intended to comply with that requirement. This plan specifically addresses *E. coli* in the Upper Granite Creek Watershed streams plus phosphorus entering Watson Lake Reservoir. Other pollutants of concern will be addressed by addressing these two. Reducing phosphorus entering the lake via Granite Creek discharges is addressed in this plan because it is an action taken within the watershed not in the lake. Phosphorus loadings entering the lake that have been reduced will help comply with the TMDLs established for Watson Lake. This is one of several actions that could be taken to address lake water quality requirements. Others are discussed separately in the Watson Lake Reservoir Lake Management Plan.

The WPRP identifies, evaluates, and recommends as appropriate the implementation of cost-effective Best Management Practices (BMPs) needed to reduce the targeted pollutants to the levels specified in the TMDLs. The WPRP will not replace the 2012 Improvement Plan for the Upper Granite Creek Watershed (2012 WIP) but will supplement it by identifying specific actions the City can implement, or continue to implement, to achieve quantified estimates of improvements in expected loadings.

1.1 Watershed Location and Characteristics

The Upper Granite Creek Watershed is located in central Arizona and is part of the Verde River Watershed. Bounded by the Sierra Prieta and Bradshaw Mountain ranges and covering approximately 50 square miles, the Upper Granite Creek Watershed stretches from the headwaters of its primary tributaries (Aspen, Banning, Butte, Granite, Manzanita, Miller, and North Fork Granite Creeks) downstream to Watson Lake. In total, the watershed includes nine named creeks and four lakes. Of these, Butte Creek, Granite Creek, Manzanita Creek, Miller Creek, Aspen Creek, North Fork of Miller Creek, Banning Creek, Government

Canyon, Slaughterhouse Gultch, two unnamed tributaries (AZ15060202-3333, and AZ15060202-3313) and Watson Lake have all been listed as impaired.

Approximately 12.2 linear miles of Granite Creek are impaired for *E. coli*, draining an area of approximately 40 square miles, which includes most of the City. When the other impaired creeks are included, the total length of impairment increases to approximately 53.2 miles.

1.1.1 Population and Demographics

The City's population in 2017 was estimated at 42,731 people, while the larger Prescott Metropolitan ("Quad-City") Area, encompassing Prescott Valley, Chino Valley, and Dewey-Humbolt, had an estimated population of 222,225 in 2015. Population density based on the 2010 census was approximately 946 people per square mile.

Private citizens and the Prescott National Forest (PNF) own most of the land in the Upper Granite Creek Watershed (49% and 40%, respectively). The Yavapai-Prescott Indian Tribe (YPIT) owns approximately 5% of the watershed, as does the State of Arizona, while the remaining 1% are military lands.

1.1.2 Land Use and Land Cover

The Upper Granite Creek Watershed encompasses a diverse array of land types, ranging from forest and grasslands in unincorporated Yavapai County and on YPIT land to the urbanized areas of the City and surrounding towns. In those areas of the watershed located on PNF land, foliage is typical of the Sonoran Desert, changing to chaparral, piñon pine, and juniper as elevation rises, until Ponderosa pine becomes the predominant form of vegetation at the highest elevations.

Land uses are primarily residential, commercial, and light industrial within urbanized areas and national forest (managed primarily for recreation) in unurbanized areas. Agriculture was not deemed a significant land use in either urbanized or unurbanized areas in the 2012 WIP.

1.1.3 Hydrogeologic Setting (include watersheds, creeks, and Watson Lake)

The 359-square mile Granite Creek Watershed is part of the Verde River Watershed located in central Arizona and bordered by the Agua Fria, Bill Williams, and Hassayampa watersheds. The Upper Granite Creek Watershed, Watson Lake Hydrologic Unit Code (HUC) 150602020102, forms the southernmost portion of the Granite Creek Watershed.

Elevations in the Upper Granite Creek Watershed range from 7,979 feet at its highest point, the top of Mount Union, to 5,100 feet at its lowest point, Watson Lake. The mean elevation across the watershed is 5,595 feet. Approximately half of the watershed has slopes in excess of 15%. Soils across most of the watershed are moderately to highly erodible.

The watershed houses more than 60 linear miles of intermittent creeks, of which Granite Creek is the longest, flowing 38 miles from its headwaters in the Bradshaw Mountains to its confluence with the Verde River, a designated Wild and Scenic River. Granite Creek's mean stream flow over a 70-year period was estimated at 5.88 cubic feet per second (cfs).

The area sees summer temperatures ranging from approximately 50-90° F and winter temperatures ranging from approximately 20-60° F. Annual precipitation varies from 13.5-19 inches (not including snowfall), with as much as 4 inches of that total falling during the months of July, August, and September. Average snowfall during the months of December through April is approximately 20 inches. Precipitation does not typically leave the watershed as surface flow; Granite Creek and its tributaries are intermittent in the winter months and ephemeral in summer months.

1.2 Water Quality Standards

ADEQ develops water quality standards for surface waters of the State, including lakes and reservoirs, and conducts monitoring to determine whether or not those standards are being met. These WQS are codified in Title 18, Chapter 11 of the Arizona Administrative Code (AAC) and vary across the state depending on each waterbody's designated beneficial uses. Designated uses, as promulgated in AAC R18-11-104, are: full-body contact (FBC), partial-body contact (PBC), domestic water source (DWS), fish consumption (FC), aquatic and wildlife (cold water) (A&Wc), aquatic and wildlife (warm water) (A&Ww), aquatic and wildlife (ephemeral) (A&We), aquatic and wildlife (effluent-dependent water) (A&Wedw), agricultural irrigation (AgI), and agricultural livestock watering (AgL).

Designated uses for Granite Creek include A&Wc, FBC, FC, AgI, and AgL. Designated uses for Butte Creek, Manzanita Creek, and Miller Creek include A&Wc, FBC, and FC. Designated uses for Watson Lake include A&Ww, FBC, FC, AgI, and AgL. Note that FBC and FC are considered recreational uses, which the 2012 WIP found to be a source of high levels of *E. coli* in the Upper Granite Creek Watershed (see Section 1.4.1).

Arizona's *E. coli* standard is intended to protect human health where recreational waters have some possibility of human ingestion. Arizona's approved water quality standard for *E. coli* allows for a geometric mean (minimum of 4 samples in 30 days) of 126 colony forming units (cfu)/100 milliliters (mL) and a FBC single sample maximum (SSM) standard of 235 cfu/100 mL. The creeks identified in Section 1.1, have all been shown to exceed that standard.

In addition to the *E.coli* standard, additional WQSs are Total nitrogen (TN) and total phosphorus (TP) with an annual mean of 1.0 mg/L for TN and an annual mean of 0.1 mg/L for TP. DO and pH WQS are based on designated uses. For A&Wc, DO is set at 7.0 mg/L and for A&Ww, it is set at 6.0 mg/L. For A&Wc, A&Ww, FBC, and AgL, the allowable pH is 6.5-9.0 standard units (SU); for AgI, it is 4.5-9.0 SU (see **Table 1**).

1.3 TMDL Development and Implementation

TMDLs identify the amount of a pollutant that a water body can assimilate and still meet WQS. ADEQ began the process of determining TMDLs for the Upper Granite Creek Watershed in 2007, sampling Watson Lake Reservoir, Willow Creek Reservoir, Granite Creek, and all the main tributaries to Granite Creek. Nutrient loading and *E. coli* were found to be issues and an *E. coli* TMDL for the Upper Granite Creek Watershed was finalized in 2015. The TMDL for Total Nitrogen, DO, pH, and Total Phosphorus for Watson Lake Reservoir was also finalized in 2015.

Generally speaking, TMDLs are calculated using the following formula:

$$TMDL = \sum WLA + \sum LA + MOS$$

In this formula, waste load allocation (WLA) is the amount of point source (PS) pollution a waterbody can assimilate, load allocation (LA) is the amount of non-point source (NPS) and background pollution, and a margin of safety (MOS) is factored in to account for uncertainties and variations associated with data collection, lab analysis, equipment and method precision and accuracy limitations, modeling, and random error.

WLAs are assigned to any entity covered by an individual or general Arizona Discharge Pollution Elimination System (AZPDES) stormwater permit (including Municipal Separate Storm Sewer System (MS4) permits, Multi-Sector General Permits (MSGP), and Construction General Permits (CGP)).

Where the existing load is larger than the LA calculated above, load reduction (LR) is required, and is calculated as follows:

$$LR = \text{Existing Load} - (LA + \text{Natural Background} + MOS)$$

$$\% \text{ Reduction} = (LR/\text{Existing Load}) * 100$$

1.3.1 *E. coli* TMDL for Watershed of Granite Creek and Tributaries

The assigned concentration-based WLA for *E. coli* is equal to the SSM, 235 cfu/100 mL, and is applied to all AZPDES permittees within the Upper Granite Creek watershed.

For the *E. coli* TMDL, the MOS is implicit rather than explicit, arising from ADEQ's choice to use the 0.75 upper confidence level (UCL) median flow value due to uncertainties in the median value associated with limited sampling events and an additional choice to adopt the 90th percentile value for attainment evaluations rather than the 75th percentile level the SSM value was originally drawn from.

Natural background (NB) for the *E. Coli* TMDL was determined by ranking loads from samples collected in headwater subwatersheds of Upper Miller, Upper Granite Creek, and Upper Aspen Creek. The 90th percentile load value was selected as representative of stormflow loading 50.4 cfu/100 ml at a flow of 15.4 cfs.

In addition to the concentration-based target of 235 cfu/100 mL required throughout the watershed, an aggregated load-based target was set at the two US Geological Service (USGS) gauges along Granite Creek where ADEQ utilized flow duration equations during TMDL development. For the lower gauge, the TMDL target load is 304.52 G-cfu/day, and for the upper gauge, the TMDL target load is 105.15 G-cfu/day (see **Table 2**).

1.3.2 Total Nitrogen, DO, pH, and Total Phosphorus TMDLs for Watson Lake Reservoir

TMDLs for nitrogen and phosphorus were developed by ADEQ to address ongoing concerns of harmful algae blooms of cyanobacteria (blue-green algae) and dinoflagellates that can cause harmful effects to human health and wildlife in Watson Lake Reservoir. The algae blooms also create nuisance conditions and contribute to anoxic conditions and periods of high pH in the lake.

Collectively, AZPDES permittees within the watershed are assigned a concentration-based WLA equal to 1.0 mg/L TN and 0.10 mg/L TP. However, a lower concentration limit applies within Watson Lake Reservoir that would likely require inflows from Granite Creek to meet that limit. Analysis of water quality data collected December 2016 through November 2017 found that TP ranged from 0.026 to 0.287 mg/L, with an average of 0.11 mg/L, yet harmful algae blooms occurred for much of the summer. Ongoing monitoring of phosphorus in Granite Creek and the lake will be needed as the WPRP is implemented to monitor effectiveness of measures and the need for additional measures and possibly lower concentrations.

A combined watershed and in-lake approach to determining nutrient loading was used by others in the development of applicable TMDLs in order to additionally meet the Verde River nutrient WQS. Based on modeling mass balance of nutrients and considering NB and MOS, the overall LR is 47 percent for TN and 49 percent for TP (see **Table 3**).

The City comprises 39 percent of the Upper Granite Creek Watershed, or roughly 17.56 square miles, while unincorporated Yavapai County land makes up 10 percent of the watershed, or 4.46 square miles. Reserving 10 percent of the WLA from **Table 3**, and prorating based on a total of 49 percent of the watershed being subject to WLAs, the City's allowable TN WLA is 5.66 lbs/day and its allowable TP WLA is 1.12 lbs/day. Total allowable WLA for the watershed is 7.88 lbs/day for TN and 1.56 lbs/day for TP (see **Table 4**).

LAs are distributed between PNF, State trust land, and military land, with a 15-percent unallocated reserve. YPIT lands make up the remainder of the watershed, but they do not fall under ADEQ jurisdiction, so were not included in the TMDL allocations. Contributions from YPIT lands can, nevertheless, affect water quality in Watson Lake Reservoir and Granite Creek downstream to the lake. Total allowable LA for the watershed is 7.88 lbs/day for TN and 1.56 lbs/day for TP (see **Table 4)**.

TMDLs for DO and pH are the applicable WQS as described in Section 1.2 and **Table 1**. Namely, for A&Wc, DO is set at 7.0 mg/L, which applies to Butte Creek, Granite Creek, Manzanita Creek, and Miller Creek. For A&Ww, DO is set at 6.0 mg/L; this TMDL applies to Watson Lake Reservoir within 1 meter of the surface only (the TMDL sets DO at 2.0 mg/L for deeper water in the lake, see **Table 5**). For A&Wc, A&Ww, FBC, and AgL, the allowable pH is 6.5-9.0 standard units (SU); this TMDL applies to Butte Creek, Manzanita Creek, and Miller Creek. For AgI, allowable pH is 4.5-9.0 SU; this TMDL applies to Granite Creek and Watson Lake.

TMDL water quality targets for all pollutants (excluding *E. coli*) are summarized in **Table 5**. Note that while Granite Creek and its tributaries have concentration-based TMDLs of 1.0 mg/L for TN and 0.1 mg/L for TP, Watson Lake's targets are lower, at 0.8 mg/L for TN and 0.06 mg/L for TP. Note also that Watson Lake was modeled in two segments, based on depth. Therefore, it has an additional DO TMDL of 2.0 mg/L for the deeper portion. Even higher levels of DO may be needed in order to meet the surface standard after autumn Lake turn-over.

1.4 Impairment Causes and Sources

The Upper Granite Creek Watershed includes waterbodies impaired for *E. coli*, TN, TP, DO, and pH. In addition, the watershed is an important contributor of TP and TN to Watson Lake Reservoir which is impaired for TP, TN, DO, and pH. This section discusses possible causes/sources of and actions to reduce *E. coli* and TP. TN, DO, and pH. DO in the watershed will be reduced by reducing fecal waste and nutrient loading associated with *E. coli* and TP. TN will be reduced by reducing TP, and TN by itself cannot be reduced sufficiently to limit algae growth in the lake (i.e. it is resupplied from the atmosphere by in-lake nitrogen fixation). DO and pH requirements are driven by the lake; these will be helped by reducing TP. The LMP describes other actions to be taken to comply with water quality requirements in Watson Lake Reservoir.

E. coli is an indicator bacteria, meaning that it can be used to detect and estimate the levels of fecal contamination in water. Sources of *E. coli* include humans and animals, both domestic and wild. Significant amounts of *E. coli* enter the watershed's creeks during storm and snowmelt events, which is considered NPS pollution, or pollution that issues from widely distributed or pervasive environmental elements. Overflowing sanitary sewers, septic seepage, and cross connections also contribute to the amount of *E. coli* entering impaired waterbodies within the Upper Granite Creek Watershed. The sources directly related to sanitary sewer systems are classified as PS pollution even though the exact points of leakage, cross connection or overflow may be rather diffuse and difficult to locate. *E. coli* can persist in the environment (for days or weeks or longer) and is difficult to remove or treat once it enters streams. *E. coli* is best addressed by reducing or eliminating it before it enters streams by reducing or eliminating fecal matter from humans, pets, or wild animals and birds.

In 2018, the City undertook one round of *E. coli* testing to determine the main host groups contributing to water quality degradation. At the time of the analysis, the sample results revealed the presence of both human and animal sources with more frequent human markers in more urbanized areas and predominantly avian and bovine markers in upstream portions of the watershed (see additional information in Section 2.2). Given the presence of both human and animal *E.coli* sources, it's important to address both sources to reduce *E.coli* loads. Below are some actions (new or continued existing) to reduce *E. coli* include the following; all sources of *E. coli* are also sources of TP:

- Human-hosted *E. coli* – it should be feasible to eliminate 100 percent of human *E. coli* by eliminating all human waste that presently enters watershed creeks
  - Failed septic systems – Septic systems should be regularly checked to ensure they treat and prevent bacteria from discharging; these should be connected to existing or new City municipal sewer system lines whenever possible. Even properly functioning septic systems release TP and TN.
  - Leaks or overflows from the municipal sanitary sewer system lines – All potential points of leakage or overflow should be identified and repaired or modified to prevent leaks or overflows.
  - Homeless camps lacking sanitation – Restroom facilities should be provided to prevent raw sewage entering creeks; short-term measures could use portable chemical toilets; longer-term measures could include relocation or construction of permanent restrooms.
- Pet-hosted *E. coli*
  - Washoff from streets and sidewalks is typically a large fraction of *E. coli* loading from residential areas - pet waste ordinances, public education, low-impact development approaches (LIDA), and frequent street cleaning using effective well maintained equipment (such as regenerative air or vacuum units) can help. These would also help reduce *E. coli* from wildlife or bird hosts that deposits on streets.
  - Washoff from parks, linear parks, and trails – pet waste ordinances, public education, and provision of pet waste bags and trash receptacles can help.
  - Trails through parks popular with dog walkers may be focused sources of higher *E. coli* – on-site treatment such as LIDA, or cleaning paved areas of track-out.
- Wildlife- and bird-hosted *E. coli*
  - Concentration of washoff from residential areas and parks – Presence of grass, water, and food all attract higher levels of birds and wildlife relative to the natural environment upstream of the City. Public education and discouraging feeding can help, but more aggressive measures may be difficult to implement.

All causes/sources of *E. coli* are also causes/sources of phosphorus because *E. coli* is associated with fecal matter that also contains nutrients. There are other contributions of TP that do not contribute elevated *E. coli*. Phosphorus can be difficult to remove from streams once it is present, because TP typically includes a large dissolved fraction that passes through many treatments that would provide for settling as if it were sediment. Possible causes/sources of and actions (new or continued existing) to reduce TP alone, beyond those for *E. coli,* include the following:

- Fertilizer – excess fertilizer for lawns and gardens can run off the lawn or garden surface and into streams. This includes effluent reuse from the City's wastewater treatment plant that is applied to area golf courses. Public education is important to reduce the overuse of fertilizer. The reuse of effluent should be monitored to ensure excess effluent does not flow into streams.
- Car washing detergents – although commercial car washes recycle and reuse their detergent, individuals who wash cars on the streets result in detergent that drains to streets and streams. Public education and requirement to use detergents that don't contain phosphorus can help.
- Aerial deposition and breakdown of vegetation – this combines a natural source (e.g. falling leaves and other sources) with the "short-circuiting" effect where effective impervious area (EIA) surfaces can quickly wash to streams and bypass the natural filtering provided by soil. Street cleaning, LIDA, public education about good housekeeping with yard debris, and yard debris collection programs can help.
- Historic dumping, landfills, and Illicit discharges to creeks – these can discharge phosphorus, but no data indicate such discharges occur except for yard debris disposal in riparian creek corridors. Ongoing monitoring can identify if this creates elevated levels of phosphorus.
- Burned vegetation and ash from fires – this is mainly a natural background source upstream of developed areas of Prescott. Ongoing monitoring can identify if this creates elevated levels of phosphorus.

The Upper Granite Creek Watershed TMDLs utilize a 50-50 split between NPS and PS, ostensibly based on analysis of sampling data. Both types of pollution are described in more detail in the following sections.

1.4.1 Nonpoint Sources

Due to the nature of NPS pollution, it is not regulated by ADEQ. Instead, ADEQ funds the development of Watershed Improvement Plans (WIPs) for watersheds impaired by NPS pollution. ADEQ funded the development of the 2012 WIP for the Upper Granite Creek (UGC) (Prescott Creeks and the Granite Creek Watershed Improvement Council, 2012), which identified potential NPS in the Upper Granite Creek Watershed, including:

- Approximately 5,000 City water service customers utilize septic systems, with more than 150 likely located within the 100-year floodplain (the 2012 WIP estimates a corresponding load of 19 lbs/yr of nitrate and 0.4 lbs/yr of orthophosphate, while microbial source tracking (MST) and emergent contaminant (EC) sampling suggest a correlation between increased levels of *E. coli* and septic use). Septic systems can contribute nutrients (nitrate and phosphorus) even if they are functioning properly and can contribute *E. coli* and nutrients (also including ammonia) if they are not functioning properly or their drain fields are saturated with rainwater.
- 55 acres of golf courses receiving treated effluent at Grade B+, with no nitrogen or phosphorus management requirement. Excess water can run off the golf course into watershed creeks with elevated concentrations of nutrients.

- The presence of domestic animals and livestock (dogs, cats, horses, cattle, goats, sheep, pigs, turkeys, geese, ducks, and chicken), wildlife (mountain lions, bobcats, deer, squirrels, wild turkeys, skunks, raccoons, and javelina), and birds (especially attracted to areas of water, grass, or feeding) and their associated waste.
- Runoff from fires, both wild and controlled burns, which likely contributes nitrate and phosphorus during storm events.
- Increased impervious cover (the 2012 WIP estimates 18.6 percent in the Watson Lake watershed alone), which typically increases the transport of *E. coli*, phosphorus, nitrogen, chemical oxygen demand (COD), and metal loads in direct proportion.
- Recreation (a source of *E. coli,* particularly from dog walking, but typically not of nutrients).

1.4.2 Point Sources

The primary point source in the watershed includes the aging sanitary sewer infrastructure, much of which was built as long as 90 years ago. Approximately one third or 15 square miles of the UGC watershed is connected to the City's municipal sewer, with over 300 miles of primarily gravity-fed wastewater collection infrastructure. There are 185 miles of municipal lines and 5 miles of private service lines within the watershed, many of which are located in or adjacent to creeks. Leaks are believed to have occurred in some of these aging sewer lines that contribute *E. coli* and phosphorus (and other pollutants such as nitrogen as ammonia or nitrate + nitrite).

The Sundog WWTP is no longer a point source in the UGC watershed, but it formerly discharged secondary treated effluent to Granite Creek about one-fourth mile upstream of Watson Lake from approximately 1950 to 1988. A study commissioned by the City in 1984 to explore management options for Watson Lake estimated that 118 lbs/day of phosphorus and 438 lbs/day of nitrogen was entering the lake, or approximately 66 percent of the total nutrient load (the remaining 33 percent being NPS). Effluent made up as much as 40 percent of the flows to Watson Lake (1,960 acre-feet per year compared to the 4,830 acre-feet total lake volume) during winter months when it was not diverted for golf course irrigation.

The effluent ponds were lined by the City and a bypass around the lake was constructed to recharge excess effluent (i.e. inject it into groundwater) near the Prescott Airport. The City no longer has (or has need of) a wastewater discharge permit; it distributes approximately 60 percent of reclaimed water for reuse at Antelope Hills, Prescott Lakes, and Hassayampa Golf Courses and other commercial facilities, with the remaining 40 percent being recharged. However, if reclaimed water exceeds the ground's irrigation demand, the excess can flow with its elevated nutrients into watershed creeks and the lake.

Storm-induced upsets do still occur; notably, in January 2010, a heavy winter storm led to sewer overflows in five manholes along Granite and Miller Creeks, which in turn resulted in a 3 million gallon-discharge of partially treated effluent from the WWTP to Granite Creek just above Watson Lake Reservoir. The City subsequently surveyed all manholes in waterways, replaced manhole covers that were ripped off in the storm, locked all covers with the locking ability, identified all manhole lids needing upgrades to incorporate the locking ability, and implemented a manhole insert program to reduce the amount of inflow water that enters manholes from the streets. The City also approved water and sewer rate increases to fund upgrades to the wastewater treatment facility and maintenance to the system.

2.0 WATERSHED MODEL

Modeling was used to quantify runoff and pollutant loadings from the UGC Watershed. The model was developed for existing conditions and was validated against observed streamflow and pollutant data, particularly *E. coli*, phosphorus, nitrogen (including ammonia, nitrates and nitrites). A separate model was developed for Watson Lake Reservoir to predict multiple interconnected water quality processes that used the results of the watershed model as one of its inputs. The lake is addressed in the Waterson Lake Management Plan and in other technical memoranda.

The watershed modeling was conducted to achieve multiple goals that included the following:

- Use non-linear relations of concentrations to stream flow to relate the finite number of observations to the continuum of time modeled;
- Model the interaction of multiple interdependent processes including accumulation, washoff, erosion, transport, deposition, and decay on the watershed land surfaces and streams;
- Obtain a continuous time series of inflow and constituents of interest (including temperature, sediment, phosphorus, and nitrogen species) needed as inputs for the continuous model of Watson Lake Reservoir that was used to evaluate lake behavior and evaluate management alternatives;
- Evaluate the effectiveness of alternative watershed management practices based on their interaction with watershed processes that sometimes reduced their effectiveness.

The watershed modeling comprised two basic steps. First, runoff and washoff for EIA surfaces in developed areas was modeled using the SIMplified Particulate Transport Model (SIMPTM) Version 5.1 computer program (Jelen, 2004). This model allowed for quantification of the interaction of processes including deposition, resuspension, washoff, and street cleaning. Results from the urban surfaces were combined as inputs into a watershed pollutant model using the Loading Simulation Program in C++ (LSPC). LSPC was used to model runoff and pollutant loading from all areas outside the developed EIA surfaces and them modeled transport, erosion, deposition and decay of pollutants in stream reaches downstream to Watson Lake Reservoir.

LSPC was used to model *E. coli* because data did not allow contributions to be distinguished between urban EIA surfaces and other sources, particularly given the atypically large contributions understood to occur in Prescott from the large number and high density of septic systems, potential leaks in the municipal sanitary sewer lines, and homeless encampments.

LSPC model inputs included geometric data such as ground topography, observed rainfall depths, soil characteristics (infiltration of water), ground cover (paved, vegetation), observed flows and pollutant concentrations (both from USGS gages and water quality data collected in the watershed), observed characteristics of accumulation on Prescott streets (size gradation and pollutant concentrations), and street cleaner types and efficiencies (from non-local measurements) (see Task 5.5 Memo for more details). Local data were supplemented with data from references where necessary for modeling.

Development and use of the watershed models are described in the following technical memoranda:

- SIMPTM model development: Task 5.6
- LSPC model development: Task 5.5
- Evaluation of existing regional water quality facilities in Upper Granite Creek Watershed: Task 7.2
- Evaluation of street cleaning practices: Task 7.3
- Evaluation of proposed regional water quality facilities in Upper Granite Creek Watershed: Task 7.4
- Evaluation of low-impervious development approaches (LIDA): Task 7.5

2.1 Street Dirt Sampling

Urban stormwater pollution results in part from the accumulation and transport of contaminated material on paved surfaces, such as streets and parking lots. The particulate portion of this contaminated material is referred to as "street dirt". The typical curb and gutter storm sewer design concentrates pollutants in street sediment, and concentrates runoff resulting in the rapid transport of high contaminant concentrations. These impervious surfaces typically have a larger impact on stormwater pollution than pervious surfaces and in urban environments, impervious areas directly connected to the drainage system are commonly referred to as "effective" impervious areas (EIAs). Prescott is somewhat atypical in that it has large contributions of *E. coli* and to a lesser extent nutrients from non-EIA sources such as failed septic systems, leaks from the sanitary sewer collection system, and homeless camps, that at present likely dwarf *E coli* contributions from EIA surfaces.

To characterize street dirt at a point-in-time, Wood performed a sampling program which consisted of collecting street dirt and subsequently performing a sieve analysis that provided a distribution of mass by particle size, and analytical testing that characterized concentration of several constituents of interest (see Wood Task 5.6 Memo, Attachments A, B, C & D, March 2019 for more information). Data resulting from this task was used in the SIMPTM water quality watershed model. Street dirt data is instrumental in creating a creditable and watershed-specific stormwater quality model for the UGC watershed. When scoping the street dirt sampling program Wood considered the requirements for *E.coli* testing but found that the six hour maximum holding times for *E. coli* analytical analyses would have complicated testing because the closest lab that could test for *E. coli* at that time was in Phoenix. So, the samples would have had to have been sent via courier to the Phoenix lab twice each day that sampling occurred (i.e. once before lunch after morning sampling and next after the afternoon sampling).

A total of 16 street dirt samples were collected in June 2017 from a selection of sites that represented the nine most prevalent land use/street type categories. Each sample was weighed, dried, weighed again, then sieved into eight particle size categories ranging from <63 microns to >6370 microns. The particle size fractions were then composited back into three particle size ranges for chemical analyses. These ranges were:

- Fine (<63 microns)
- Medium (63 to 250 microns)
- Course (250 to 2000 microns)

The fraction >2000 microns was discarded along with the >3270 micron fraction after a subsample of any organic material found in the >3270 micron fraction was obtained. These subsamples of organic material when found were also analyzed chemically.

In total 41 composited particulate samples (i.e. only 9 of the 16 "Fine" fractions had enough mass for analysis,16 Medium, and 16 Course) and 6 sub-samples of organic material (when found) were analyzed for the following:

- Total Kjeldahl Nitrogen (TKN)
- Nitrates + Nitrites
- Total Phosphorus (TP)
- Ortho Phosphorus (OP)
- Total Nitrogen was tracked as a summation of TKN and Nitrates + Nitrites, as total nitrogen is utilized as a TMDL.

The particle size chemical data results showed there was a fairly wide range of chemical concentrations found depending on the pollutant of interest, the particle size fraction analyzed (i.e. fine, medium, and course), the street type (i.e. minor, collector, and arterial), and the land use (i.e. low to medium density residential, medium to high density residential, commercial, or industrial). For example, TP Fine concentrations ranged from 13.03 to 159.11 mg/kg with the median at 63.43 mg/kg. TP Medium concentrations ranged from 4.5 to 60.03 mg/kg with the median at about 23.0 mg/kg. TP Course concentrations ranged from 4.8 to 246 mg/kg with the median at about 46.1 mg/kg. Interestingly, the TP concentrations were found to be much higher in the Course fraction than in any other street dirt study the authors have conducted. So this is unusual since pervious street dirt chemical analyses of TP have shown that the concentrations in the Fine fraction are generally the highest followed by those in the Medium fraction followed by those in the Course fraction (Sutherland, R., R. Myllyoja and S.L. Jelen. 2002). Wood believes that pulverized organic material that was able to pass the 2000-micron sieve (i.e. <1/8 inch) was likely responsible for these elevated nutrient TP results. Similar Course particle size fraction elevated results were also observed for the other three measured nutrients which were TKN, Nitrates + Nitrites, and PO4.

The chemical results for the six subsamples of organic material that couldn't pass the 3270-micron sieve (i.e. >3/16 inch) found even higher nutrient concentrations than those in any of the three particle size fractions. For example, TP organic material concentrations ranged from 240 to 455 mg/kg with the median at about 328 mg/kg which was 5.2 times higher than the TP concentrations found in the Fine particle size fraction and 7.1 times higher than those found in the Course particle size fraction. Once again similar results were found for the other three nutrients. Organic material was only found in samples collected on minor streets (i.e. low traffic volume streets) with five being a residential land use and one being industrial. The industrial street site paralleled a tributary of Granite Creek which might explain its higher organic loading.

The high organic material nutrient concentrations found in the street dirt samples taken from minor streets were not included when assigning model values because the weight of the organic material was not measured. So, the nutrient concentrations of stormwater from EIA surfaces discussed in Task Memos 5.6, 7.3 and 7.6 are likely underestimated for minor residential streets. This means the nutrient reduction benefits of street sweeping on minor streets are likely being also underestimated.

2.2 E. coli Sampling

Wood performed one round of stormwater sampling for microbial source tracking (MST) marker analysis to characterize sources of microbial contamination in order to better understand the likely sources and contributors of *E. coli* (see Wood Task 7.8 Memo - *E. coli* Sampling Activities, March 2019 for more information), MST analysis is used to identify specific host sources of fecal contamination through the extraction of bacteria group DNA and the quantitative Polymerase Chain Reaction (qPCR) amplification of unique DNA Marker Sequences, which can measure fecal pollution levels and identify the source (human or host animal / bird) of the pollution. Wood and City personnel agreed on twelve sampling locations located throughout the watershed. Locations were selected based on the following considerations:

- receiving water,
- sewered/unsewered drainage area,
- pervious/impervious area,
- likelihood of flow during a moderate rain event, and
- accessibility and safety for sampling personnel.

Sampling was performed on December 7, 2018 using standard grab sample collection methods. Given the variation in precipitation across the watershed, runoff characteristics of each drainage area, and distances between sampling locations; samples were collected during storm flow conditions towards the middle to end of the rain event, using appropriate procedures, PPE, and sample collection containers.

Samples were analyzed for the following markers:

- All markers combined
- Human
- Bovine
- Equine
- Canine
- Avian
- Javelina (preliminary marker developed at HelixBio and tested with a scat sample collected at Heritage Park Zoo)

A sample testing positive for a host source associated DNA marker indicates that the host source associated DNA marker was detected, thus confirming the presence of that host source associated DNA marker in the sample. A sample testing negative for a host source associated DNA marker indicates that the host source associated DNA marker was not detected. Note that "not-detected" should not be equated with not-present, because concentrations may have been below the detection limit of the equipment used for the analysis. In addition to presence/absence, qPCR can also be used to determine the proportional amounts of each host-source-associated DNA marker where multiple markers are detected at a collection site.

The following makers were detected at sampling locations:

- 100% of the samples were positive for Bovine marker
- 75% of samples were positive for Avian marker
- 67% of samples were positive for Human marker
- 58% of samples were positive for Canine marker
- 17% of samples were positive for Equine marker
- 8% of samples were positive for Javelina marker
- Virginia Street Wash (site #12) was the only site where all markers were detected.
- Human markers were detected predominantly in more urbanized areas.
- Upstream portions of the watershed contained predominantly Avian and Bovine markers.

There was a marked increase in occurrence of bovine marker in comparison to past results. These past analyses were conducted by the University of Arizona in 2010 as part of the work done to develop the 2012 Watershed Improvement Plan (See WIP, Appendix B – Microbial Source Tracking Methods and Results). In this study a total of 46 samples were collected across 23 sites throughout the watershed but only one tested positive for the bovine marker. There may be several reasons for this change. Some possibilities include:

1) The specific MST marker may have been different from the marker used in the past. Other ruminant animals (such as deer) may be detected by the marker used in this test, whereas past markers were more selective (specific) to cattle.
2) Increased use of or recent application of fertilizers with cow manure in the drainage area.
3) Bovine may have become the most dominant marker after contribution from human sources were reduced.

The 2010 MST found that 93% of the samples tested positive for the human maker compared to only 67% for this most recent effort which seems to indicate that ongoing sanitary sewer line repairs and other improvements by the City are working to reduce this significant source of *E. coli*. While sample results can be used to inform policy and approaches to achieve *E. coli* loading reductions, they should be viewed as a single point-in-time. The results of MST marker analysis work were incorporated into the larger watershed water quality model.

2.3 SIMPTM/LSPC Model Development

As stated previously two models were developed and implemented to address the Watershed TMDL, the LSPC and SIMPTM. While the LSPC and SIMPTM models are two separate models, they are designed and executed to be highly interrelated to depict the entire watershed.

2.3.1 Description

LSPC is a comprehensive watershed water quality and hydrologic model and SIMPTM is an urban stormwater pollutant loading model. Both models are continuous in time and are driven by the same historic precipitation record. The LSPC model was utilized to simulate the pollutant loadings from undeveloped portions of the watershed and the transport (including aggregation, transport, and deposit/degradation) pollutants of interest by the delineated waterways. SIMPTM was utilized to simulate the loading of pollutants of interest discharged from urbanized areas (i.e. referred to as EIA surfaces) of the watershed via Upper Granite Creek and major tributaries.

After developing and calibrating the baseline model (under existing conditions), Wood used the LSPC/SIMPTM model to evaluate anticipated reductions of pollutant loading for a variety of scenarios. A matrix of results from the LSPC/SIMPTM model was used to evaluate watershed-wide alternative best management practices (BMPs). The ultimate goal of the TMDL implementation planning project is to complete an evaluation of the effectiveness of various BMPs and proposed water quality facilities to reduce pollutant loads and comply with the TMDLs. Both LSPC and SIMPTM models have been calibrated, the SIMPTM model was able to establish of the baseline conditions for the EIA surfaces in the LSPC model and to evaluate the potential pollution reduction benefits of implementing high efficiency street cleaning practices.

2.3.2 Baseline

The SIMPTM model was used to simulate the sediment and associated nutrient loadings and concentrations that are being discharged from ten land use/street types found throughout the UGC Watershed these contaminants include: TSS, TKN, Nitrates + Nitrites, Total Phosphorus, and Ortho Phosphorus washoffs over a 12-year period of historic hourly precipitation that has occurred throughout the lower elevation and higher elevation portions of the watershed. Average annual pollutant loadings or washoffs from these land use/street type categories, representing baseline conditions with no street cleaning, were presented and discussed along with average annual pollutant concentrations. In addition, simulations were made of the pollutant loadings and concentrations that would have occurred over the same 12-year period, if eight different street cleaning operations involving five different sweepers have been implemented. An examination of the projected TSS washoffs and removals from washoffs was made that suggested increases in street sweeping practices on selected land use/street type categories could result in cost-effective reductions of TSS washoffs, and potentially the washoff of nutrient pollutants of interest, as well. The effectiveness of specific street cleaning operations in reducing nutrient washoffs was further investigated (see Wood Task 5.6 Memo for more information on SIMPTM model development).

The LSPC simulation of instream transport of the *E. coli* bacteria concentrations were compared with measured instream concentrations and how both simulated and measured bacterial loads changed with respect to development of the upstream drainage area. The simulated concentrations were similar to the measured concentrations. Observed and simulated bacteria concentrations both increase rapidly as developed area increased from 0 to 7 percent, and above that observed concentrations showed no dependence on area and simulated concentrations only slightly increased. Developed area includes both developed open space (pervious) and impervious areas. Simulated bacteria concentrations for each of the reaches were within the range of the measured values. One noticeable trend with the simulated bacteria concentrations was a general decrease in the concentrations with flow. This relation is because after the initial bacteria washoff and transport from the land surfaces during the beginning of a storm period, subsequent runoff has less (or none) bacteria available for further washoff. This "cleaner" runoff then dilutes the concentration of bacteria in the downstream reach. Simulated bacteria concentrations along Granite Creek from the headwater (subbasin 50) to Watson Lake (subbasin 400). Bacteria concentrations increase going downstream until they begin to level off near the 30 square mile mark and then decrease in Watson Lake. This behavior is consistent with the increase in developed area closer to Prescott (see Wood Task 5.5 Memo for more information on LSPC model development).

As part of the baseline model development, Wood incorporated three stormwater regional facilities that were listed in the 2012 Watershed Improvement Plan. Facilities included: Acker Park Regional Detention Basin Project, Rodeo Grounds Sediment Control Basin, and Whipple Street Detention Basin. Wood understands that several smaller facilities have been constructed, they are localized in nature and were not designed to affect the watershed at large (see Wood Task 7.2 Memo for more information).

2.3.3 Alternatives

After developing the baseline LSPC/SIMPTM model, Wood and the City developed a combination of alternatives that were then modeled to determine which would have the greatest impact on Water Quality. Alternatives were based on:

- Construction of additional regional facilities;
- Variation of street sweeping frequencies and equipment types; and
- Implementation of Low Impact Development Approaches (LIDA).

Quantitative results can be used to anticipate nutrient reductions (beneficial for both the Watershed Pollutant Reduction Plan as well as the Watson Lake Management Plan) and both qualitative and to a lesser extent quantitative recommendations.

3.0 WATERSHED IMPROVEMENT STRATEGY

This WPRP is intended build off the 2012 WIP to identify and prioritize specific water quality improvement projects and best management practices (BMPs) to comply with TMDL requirements in Granite Creek and its tributaries, and to support compliance with the TMDL requirements in Watson Lake Reservoir in combination with other actions described in the LMP.

3.1 Goals and Objectives

This Plan is intended to be a living document that is adaptively managed over time, so that as the City takes actions to improve water quality, and as water quality data are collected in streams and at ends of pipe to show effectiveness of those actions, further actions may be identified and recommendations may be refined.

This Plan specifically addresses efforts to reach the following goals:

- Comply with the *E. coli* TMDL and meet concentration limits by eliminating sources of human-hosted *E. coli* and by reducing sources of *E. coli* hosted by animals and birds. (Reducing concentrations in creeks after discharge is not recommended because *E. coli* is difficult to remove once it enters creeks.)

- Reduce concentrations of phosphorus (TP) in Upper Granite Creek and its tributaries in order to reduce the flux of phosphorus delivered to Watson Lake Reservoir. This is an important role in support of the Watson Lake Water Quality Management Plan (Lake Plan) because inflow from the creek dominates the mass balance in the lake and reducing influx of phosphorus is the most sustainable approach to improving lake quality for the long term. The Lake Plan provides more detail on how required lake quality depends on inflow concentrations, and a lower target of TP than the TMDL for the lake may be required in order to achieve desired reductions of harmful algae blooms.

- Other TMDLs including TN, pH, and DO do not require specific actions because by reducing sources of E. coli and loadings of phosphorus, TN is automatically also reduced as is the oxygen demand, leading to higher DO and more normal pH levels.

3.2 Existing Management Practices

The following sections describe activities that the City currently performs that can reduce pollutant loadings from the watershed.

3.2.1 Street Sweeping

Street sweeping has long been recognized as an effective best management practice (BMP) to reduce stormwater pollutants entering storm conveyance systems and receiving waters. Many stormwater professionals, including the authors of this report, believe that sweeping should be the “first line of defense” to prevent pollutants from entering the runoff stream.

In 2019, University of Florida researcher Dr. John Sansalone completed a comprehensive study that involved fourteen Florida MS4 communities, spanned a period of 12 years, and cost 1.6 million dollars. The study examined contaminated material captured by a variety of BMP facilities and concluded that street sweeping was by far the least expensive and most cost effective way to capture stormwater pollutants. For example, it found the median cost of removing a pound of phosphorus by street sweeping was $294 compared to $1,656 for catch basin cleaning, $8,511 for a baffled hydrodynamic separator, $10,521 for a screened hydrodynamic separator, and $37,243 for wet basin sedimentation followed by granular media filtration (University of Florida, 2019).

Dr. Sansalone stated in a December 2019 interview at WorldSweeper.com regarding these studies that “The recovery of particulate matter and, therefore, chemical load, is orders of magnitude greater from street sweeping compared to any other municipal BMP." With such a strong endorsement, an enhanced street sweeping program should now be used in every city and county in the country that seeks to or is required to reduce urban stormwater runoff pollution.

3.2.2 Literature Review on Bacteria Reductions by Street Sweeping

References found on the topic of bacteria removals by street sweeping and bacteria concentrations found in street sweepings or accumulated street dirt were few, and none dealt with *E. coli*. The bacteria of interest use in these studies was fecal coliform which was widely used as a standard bacteria indicator before further research suggested that *E. coli* would be a much better indicator.

Sartor and Gaboury (1984) reported that on average, one kilogram of street dirt contains 3 million colony forming units (CFU) of fecal coliform bacteria. Burnhart (undated) examined sources of bacteria in stormwater at commercial, industrial, and residential-institutional land-use sites in Wisconsin. Runoff samples were collected from streets, parking lots, roofs, lawns, sidewalks, and driveways. These samples indicated that nearly 92 percent of the bacteria originated from streets in the residential-institutional land-use site, whereas only about 33 and 19 percent of the bacteria originated from streets in the industrial and commercial land-use sites, respectively. Burnhart suggested that bacteria incubate in puddles on street surfaces between storms. He also concluded that dog feces accounted for only about 12 percent of the total bacteria at the storm-sewer outfall.

Bannerman et al (1993) reported that 78 percent of the fecal coliform bacteria load for one of the same residential land-use study subbasins studied by Waschbusch et al (1999) originated from streets. Bannerman reported that for most constituents, 75 percent or more of the total residential basin loads originate from street surfaces; total phosphorus was one of the exceptions, which originated mostly from driveways and lawns. This study also concluded that streets and parking lots are a critical source area for many contaminants in the commercial and industrial land-use areas and that best management practices that target streets and parking lots would provide the most cost-effective way for controlling contaminant loads.

Baldys et al (1998) investigated urban stormwater quality from 26 basins in Dallas–Fort Worth, Texas, and found that residential land-use basins produced higher concentrations of bacteria and nutrients than commercial and industrial land-use basins.

The following general comment regarding street sweeping as a stormwater treatment practice was offered by Zarriello et al, 2002. "Efficiencies of street sweepers in removing dirt and associated contaminants differ widely. Few studies report the sweeper efficiencies for removing phosphorus and metals, and information about the removal of bacteria by street sweeping is virtually nonexistent."

The only definitive reference Wood found on street sweeping effectiveness in reducing bacteria discharges was the 1982 report *Urban Bacteria Sources and Control by Street Cleaning in the Lower Rideau Watershed in Ottawa, Ontario* (Pitt, 1982). Pitt concluded that extensive weekly street cleaning may reduce annual fecal coliform bacteria discharges by as much as 20%, but 10% is a more likely value for large areas.

The 2002 USGS Lower Charles River Watershed study (Zarriello, et al, 2002) estimated the annual reductions in fecal coliform bacteria discharges to the Lower Charles River from a combination of structural controls and street sweeping as part of a modeling study using the Stormwater Management Model (SWMM; Huber and Dickinson, 1992). SWMM simulations were apparently well calibrated to an extensive water quality data set collected by the USGS from 1999 to 2000 (Breault et al, 2002). Reduction of constituent loads to the lower Charles River by the combined hypothetical practices of structural controls and street sweeping was estimated for a range of removal efficiencies because of their inherent variability and uncertainty. The upper estimated load reduction from combined street sweeping and structural controls, as a percentage of the total non-combined sewer overflow (CSO) load entering the lower Charles River downstream of Watertown Dam was 44 percent for suspended solids, 34 percent for total lead, 14 percent for total phosphorus, and 17 percent for fecal coliform bacteria. The lower estimated load reduction was 14 percent for suspended solids, 11 percent for total lead, 4.9 percent for total phosphorus, and 7.5 percent for fecal coliform bacteria. However. the bulk of these removals appears to have been related primarily to the assumed effectiveness of the structural controls and not the street sweeping.

Sutherland and Jelen (2003) have fully documented shortcomings with SWMM's ability to accurately model the effectiveness of street sweeping operations in reducing urban stormwater pollutants. The net result of these is that SWMM underestimates the effectiveness of street cleaning operations in removing pollutants from stormwater so the actual fecal coliform removals from street sweeping may be greater than those estimated by the 2002 SWMM simulations.

No data were found on the concentration of *E. coli* in street dirt in Prescott. Also, no data were found for Prescott that related the *E. coli* load from street surfaces to the load from other surfaces like pervious surfaces or EIA surfaces other than streets. These reasons are why *E. coli* loads from EIA surfaces were not modeled by SIMPTM as were other nutrient loads. However, Wood believes that some *E. coli* is being captured by the existing street sweeping operation and that the operation can be optimized to capture more *E. coli* as considered in this WPRP. Based on this literature search, an effective street sweeping program that involves frequent sweepings as discussed in Section 3.3.5 is expected to remove at least 10% of the *E. coli* bacteria associated with developed areas.

Wood also found that it would be helpful to monitor *E. coli* loads from a variety of streets, other surfaces, and at certain times to adaptively manage the street sweeping operation to remove more *E. coli* from stormwater runoff. For example, increased street sweeping in targeted areas or at certain times of higher rates of *E. coli* loading (ex. near areas of dense animal activity, following recreational events, etc) would more efficiently reduce *E. coli*.

Information obtained from the City in 2016 shows that the City presently owns two vacuum street sweepers and one backup mechanical broom sweeper. The City indicated in their 2016 submittal to Wood that their current practice is to sweep downtown commercial streets at least two times per week; other streets are swept about three times per year.

3.2.3 Repairing and/or Replacing Sanitary Sewer Infrastructure

For the past several years, the City has undertaken a significant project to address leaks and discharges of untreated sewage from it's sanitary sewer system. Activities have included mapping and identifying damaged or aging sections of sewer infrastructure, developing a plan to perform needed repairs, then subsequently performing improvements. A combination of pipe bursting and slip lining have been used to repair nearly 20,000 linear feet of sewer line throughout various sub-watersheds within the UGC watershed. These improvements are critical for reducing human sources of *E.coli* and other parameters of concern in meeting TMDL requirements.

3.2.4 Other Current Activities

The City is currently performing several activities that help to reduce pollutant loading throughout the watershed including the following:

- Proactively implementing an Illicit Discharge Detection and Elimination (IDDE) program and creating a website for faster reporting and follow up
- Extending sanitary sewer service into unsewered areas (first extension of sewer expected to be in design Spring of 2021 and under construction Summer 2021)
- Providing pet waste bags, dispensers, and signage at most trailheads and parks
- Incorporating LIDA in development and re-development projects
- Monitoring trails and cleaning up homeless encampments
- Offering rebates for the installation of rainwater harvesting tanks and passive rainwater harvesting gardens
- Prohibiting grey water discharges.
- Installing a publicly accessible restroom near the homeless shelter on Miller Creek and portable toilets at meal service sites (West Granite Creek Park)
- Obtaining certification for the Sundog water lab for Colilert *E. coli* quantification.

3.3 Recommended Best Management Practices and Projects

BMPs can be broadly classified as structural and non-structural measures. Structural measures consist of physical improvements, structures, or devices that are aimed at detaining, retaining, treating, or diverting stormwater through a chemical, physical, and/or biological process. Non-structural measures are focused on pollution prevention and typically require active involvement or participation. Generally speaking, structural control measures have a higher capital cost; whereas cost for non-structural controls is typically from personnel hours. The distinction may be "fuzzy" where construction occurs on a dispersed scale, such as new sewer lines or repair or replacement of existing sewer lines.

As part of this evaluation, measures were either quantitively or qualitatively assessed, depending on how well the measure's effectiveness and the contribution it would address could be quantified. Structural controls were more quantitatively assessed using modeling, and non-structural controls were more qualitatively assessed. The level of pollutant removal (particularly for non-structural controls) is dependent on the scale of the control measure implementation, consistent performance, regular maintenance, proactive monitoring, and for some, enforcement.

Wood recommends the City implement a combination of structural and non-structural controls measures. These measures are outlined along with their priorities in the table at the end of this section. The measures are then described in sections that follow.

Associated with each measure is a two-letter code: estimated effectiveness in reducing the targeted pollutants (**H**igh, **M**edium, and **L**ow) followed by estimated difficulty of implementation (also **H**igh, **M**edium, and **L**ow). A high-difficulty of implementation is either a high financial cost or a high expected difficulty of social acceptance or change.

The recommended priorities associated with the measures are as follows (see figure below):

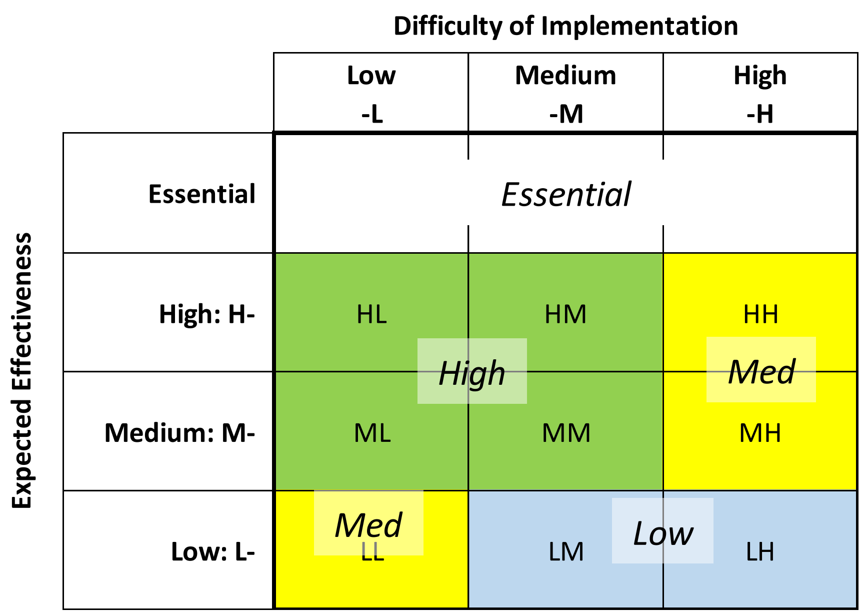
- **Essential**. Compliance with *E. coli* limit is not expected to be possible without this measure because the contribution addressed is very high and other means to address the contribution are not feasible. These measurements are recommended irrespective of cost or difficulty.

- **High**. Measure is expected to have high or medium effectiveness with medium or low difficulty of implementation (HM, HL, MM, ML).

- **Medium**. Measure is expected to have high or medium effectiveness with high difficulty of implementation, or low effectiveness with low difficulty of implementation (HH, MH, LL).

- **Low**. Measure is expected to have low effectiveness with high or medium difficulty of implementation (LH, LM). Measures with low-priority are described in less detail and are not considered further in this WPRP.

Recommended Priorities of Measures



Expected effectiveness is evaluated either qualitatively or quantitatively depending on the measure and whether it can be quantified. *E. coli* effectiveness considers concentrations and loadings in the mainstem of UGC and its tributary streams. Nutrient effectiveness focuses on concentrations and loadings at the mouth of UGC where the flow enters Watson Lake Reservoir because Lake limits are more restrictive than in-stream limits.

The following table outlines these measures and their priorities. Concise descriptions of each recommended measure or practice are in the sections that follow the table.

Structural Controls	Non-Structural Controls
Essential: • Retrofit or repair existing sanitary sewer lines **HH** • Construct new sewer lines and connect developed areas that currently utilize septic systems **HH** • Provide portable toilets at high-traffic recreation areas and homeless encampments in near-term **(HL)** and construct more permanent restrooms in long-term (**HM)** ***High Priority:*** • Identify and install private stormwater treatment systems (ex. filtration cartridges) that effectively remove or infiltrate *E. coli* and phosphorus from local areas of higher loadings (such as areas of dense animal presence, dog parks, manure lots, RV dump station portable toilet operations, etc.) **MM** ***Medium Priority:*** • Install LIDA infiltration structures in suited areas, including retrofitting trail drainage to prevent animal droppings from washing to creeks **ML** ***Low Priority:*** • Provide regional water quality treatment near Watson Woods through wetland creation and restoration. **LH**	***Essential:*** • Inspect, maintain, and monitor septic systems to ensure no release of *E. coli* until connected to sewer system **HM** • Enforce ordinance requiring connection to sewer system when system is available or for new development in septic-tank areas **HM** ***High Priority:*** • Clean minor streets monthly and arterials and collector streets weekly using regenerative air (preferred) or straight vacuum (acceptable) machines with dust control that doesn't rely on water spray **MM** • Provide pet waste bags, trash receptacles, and animal waste educational signage, in parks and other areas **ML** • Require sale and use of low/no-phosphorus fertilizer and detergents and encourage use of commercial car washes that recycle or reuse detergent **MM** • Enforce ordinance for leash requirement (PCC15-1), no feeding of wild animals, pet waste collection and disposal, and sanitation in homeless encampments **MM** ***Medium Priority:*** • Creek maintenance cleanup (debris and vegetation) **LM** • Implement yard debris collection / recycling program, prohibit dumping near streams **MH** ***Low Priority:*** • Require horse dropping pickup / collection from streets and trails that drain to creeks **LH** • Quarterly/seasonal encampment cleanup and encourage use of locations with restrooms for encampments **LM** • Restrict charitable food donations/meals to certain areas **LM**

3.3.1 Retrofit or Repair Existing Sanitary Sewer Lines

Priority Level: **Essential**	Control Effectiveness: **High**	Cost: **High**	Difficulty: **Medium**	Targeted Pollutants: ***E. coli*, TP, Others**
Method Description	Eliminate routine and preventable leaks and overflows from existing sanitary sewer lines / collection system that is in some places up to 90 years old; leaks release raw untreated sewage to streams with high concentrations of nutrients and bacteria including *E. coli*			
Anticipated Load Reduction	100 percent of pollutants from this contribution would be eliminated permenantly; the fraction of total load from this source cannot be quantified until this action is completed and more sampling is undertaken.			
Resources Required (public, regulatory, technical, financial)	No additional CIP funding is required because this essential measure is already included in the existing CIP budget. This measure is a one-time long-term solution per segment of infrastructure, but routine inspections and maintenance are an ongoing effort.			
Schedule and Milestones	Work is presently ongoing and should continue as an essential measure.			
Future Monitoring and Effectiveness Verification	Ongoing dye testing in sewer lines and monitoring of *E. coli* in creeks to identify leaks / confirm leaks are addressed.			
Cost & Time-Effectiveness Comparison	Measure is expensive but highly effective and essential in order to comply with requirements for *E. coli* reduction.			
Resources and Barriers	None except cost; work is already in progress by City.			

3.3.2 Connect Septic-Tank Systems to New Sanitary Sewer System in Developed Areas

Priority Level: **Essential**	Control Effectiveness: **High**	Cost: **High**	Difficulty: **High**	Targeted Pollutants: ***E. coli*, TP, Others**
Method Description	Eliminate septic tank systems in developed areas and connecting those areas to the public sewer system.			
Anticipated Load Reduction	100 percent of pollutants from this contribution would be eliminated; the fraction of total load from this source cannot be quantified until this action is completed and more sampling is undertaken.			
Resources Required (public, regulatory, technical, financial)	Public: CIP funding for construction of new sewer lines; private or CIP, funding for sewer connections (Sewer Commission expansion tentatively scheduled to begin construction Summer of 2021). This measure is a one-time long-term solution per segment of infrastructure, but inspections and maintenance are an ongoing effort.			
Schedule and Milestones	The City already has ordinances that require connection to the public sewer system when a line is extended to an unsewered property or when an unsewered property develops / redevelops.			
Future Monitoring and Effectiveness Verification	Ongoing monitoring of human markers to better understand how much *E. coli* and total phosphorus (TP) are contributed from septic-tank areas and their reduction with connection to the sewer system.			
Cost & Time-Effectiveness Comparison	Measure is expensive but highly effective and required in order to comply with requirements for *E. coli* reduction.			
Resources and Barriers	Public resistance in septic-tank areas, particularly if owners do not see when private systems fail. Also, shallow bedrock may increase difficulty and cost, but similar areas with shallow bedrock inside City limits have sewer lines.			

3.3.3 Provide Toilets at Recreation and Homeless Encampment Areas

Priority Level: **Essential**	Control Effectiveness: **High**	Cost: **Low to Medium**	Difficulty: **Low**	Targeted Pollutants: ***E. coli*, TP, Others**
Method Description	Portable toilets (near-term) and permanent toilets (longer-term) will eliminate human fecal matter from entering streams from these areas. Rerouting or strategically allowing food-donation to take place farther upstream from surface waters.			
Anticipated Load Reduction	100 percent of pollutants from this contribution would be eliminated; the fraction of total load from this source cannot be quantified.			
Resources Required (public, regulatory, technical, financial)	Public: Providing portable toilets is a low-cost approach; CIP, parks and recreation, or other funding could fund permanent facilities depending on location served. This is a one time up front installation of restrooms that will have some minimal long-term maintenance needs.			
Schedule and Milestones	The City has started installing permanent restrooms. Portable units are provided and regularly serviced while permanent restrooms are built.			
Future Monitoring and Effectiveness Verification	Ongoing monitoring of human hosted *E. coli* in creeks to track reduced concentrations in conjunction with Prescott Creeks and Prescott College's Butte Creek Restoration Council. The size of this source's contribution is unknown.			
Cost & Time-Effectiveness Comparison	Measure is inexpensive in the near-term using portable toilets and moderately expensive in the longer term but highly effective and required in order to comply with requirements for *E. coli* reduction.			
Resources and Barriers	Work is already in progress; cost and perception of enabling homeless presence are possible barriers.			

3.3.4 Identify and Treat or Divert Stormwater from Concentrated Sources of *E. coli*

Priority Level: **High**	Control Effectiveness: **Medium**	Cost: **Medium**	Difficulty: **Medium**	Targeted Pollutants: ***E. coli*, TP, Others**
Method Description	Identify localized sources of high loadings and install stormwater treatment systems to remove or infiltrate *E. coli* and TP. Areas might include high concentrations of animals like Rodeo Grounds, dog parks, manure lots, RV dump stations, portable toilet operations, etc.			
Anticipated Load Reduction	High reduction of loading from these areas but the fraction of total load from this source is likely low, thus the “medium” effectiveness.			
Resources Required (public, regulatory, technical, financial)	Funding is by owner of the area – City, private, or another public agency. This is a one time up front cost for installation of restrooms and will have some long-term maintenance needs.			
Schedule and Milestones	Data collection is needed to identify areas of concentrated sources; runoff from sources should not exceed the target limit for *E. coli* or phosphorus. The implementation can occur.			
Future Monitoring and Effectiveness Verification	Monitoring of *E. coli* and phosphorus from localized site runoff to track reduction or elimination of elevated pollutant concentrations.			
Cost & Time-Effectiveness Comparison	High cost-effect for monitoring and identifying these sites. High-concentration sites need to be addressed because there is no “room” in receiving water to dilute their runoff. It’s cost-effective to reduce these concentrations also.			
Resources and Barriers	Interagency cooperation if owned by other public agencies; private owner resistance to perceived government interference.			

3.3.5 Street Cleaning at Frequent Intervals

Priority Level: **High**	Control Effectiveness: **Medium**	Cost: **Medium**	Difficulty: **Low**	Targeted Pollutants: ***E. coli*, TP, Others**
Method Description	Reduce accumulation of pollutants on streets before it washes off to streams through targeted and seasonal sweeping schedules. Clean minor street types monthly and arterials and collector street types weekly for full year period using regenerative air (preferred) or straight vacuum (acceptable) machines with fugitive dust control that doesn't rely on water. Reduce sweeping of the downtown area to once per week from twice per week.			
Anticipated Load Reduction	Varies by frequency, land use type, type of street cleaning unit, and subbasin elevation (rainfall) (see Task 7.3 Memorandum for details).			
Resources Required (public, regulatory, technical, financial)	City funding for staff and for equipment purchase, operations, and maintenance. Disposal fees are required, but those are small fraction of the total cost. This is a long-term recurring requirement.			
Schedule and Milestones	City already sweeps City streets; recommendation is to refine focus to achieve improved water quality benefit (see Task 7.3 Memorandum for details).			
Future Monitoring and Effectiveness Verification	Data collection and monitoring of direct runoff from EIA surfaces / end-of-pipe (before entering streams) to compare baseline (no-sweeping) and with-sweeping with focus on *E. coli* and phosphorus.			
Cost & Time-Effectiveness Comparison	Street cleaning is the most cost-effective way of reducing pollutants available for washoff since it is much cheaper than trying to remove pollutants from the stream once they are present or to remove pollutants from the discharge locations where these pollutants enter the streams.			
Resources and Barriers	Cost. Public perception of street cleaning is usually a positive factor. However there may be a need for mandatory removal of parked cars during sweeping in some portions of the City. This could lead to some public resistance, but parking enforcement fees would offset the cost of sweeping.			

3.3.6 Pet Waste Collection in Parks and Similar Areas with Signage and Enforcement

Priority Level: **High**	Control Effectiveness: **Medium**	Cost: **Low**	Difficulty: **Low**	Targeted Pollutants: ***E. coli*, TP, Others**
Method Description	Provide pet waste bags, trash receptacles, and animal waste educational signage, in parks and other areas where dogs are walked. Includes informational signage discouraging feeding birds and other waterfowl (particularly around Watson Lake), and increased parks patrols for enforcement. Compliance training for voluntary park rangers and bicycle patrol police officers.			
Anticipated Load Reduction	Cannot be quantified, but parks and trails may easily drain to streams so the reduction is a good, low-cost method to help with *E. coli* compliance.			
Resources Required (public, regulatory, technical, financial)	Cost for bags, trash receptacles, and signage is expected to be low. Private businesses can be encouraged to “sponsor” pet waste bag dispensers. This is a long-term, recurring practice with some upfront cost as well as seasonal efforts.			
Schedule and Milestones	Identify pet waste bag sites and educational signage, then identify gaps. Train Parks, Code Enforcement and volunteer park rangers to identify and report problem areas.			
Future Monitoring and Effectiveness Verification	Monitor *E. coli* concentrations in runoff from park lawns and pavements where waste might collect. Reductions will be difficult to discern especially when mixed with other stream flow.			
Cost & Time-Effectiveness Comparison	Good cost-effectiveness because of low cost.			
Resources and Barriers	Low cost and positive public perception / acceptance expected.			

3.3.7 Low-/No-Phosphorus Detergents and Fertilizers

Priority Level: **High**	Control Effectiveness: **Medium**	Cost: **Low**	Difficulty: **Medium**	Targeted Pollutants: **TP**
Method Description	Require sale and use of low-/no-phosphorus fertilizer and detergents in watershed and encourage use of commercial car washes that recycle or reuse detergent, to reduce import of phosphorus that discharges to creeks.			
Anticipated Load Reduction	Moderate reduction expected; lawns are the largest source of phosphorus in residential areas and a high source in other areas; overapplication of fertilizer with phosphorus results in high concentration in runoff entering creeks.			
Resources Required (public, regulatory, technical, financial)	Requires ordinance adoption and working with points of sale and extensive public education / awareness of need. This is a low-cost method, but the medium difficulty reflects need for public acceptance. This is a long-term practice involving mostly time commitment.			
Schedule and Milestones	Can be quickly implemented because of low cost, but time required for public acceptance.			
Future Monitoring and Effectiveness Verification	Monitoring of phosphorus in EIA surface runoff, especially from residential areas, can show decrease over time.			
Cost & Time-Effectiveness Comparison	Good cost-effectiveness because of its low cost to City and no cost to private parties.			
Resources and Barriers	Public acceptance and possible perception that non or low-phosphorus detergents are less effective, and resistance to public regulation.			

3.3.8 Ordinances to Prohibit Feeding Wild Animals / Dog Leashes / Pet Waste / Sanitation in Camps

Priority Level: **High**	Control Effectiveness: **Medium**	Cost **Low**	Difficulty: **Medium**	Targeted Pollutants: ***E. coli*, TP, Others**
Method Description	Enforce ordinances for dogs-on-leash requirement (PCC 15-1-15), no feeding of wild animals (PCC 5-3-16), pet waste collection and disposal (PCC 5-3-4), and sanitation in homeless encampments (PCC 7-6-1).			
Anticipated Load Reduction	The ordinances themselves do nothing to reduce loadings, but they provide enforcement of other actions in this WPRP that will have medium effect in reducing pollutant loadings. The reduction cannot be quantified.			
Resources Required (public, regulatory, technical, financial)	Requires ordinance enforcement and extensive public education / awareness of need. This is a low-cost method, but the medium difficulty reflects need for public acceptance. This is a long-term practice involving mostly time commitment.			
Schedule and Milestones	Can be quickly implemented because of low cost, but time required for public acceptance.			
Future Monitoring and Effectiveness Verification	Monitoring of *E. coli* and phosphorus in runoff is discussed with the methods that are supported by these ordinances.			
Cost & Time-Effectiveness Comparison	Good cost-effectiveness because of its low cost to City and no cost to private parties.			
Resources and Barriers	Public acceptance and resistance to public regulation.			

3.3.9 LIDA: Low-Impact Development Approaches

Priority Level: **Medium**	Control Effectiveness: **Low**	Cost: **High to Low**	Difficulty: **Medium**	Targeted Pollutants: ***E. coli*, TP, Others**
Method Description	Install LIDA infiltration structures in suited City owned areas, including retrofitting trail drainage to prevent animal droppings from washing to creeks. Require the use of LIDA for any new development and redevelopment of parcels where physical and soil characteristics safely allow such a practice.			
Anticipated Load Reduction	Load reduction varies with type of pollutant and type of LIDA. Infiltration-type LIDA (with no underdrain) would remove almost all pollutants in the fraction of volume infiltrated. Flow-through / vegetative-filter type LIDA will have lower removals as dissolved fractions (about half for TP) will pass through and low-density pollutants like *E. coli* will not settle easily. (See Task 7.5 Memorandum for details on overall areawide LIDA effectiveness)			
Resources Required (public, regulatory, technical, financial)	LIDA is high cost to construct, particularly if the sole purpose is retrofitting of the existing upland drainage system with LIDA (not recommended). LIDA can be very cost-effective from the City's vantage point for new development since the costs are borne by the developer; when LIDA is added to a redevelopment project that would be constructed anyways the cost is low to medium depending on the extent of the work being undertaken. This is a long-term high-maintenance practice recurring regularly.			
Schedule and Milestones	Ongoing and likely long-term since LIDA would be most cost-effective when installed as part of other street projects.			
Monitoring and Effectiveness Verification	Monitoring inflow and outflow from LIDA, before flow enters creeks, can show changes in concentration; monitoring of infiltration LIDA needs to monitor flow rates to observe reduction in volume and pollutant flux.			
Cost & Time-Effectiveness Comparison	Varies widely depending on if only added to projects that would be constructed regardless of LIDA (moderate cost-effective) or LIDA-only retrofit (low cost-effective).			
Resources and Barriers	Cost and public perception can both be barriers.			

3.3.10 Creek Corridor Cleanup and Maintenance

Priority Level: **Medium**	Control Effectiveness: **Low**	Cost: **Low**	Difficulty: **Medium**	Targeted Pollutants: **TP, Others**
Method Description	The creek corridor is periodically walked and observed, and excess vegetation is removed or trimmed to reduce the decay of elevated vegetation in developed areas from entering creeks. This also includes monitoring for debris dumping.			
Anticipated Load Reduction	The load reduction is unknown; the reduction may be low, and the source may be small relative to others. The LSPC model assumes that nutrient reductions from inflows such as street sweeping recover quickly without the user actually specifying the amount of nutrient supply available. This measure will reduce the actual nutrient supply and may turn out to be more effective than estimated.			
Resources Required (public, regulatory, technical, financial)	Staff time to walk or observed creeks and facilitate volunteers including local residents to support creek observation. Training for Parks and Recreation staff and volunteers and posted information on pollution reporting proceeedures for the public. This is otherwise a low-cost method, but it might identify other needs with their own cost. This is a long-term maintenance practice.			
Schedule and Milestones	Implementation can occur rapidly, but time should be allowed to build public acceptance for and interest in participating in creek observation.			
Future Monitoring and Effectiveness Verification	This method is its own monitoring by walking or otherwise observing the creek. TP monitoring instream before and after corridor clean up could quantify the effectiveness of this measure.			
Cost & Time-Effectiveness Comparison	Good cost-effective approach for observing creek conditions while fostering increased connection between residents and their creeks.			
Resources and Barriers	Perception of government regulation. However, this measure can foster stronger connections between the public and the streams.			

3.3.11 Yard Debris Collection and Recycling

Priority Level: **Medium**	Control Effectiveness: **Medium**	Cost: **Low**	Difficulty: **High**	Targeted Pollutants: **TP, Others**
Method Description	Implement yard debris collection and recycling program and prohibit dumping near streams to prevent elevated rates of decay of vegetation that release elevated phosphorus and other nutrients to the creeks.			
Anticipated Load Reduction	Phosphorus and other nutrients enter the creeks from decomposition of natural vegetation near the creek. This method reduces high decomposition by collecting debris that could otherwise accumulate near the creek.			
Resources Required (public, regulatory, technical, financial)	Partnership with waste collection agent/private industry and possible expansion of current seasonal green waste pick-up. Extensive public education and acceptance would be required to move from the typical tendency to dump yard debris in or along creeks. This is a high up-front-cost maintenance practice with routine maintenance.			
Schedule and Milestones	Implementation would take time during which agreements are developed, infrastructure is constructed, and public acceptance is built.			
Future Monitoring and Effectiveness Verification	This is likely a lower-fraction source relative to others and would be difficult to observe in the creek. Monitoring would be qualitative by observing increase or reduction of debris piles in creek corridor when walking the creek.			
Cost & Time-Effectiveness Comparison	City cost is low but cost to others is higher and leads to high difficulty of implementation. Moderate cost-effectiveness, depending on fraction of phosphorus arising from this source and if, after higher priority actions are completed, further reductions in phosphorus are still needed.			
Resources and Barriers	Public resistance to increased cost of refuse collection, and to government regulation. Need for supporting infrastructure to process debris.			

3.3.12 Provide Regional Water Quality Treatment above Watson Lake Reservoir

Priority Level: **Low**	Control Effectiveness: **Low**	Cost: **High**	Difficulty: **Medium**	Targeted Pollutants: **TP, Others**
Method Description	Provide regional water quality treatment to reduce phosphorus and other nutrient loading into Watson Lake Reservoir. Watson Woods is a dedicated USACE Fee in Lieu site. Wetland creation and restoration would allow the City to Partner with organizations such as Prescott Creeks and tap into available and designated funds for the use of wetlands as nutrient sinks.			
Anticipated Load Reduction	The load reduction was low based on LSPC modeling conducted (see Task 7.4 memorandum for more information).			
Resources Required (public, regulatory, technical, financial)	Providing regional treatment in the Watson Woods area (just upstream of the Lake) may be expensive and medium difficulty because of low stream gradient, difficult soil conditions, land ownership, and other constraints. Funding would be needed, but this could be achieved through the fee in lieu program. This is a high-maintenance one-time practice that is time consuming but once implemented does not require routine maintenance.			
Schedule and Milestones	Time is needed to refine site selection if needed, advance the concept to preliminary design, obtain funding, and develop a design that makes the best use of the available land. A conservation easement at this site would prevent its development and help it persist as a fee-in-lieu site serving as a nutrient sink.			
Future Monitoring and Effectiveness Verification	Monitoring of inflow and outflow rates and concentrations will show the effectiveness of this facility to reduce concentrations both by infiltration and by settling by looking at reduced concentrations and mass balance.			
Cost & Time-Effectiveness Comparison	Such a facility is less cost-effective than other measures because of its high cost and only partial effectiveness at removing pollutants.			
Resources and Barriers	A facility near the lake is more effective than the same facility further upstream in the watershed, but removals are only partially effective because dissolved pollutants (including a large fraction of the phosphorus) pass through the facility			

	with little or no treatment. Infiltration may provide higher removals but would be less feasible in the creek channel near Watson Lake Reservoir. Further upstream, any reductions would be lessened by the time flow reached the lake.

3.3.13 Other Low-Priority Methods

Several other methods were identified and evaluated as low-priority. These were not given their own sections or figures in this plan, but are summarized as follows:

- Require horse dropping pickup and collection from streets and trails that drain to creeks. Horse droppings are sources of *E. coli* that can wash into creeks. The method was deemed low effectiveness because the source is likely to be not very high compared to several others and is too difficult to quantify without additional monitoring activities. This method was deemed to be of a high difficulty because, even though it is low cost, the public resistance would be expected to be high. This source is in part already addressed by the method to retrofit trails using LIDA to reduce runoff with high concentrations of *E. coli* (**Section 3.3.9**).

- Specific and targeted street sweeping and thorough cleanup after parades, specifically seasonal ones like the Rodeo parade before monsoon season. This targeted cleanup would fall under the realm of seasonal sweeping (**Section 3.3.5**).

- Quarterly or seasonal cleanup of homeless encampments and continued city support and partnership with CCJ's cleanup efforts. The litter in these camps can be sources of elevated *E. coli* and other pollutants. This method was deemed low effectiveness because the source is likely lower than several others and is too difficult to quantify without additional monitoring. This method was deemed to be of a medium difficulty to implement because, even though it might have a low cost, particularly if volunteers are included, public resistance or other difficulties might be higher. This source is in part already address by the method to provide toilets to high-traffic recreation areas and homeless encampments (**Section 3.3.3**).

3.4 Future Monitoring

Compliance with watershed TMDLs, including supporting compliance with TMDLs for Watson Lake Reservoir, is an ongoing process of identifying needed actions, taking those actions, and monitoring conditions in the watershed to see results and potentially a need for further actions.

3.4.1 Water Quality Monitoring

The following monitoring activities are recommended to improve quantification of sources, including areas with higher-concentration runoff, and inform adaptive management and implementation of this Plan:

- Continued MST Marker testing. As part of this study effort, only one new data set was obtained. Some trends and correlations were identified when these results were compared to earlier MST Marker testing reported in the 2012 WIP. However, a regular and consistent monitoring program of MST Marker testing is recommended to observe changes over time and establish a better record of *E. coli* sources by host group. This will become increasingly important as the sewer rehabilitation project becomes more substantively complete to identify and track host-specific sources of observed areas contributing higher levels of *E. coli*. Based on historic efforts, the labor and analytical cost to perform one round of sampling for MST Marker Testing at 12 locations throughout the watershed for one storm event, equated to approximately $7,000. To identify fluctuations and trends in source contributors, Wood suggests 1 round of MST marker testing per wet season at 8 to 10 locations with written documentation including any trends discovered and coordination with additional *E. coli* data being collected annually (see the next items). This would cost approximately $15,000 to $20,000/year.

- Continued *E. coli* sampling in runoff from developed areas including dilution of samples by 10- and 100-times to avoid readings that are limited by the maximum detection limit (i.e. when there are too many colony forming units that they overlap and cannot be counted). This testing should include creek concentrations, direct runoff from various urban surfaces (to characterize EIA surface washoff), end-of-pipe concentrations (see below), and washoff from localized high sources (e.g. rodeo grounds, dog park, parks with high waterfowl, etc.). This will allow for better understanding of actions that might be needed to address local "hot spots".
- Conduct end-of-pipe *E. coli* monitoring of specific outfalls to focus on runoff from EIA surfaces. This testing should compare multiple land use types (e.g. residential and commercial) and compare with and without street cleaning in order to characterize their contribution and the potential for street cleaning to reduce *E. coli* loadings to creeks.
- Monitor inflow and outflow concentrations and rates of flow at multiple LIDA facilities. This will show locale-specific LIDA performances. Concentration reductions will characterize flow-through types of LIDA (e.g. grass / vegetation filters). Flow and concentrations will be multiplied to compare mass into and out from the LIDA structure to characterize infiltration-type LIDA.

3.4.2 Scientific Investigations

The following scientific studies are recommended to improve identification of new strategies for achieving targeted reductions, evaluate the effectiveness of measures under consideration from this Plan, and inform adaptive management and implementation of this Plan:

- Test the pick-up performance of the City's currently owned sweepers. Tests would use a street dirt simulant that mimics the particle size distribution of the street dirt found throughout Prescott and would test the machines at multiple speeds. Tests could include brand new sweeper models on loan from participating local dealers and national sweeping manufacturers to be used by the City for future purchases. Depending on the number of street sweepers being tested from say 3 to 7 this one-time activity along with its written documentation would cost approximately $20,000 to $30,000.
- Conduct a comprehensive analysis of street dirt accumulation and characterization by land use/street type categories that focuses on *E. coli*, phosphorus, and other nutrients from curbed streets but also including some sampling of uncurbed streets when possible. Depending on the number of street dirt sampling sites identified (Wood sampled sixteen sites in June 2017), the number of sampling events where one sample is collected at each site, and most importantly the logistics associated with testing the street dirt samples for *E. coli* concentrations with holding times not to exceed 6 hours. This one-time activity along with its written documentation would cost approximately $70,000 to $90,000.
- Study how street sweeping effectiveness is affected by parked car interference in regular street sweeping operations on the various land use/street type categories. The study would evaluate the need for mandatory parked car removal regulations for those street segments throughout the City where parked cars are found to significantly reduce street sweeper effectiveness by excessively blocking access to the curb. This type of study would provide the City with an understanding of where parked cars are significantly reducing the effectiveness of street sweeping operations for water quality benefits. Findings would include expected increase of

mass of pollutants being removed from the stormwater discharges, how much the implementation of the program would originally cost and how much annual revenue is likely to be obtained from the mandatory program's enforcement. This one-time activity along with its written documentation would cost approximately $50,000 to $75,000.

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TABLES

Table 1 – Water Quality Standards for TN, TP, DO, and pH

Analyte	Verde River and tributaries	A&Wc	A&Ww	FBC	AgI	AgL
TN (mg/L) SSM Annual Mean	 3.0 1.0					
TP (mg/L) SSM Annual Mean	 1.0 0.1					
DO (mg/L)		7.0	6.0			
pH (SU)		6.5-9.0	6.5-9.0	6.5-9.0	4.5-9.0	6.5-9.0
Narrative Standard	"A surface water shall not contain pollutants in amounts or combinations that cause the growth of algae or aquatic plants that inhibit or prohibit the habitation, growth, or propagation of other aquatic life or that impair recreational uses."					

Source: Watson Lake TMDL: Total Nitrogen, DO, pH, & Total Phosphorus Targets, ADEQ, February 2015.

Table 2 – Aggregated Loads and Allocations (G-cfu/day*)

TMDL Static Load Sites	Target Flow (cfs)	TMDL Target Load	Existing Load	Percent Reduction	Natural Background	Total Allocation	LA 50%	WLA 50%	Concentration Target (cfu/100 mL)
Lower USGS Gauge #0950300	53	304.52	4,200.30	92.8	18.98	295.54	144.77	144.77	**235**
Upper USGS Gauge #09502960	18.3	105.15	2,070.57	94.9	18.98	86.17	43.085	43.085	**235**

*G-cfu/day = 1 billion cfu/day = *E. coli* concentration (#cfu/100ml) * cfs (discharge) * conversion factor of 0.02446
Source: Final Upper Granite Creek Watershed E. coli *TMDL, ADEQ, November 2015.*

Table 3 – Existing Loads, Load Capacity, and Allocations

Conditions/Allocations	Annual Loading to Watson Lake Reservoir	
	TN (lbs/yr): lbs/day	TP (lbs/yr): lbs/day
Existing Conditions	10,888/365 = 29.83	2,228/365 = 6.12
Loading Capacity (LC) 34% TN Reduction 32% TP Reduction	7,186/365 = 19.69	1,515/365 = 4.15
Natural Background (NB) 10% of LC for TN 15% of LC for TP	1.97	0.62
Margin of Safety (MOS) (10% of LC)	1.97	0.42
Available Capacity (LC – NB – MOS)	15.75	3.11
Waste Load Allocation (WLA)	2,874/365 = 7.88	568/365 = 1.56
Load Allocation (LA)	2,874/365 = 7.88	568/365 = 1.56
% reduction from existing	47%	49%

Source: Watson Lake TMDL: Total Nitrogen, DO, pH, & Total Phosphorus Targets, ADEQ, February 2015.

Table 4 – Breakdown of WLA and LA Based on Jurisdiction/Ownership

Ownership Categories	Watershed Area (%)	Watershed Area (sq mi)	TN WLA (lbs/day)	TP WLA (lbs/day)	TN LA (lbs/day)	TP LA (lbs/day)
Unallocated WLA Reserve 10% ADOT Other TBD			0.80	0.16		
City of Prescott	39	17.56	5.66	1.12		
Yavapai County (unincorporated)	10	4.46	1.42	0.28		
Total	49	22.02	7.88	1.56		
Unallocated LA Reserve 15% TBD					1.18	0.23
Prescott National Forest	40	18.11			5.90	1.17
State Land	5	2.24			0.74	0.015
Military	0.2	0.08			0.06	0.001
Total	45.2	20.43			7.88	1.56

Source: Watson Lake TMDL: Total Nitrogen, DO, pH, & Total Phosphorus Targets, ADEQ, February 2015.

Table 5 – Standards and Water Quality Targets

Granite Creek & Tribs Nutrient Targets: Annual Mean Verde Standards Applied to Stormflow (mg/L)		Watson Lake Nutrient Targets: Modeled Targets to Meet Annual Mean Verde Standards (mg/L)		Watson Lake pH Standard (SU)	Watson Lake Surface DO Standard (mg/L)	Watson Lake Deep DO Standard (mg/L)
TN	TP	TN	TP	6.5-9.0	6.0	2.0
1.0 *	0.1 *	0.8 **	0.06 **			

Source: Watson Lake TMDL: Total Nitrogen, DO, pH, & Total Phosphorus Targets, ADEQ, February 2015.
Notes: (*) Granite Creek and tributaries will actually be limited to the lower standard for Watson Lake
(**) Lower limits may be required than these in Watson Lake and Granite Creek and tributaries in order to limit formation of harmful algae blooms

Figure 1

E.coli Source Map

Legend
Homeless Key Locations
E. Coli Sources
Animal Sources
Public Park Sources
Dump Sites
Sampling Location
Impaired Waters
Impaired
Non-Attaining
Stream
Sewer Line
State Route
Watson Lake
Yavapai Prescott Indian Community
Prescott National Forest
Sewered, Developed Areas
Unsewered, Developed Areas
Unsewered, Undeveloped Areas
Subbasins
Impervious Surface (%)
0 - 20
20 - 40
40 - 60
60 - 80
80 - 100
Notes:
Sampling Location Positive Hits
All All Bacteria
Av Avian
Bo Bovine
Ca Canine
Eq Equine
Hu Human
Jav Javalina
Prescott Water Quality Compliance
FIGURE X
Overview Map
0 1,000 2,000 4,000 6,000 Feet
N
The map shown here has been created with all due and reasonable care and is strictly for use with Wood Environment & Infrastructure Solutions, Inc. Project Number 37-2015-6008. This map has not beencertified by a licensed land surveyor,and any third party use of this map comes without warranties of any kind. Wood Environment & Infrastructure Solutions, Inc. assumes no liability, direct or indirect, whatsoever for any such third party or unintended use.
Job No. 37-2015-6008
PM: RS
Date: 4/9/2020
Scale: 1" = 2000'
1 - All, Av, Bo, Hu
2 - All, Bo, Ca
3 - All, Av, Bo, Ca, Hu
4 - All, Av, Bo, Ca
5 - All, Av, Bo
6 - All, Bo, Ca, Hu
7 - All, Av, Bo, Hu
8 - All, Av, Bo, Ca, Hu
9 - All, Av, Bo, Ca, Eq, Hu
10 - All, Bo, Hu
11 - All, Av, Bo
12 - All, Av, Bo, Ca, Eq, Hu, Jav
Watson Lake Park
Granite Creek
Lower Granite Creek Trail (Horses)
Prescott Solid Waste Division
Peavine Trailhead (Horses)
Yavapai Humane Society
Watson Woods Trail (Horses)
Slaughterhouse Gulch
North Fork Miller
North Granite Creek
Rodeo Grounds
Rodeo Grounds Trail (Horses)
Flinn Park
A.C. Williams Granite Creek Park
Miller Creek
Butte Creek
Butte Creek Trail (Horses)
Creature Comforts Pet Vacations
Doggie Walkers, Inc.
Acker Park
Government Canyon
Virginia Street Wash
Ackers East
Aspen Creek
Aspen Creek Trail (Horses)
Rancho Vista Trail (Horses)
Manzanita Creek
Goldwater Lake
Banning Creek
89
69