Granger Drain
Fecal Coliform Bacteria
Total Maximum Daily Load

2013 Adaptive Management Monitoring Report

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For more information contact:

Washington State Department of Ecology
Central Regional
Water Quality Program
15 West Yakima Avenue Suite 200
Yakima, WA 98902

Phone: 509-454-7888

Washington State Department of Ecology - www.ecy.wa.gov/

Headquarters, Olympia	360-407-6000
Northwest Regional Office, Bellevue	425-649-7000
Southwest Regional Office, Olympia	360-407-6300
Central Regional Office, Yakima	509-575-2490
Eastern Regional Office, Spokane	509-329-3400

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by

Greg Bohn
Water Quality Program
Central Regional Office

Washington State Department of Ecology
Yakima, Washington

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Introduction

The Granger Drain is one of the principal irrigation return drains in the lower Yakima Valley that discharges to the Yakima River. Historically, this drain has been a source of several agricultural pollutants. In 1996, the Granger Drain was placed on the Washington State's (State's) list of impaired waters because of fecal coliform bacteria (FCB) concentrations in excess of the State's water quality standards (WQS). FCB is the principal group of bacteria that is found in the manure of warm-blooded animals and humans. The State utilizes FCB as a measure of bacteria pollution and the potential for disease that could affect persons that come into contact with the polluted water.

Placement on the impaired water body list (the 303(d) list) requires the development of a total maximum daily load (TMDL). The Washington State Department of Ecology (Ecology) published the *Granger Drain Fecal Coliform Bacteria TMDL* (Publication #01-10-012) in 2001. The report determined that the "critical condition" for FCB pollution was during the local irrigation season (April to mid-October). The TMDL hypothesized that irrigation-induced overland runoff from agricultural fields was the principal transport mechanism of FCB pollution reaching the watershed's surface waters. The report also included an analysis of the 1997-2000 monitoring data, which showed a highly significant and moderate correlation between FCB concentrations and total suspended solids (TSS) concentrations. Bacteria have a strong affinity to adsorb onto very fine particles of TSS and can travel substantial distances while suspended in the water column.

Physiography and Topography

The Granger Drain watershed covers an area of approximately 62 square miles, and is located within an intensively irrigated agricultural area in eastern Washington State along the Interstate 82 corridor. Watershed elevations range from 740 feet (ft.) in the valley floor to 3,020 ft. along its northern border. The Granger Drain watershed lies in the Yakima fold belt near the western margin of the Columbia Plateau physiographic province. The watershed is bounded on the north by the Rattlesnake Hills and on the south by Snipes Mountain (see Figure 1, below).

The watershed contains sediments that are characterized by 29 generalized soil series. However, the majority (>95%) of the soil in the cropland's areas is represented by deep silt loams of moderate permeability and high available water capacity. The permeability causes only minor retention and attenuation of nutrients that infiltrate beyond the root zone. This results in a significant potential for groundwater contamination from the application of liquids onto the soil surface.

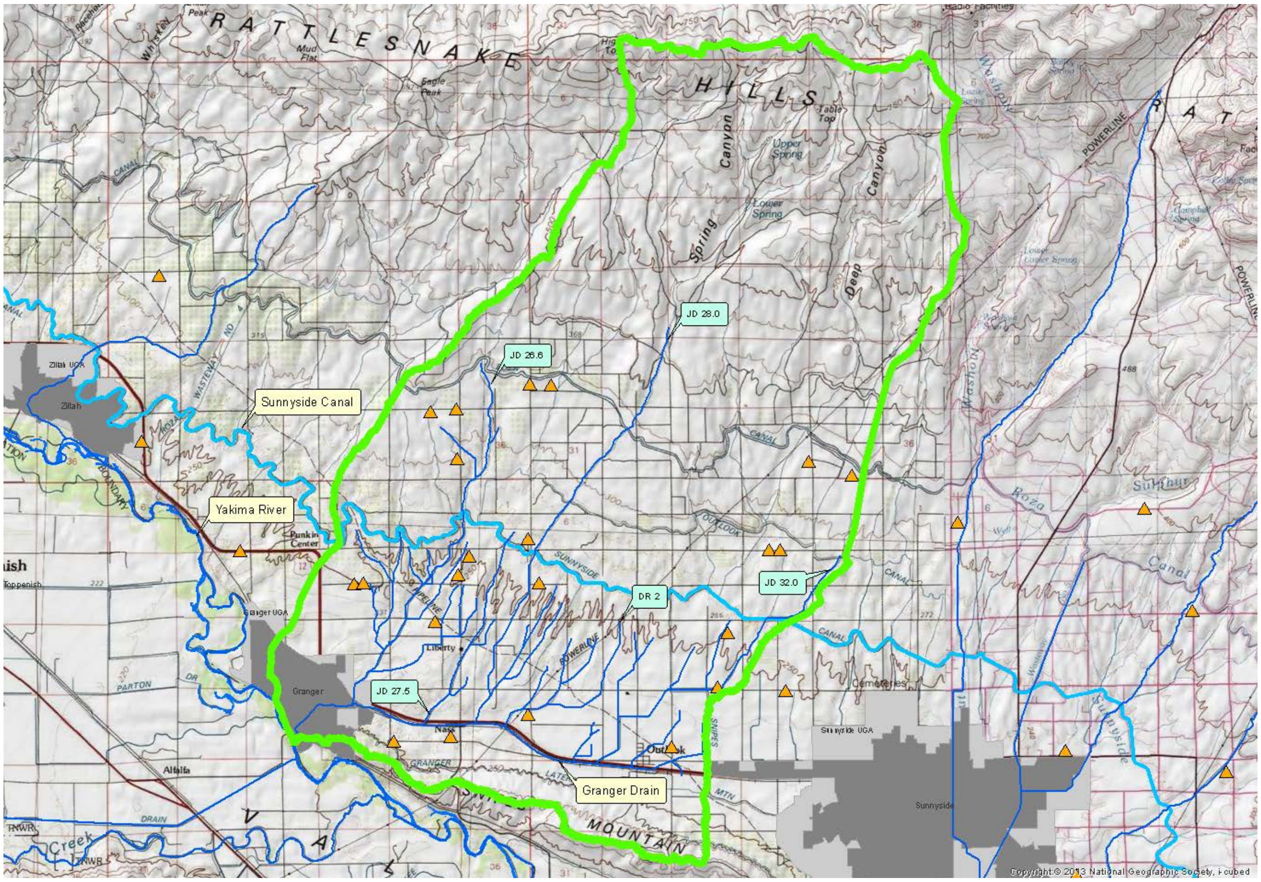

Figure 1 Granger Drain watershed location

Climate

The Granger Drain watershed is located within the rain shadow of the Cascade Mountains, and its climate is semi-arid with hot, dry summers and cold winters with limited snow and rain. During 1948-2012, the average minimum and maximum temperatures were 39.4°F and 65.5°F, respectively. The warmest months are July and August with average highs of 87.2 and 86.5°F, respectively. The coldest months are December and January with an average low of 20.5°F for both months. The hottest temperature recorded was 110°F in August 1971. The coldest temperature recorded was -25°F in February 1950.

During 1948–2012, the average annual precipitation was 8.26 inches. The driest year recorded was 1999 with a scant 1.33 inches of precipitation, while the wettest year recorded was 1995 with 12.92 inches of precipitation. The majority of precipitation occurs between November and March, with less than one inch occurring between April and October. Snowfall is common in December and January and averages 10.36 inches per year. July and August usually are the driest months with an average of 0.29 inches of precipitation per month.

The watershed's agricultural growing season is 180 to 210 days long and occurs from April through October. Due to minimal precipitation during that period, local agricultural crops need an average of 36 inches of irrigation water. This amount of irrigation combined with the moderate permeability of the watershed's agricultural soil results in substantial irrigation return flows. The return flows are composed of both overland runoff and subterranean inflow.

Land Use and Population

The major agricultural land-use activities within the Granger Drain watershed are irrigated cropland (55%), pastures (7%), and rangeland (37%). The major crops within the watershed are corn, wine and juice grapes, asparagus, alfalfa, forage grasses, pasture, and animal feeding operations (AFOs). The watershed's AFOs are principally in the form of dairies; three of the dairies have NPDES permits because they are classified as concentrated animal feeding operations (CAFOs). Most local dairies grow their own feed (alfalfa and corn). Zuroske (2009) reported that approximately 29% of the irrigated cropland in the watershed is owned by its 20+ dairies (Figure 2).

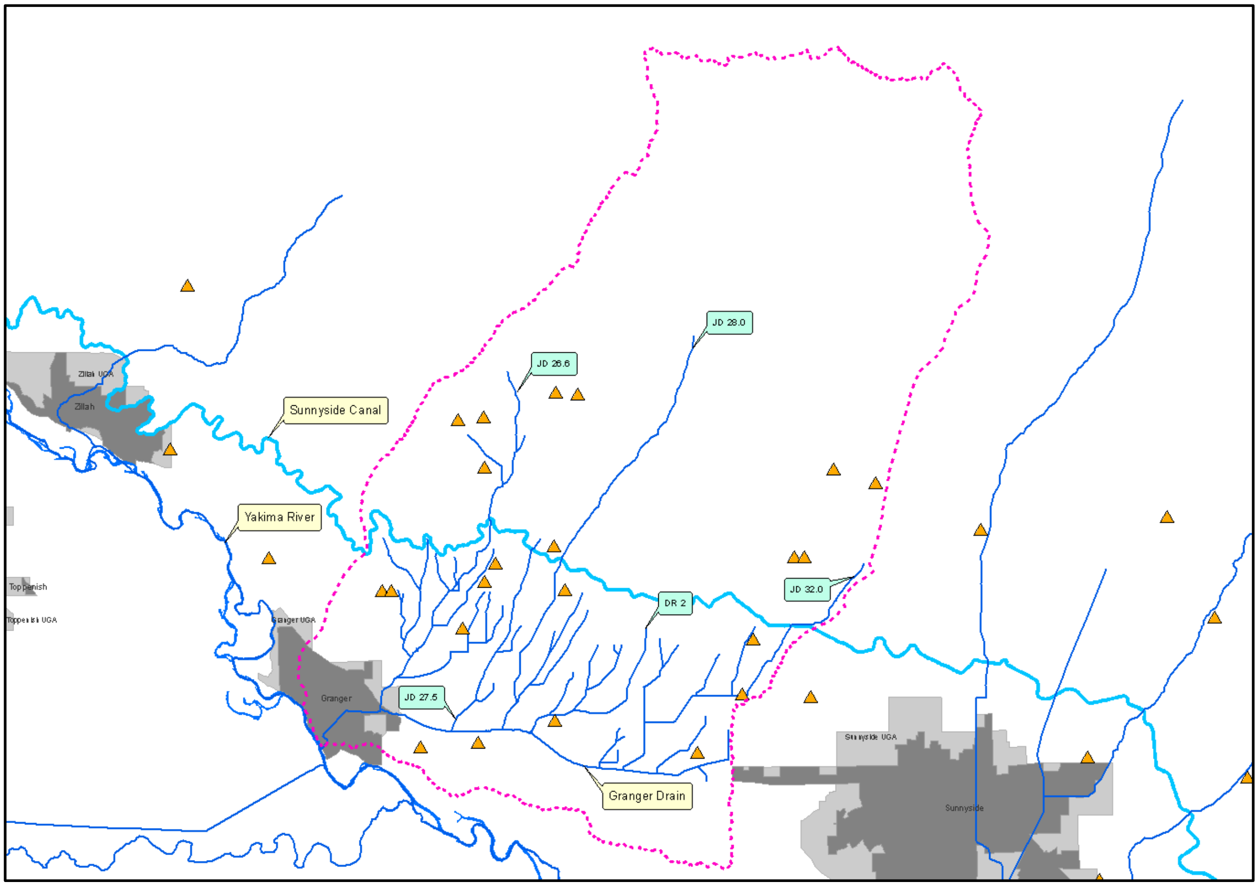

Figure 2 Granger Drain watershed dairy locations

Several rural residences, with associated septic tanks, are dispersed throughout the watershed. The greatest concentration of population is in the city of Granger (population of 3,246), which is located in the southwest portion of the watershed. The small community of Outlook (population of 292) is located in the southeast portion.

Hydrology

Prior to agricultural development in 1893, sagebrush and smaller desert shrubs covered much of the Granger Drain watershed. Historical documents provided no indication of year-round flowing or standing water in the watershed. The typical groundwater depth range was from 50 to 100 feet.

In 1889, Walter M. Granger started the Yakima Canal and Land Company. Realizing the potential for huge profits from sales of irrigated land compared to non-irrigated lands, he began the construction of the Sunnyside Canal in 1891. The 1900 Annual Report to Congress of Irrigation and Drainage acknowledged that the Yakima River was over-appropriated by stating that: “it would require about four times the average flow of the [Yakima] river for the months of August, September, and October to supply the [irrigation] ditches in service and those projected.” Upon widespread irrigation, the local water table rose to within 4 feet of the land surface and began rendering large tracts of land unsuitable for agriculture by turning them into seasonal wetlands or concentrating alkali in their soils.

In 1906, the U.S. Secretary of the Interior settled conflicting water right disputes by awarding 147 second-feet of the Yakima River to the Yakama Tribe and 650 second-feet to the other parties. This was a precondition for the federal government taking over the irrigation systems and constructing new storage capacity. The Sunnyside Canal was then sold to the U.S. Reclamation Service (now the U.S. Bureau of Reclamation, or USBR) and the agency began construction of an extensive irrigation supply and drainage systems. The USBR also initiated 1,082,000 acre-feet of storage capacity in the surrounding mountains.

The Granger Drain is part of the Sunnyside Division of the USBR’s Yakima Project. The watershed contains 13.8 miles of surface and 26.9 miles of subsurface drainage systems from 4 to 54 inches in diameter. Irrigation return water collected via the surface and subsurface systems is the principal source of pollutants such as suspended sediments, high temperatures, pesticides, nutrients, fecal coliform, and metals to the Yakima River (Ecology, 1997; US Army Corps of Engineers, 2011). Many fields within the watershed also contain tile drainage (see Figure 3, below) which is installed below a crop’s root zone for preventing groundwater levels from saturating a crop’s roots and to flush away salts. The exact amount and placement of the tile drains is not entirely known.

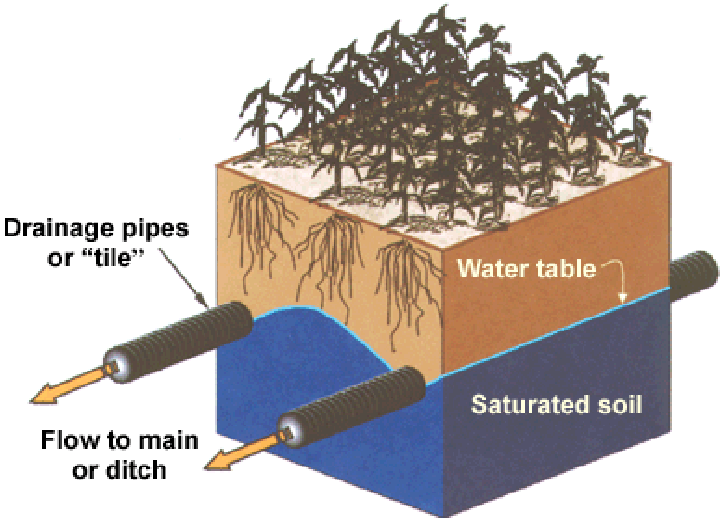

Figure 3 Subsurface tile lines in operation

(Diagram courtesy of University of Minnesota Extension)

Subsurface drainage systems typically utilize numerous surface inlets (Figure 4, below) that act to equilibrate air pressure for facilitating gravity drainage. However, those same inlets can also allow the entrance of surface runoff which at times is polluted by manure applications (see Figure 5, below). Sylvester and Seabloom (1962) found that subsurface drainage in the Yakima Valley "... at times contains some surface drainage that entered ... directly through vents, holes or other piped connections."

Figure 4 Surface inlet

(Photo courtesy of University of Wisconsin Extension)

Figure 5 Liquid manure application runoff into surface inlet in Granger Drain watershed

The Sunnyside Valley Irrigation District (SVID) and Roza Irrigation District (RID) divert water from the Yakima River, and then deliver the irrigation water to farms in the Granger Drain watershed. Irrigation return flows subsequently enter the mainstem Granger Drain via surface and subsurface drainage systems. The Granger Drain runs parallel to Interstate 82 and the Yakima Valley Highway, flowing east to west. The drain begins one-quarter mile east of the community of Outlook and flows west to the City of Granger. Nearing the City of Granger, the drain turns southwest and passes around the city's southern edge. It finally discharges into the Yakima River at river mile 82.8.

There are five tributary drains entering the mainstem Granger Drain from the north, as it flows from east to west: Joint Drain (JD) 32.0, DR2, JD 28.0, JD 27.5, and JD 26.6 (refer to Figure 2, pg 6). Although no formally identified drains exist on the south side of Interstate 82, two small ravines drain to the north, pass underneath Interstate 82, and discharge into the Granger Drain.

Flow in the drain is highest during the summer irrigation season and lowest during the winter non-irrigation season. During the irrigation season, the average flow in the drain ranges between 34 and 52 cubic feet per second; whereas, the non-irrigation season average flow ranges between 18 and 21 cubic feet per second. The vast majority of the drain flow during the irrigation season is irrigation return flow. Even during the non-irrigation season, base flow is composed primarily of shallow groundwater that originates as infiltrating irrigation during the previous irrigation season. In support of that, the USGS (2009) determined that the isotopic signature of the DR2 drainage water is similar to that of shallow groundwater and the SVID Canal.

Analysis of the downstream drainage from the watershed shows that the dissolution of applied fertilizers and manure accounted for virtually all nitrate and many other solutes. Thus, the USGS (2009) concluded: "This work indicates that combining irrigation and artificial-drainage networks may exacerbate the ecological effects of agricultural runoff by increasing direct connectivity between fields and streams and minimizing potentially mitigating effects of longer subsurface pathways such as denitrification and dilution."

Statement of Problem

Researchers have historically attributed excessive FCB pollution in the Granger Drain and its tributaries to over-application of livestock manure throughout the watershed. In 2009, 53,820 milk cows produced 1.45 million tons of wet manure in the Granger Drain watershed. The majority of the watershed's dairy manure is spray-applied as a diluted liquid onto dairy-owned land (Figure 6). Solid manure (Figure 7, below) is usually transported to non-adjacent fields.

Figure 6 Spraying liquefied manure

Figure 7 Spreading solid manure

The problem of excessive FCB pollution associated with the Granger Drain watershed has been reported since the 1970s:

1. Ecology’s 1973 *Technical Report No. 73-002: Yakima River Water Quality Report: December 1970 – September 1971* stated that there was a tendency for FCB concentrations near Granger to reach “... significant proportions during the summer [irrigation season].”
2. Ecology’s April 1975 publication *Water Resources Information System Technical Bulletin No. 8* found the FCB concentration in the Granger Drain to be far in excess of the State’s WQS. The report concluded that “it appears that bacteria present ... are of animal original”, and that “individual farm operations are the significant cause of pollution in irrigation return flows.”
3. In 1976, Ecology’s publication #76-17 *Water Quality Assessment Yakima River Basin* indicated that Yakima River samples collected below the outfall of the Granger Drain showed an increase in FCB concentrations, which was reported as coming principally from animal sources.
4. The U.S. Army Corps of Engineers, *Yakima Valley Regional Water Management Study* (1978), wrote that FCB concentrations “reach their maximum value ... immediately downstream of Granger” and was due to the “large concentration of confined livestock” located in the Granger Drain watershed.
5. In its June 1986 *Priority Waterbody Assessment of the Lower Yakima River*, Ecology stated that: “Irrigation return flow is the single most significant source of pollutants in the lower Yakima River.” The report concluded that “…individual farm operations are the most significant cause of pollution in irrigation return flows.”
6. In 1992, the USGS stated that: “Most of the [FCB] exceedances in the mainstem [Yakima River] occurred downstream from Granger … [and] could be attributed to increases in the number of livestock in the basin.”
7. An October 1, 1993 drain log record of an employee of the SVID stated that he had been told that farmers were complaining about "cow manure in the irrigation laterals [to the Granger Drain]." Exhibit #24 in 2001 WL 1704240 (E.D.Wash.), 52 ERC 1167: CARE v. Henry Bosma Dairy.
8. The South Yakima Conservation District (SYCD), in its *1995-97 Water Quality Implementation/Competitive Grant Application*, stated that: “The high bacterial loading [to the Granger Drain] does reflect mismanagement of animal waste in storage and application.” FCB concentrations were found to be as high as 160,000 cfu/100mL in the drain’s effluent.
9. In 1997, the Roza-Sunnyside Board of Joint Control (RSBOJC) reported an irrigation season FCB geomean of 622,575 cfu/100mL in JD 26.6, just above the SVID Canal.

During the irrigation season, upstream JD 26.6 flows are diverted into the canal; during the off-season, these flows are sent to Granger Drain.

10. The Washington State University Cooperative Extension (1998) stated that: “Dairy manure is added to much of the Granger Drain [watershed] … [which] results in an easy disposal system for dairy manure and relatively low priced fertilizer for row crops.”

11. In June 1999, two large dairies (Liberty Dairy and Henry Bosma Dairy) were sued by “third-parties” for repeatedly discharging wastewater into JD 26.6 since 1993. In court, it was determined they had actually been discharging to the drain since the 1980s.

12. The October 2001 *Granger Drain Fecal Coliform Bacteria TMDL Assessment and Evaluation* found that FCB pollution was significantly correlated to acreage of row-crops. Surface agricultural return waters were identified as the principal transport system of bacteria.

13. The SVID’s summer 2002 edition of *The Waterfront* indicated that majority of *E. coli* bacteria found in the Granger Drain watershed were from bovine sources according to a microbial tracking study.

14. The USBR (2002) stated that: “High volumes of manure and water are often applied to lands that are directly connected to surface drains or underlain by subsurface tile drains.”

15. In 2009, the RSBOJC published its *Water Quality Conditions in Irrigation Waterways within the Roza and Sunnyside Valley Irrigation Districts, Lower Yakima Valley, Washington, 1997-2008*. The report stated that: “The [State] fecal coliform standard was exceeded at the mouth of Granger [Drain] ... during each irrigation season”.

Historical Monitoring

Several agencies have collected samples in the Granger Drain, over several years. However, the SYCD conducted extensive sampling in 1991 and prepared a report (Zaragoza, 1992) which established a baseline for FCB pollution in the sub-basin. Ecology conducted a small set of sampling during 1994-95. In 1997, the RSBOJC initiated a permanent water quality improvement program, which included construction of an in-house water quality laboratory and annual widespread water quality sampling throughout its jurisdiction.

The sampling site that represents the entire mainstem Granger Drain watershed is located downstream within the City of Granger and known historically as “at the sheep barns” or “site #24”. Figure 8, below, presents the geomean and statistical threshold value (STV) FCB concentrations from 1997 to 2013 at site #24. All of the bacteria data was collected and analyzed by the RSBOJC. All data passed adequate sampling and laboratory quality control requirements.

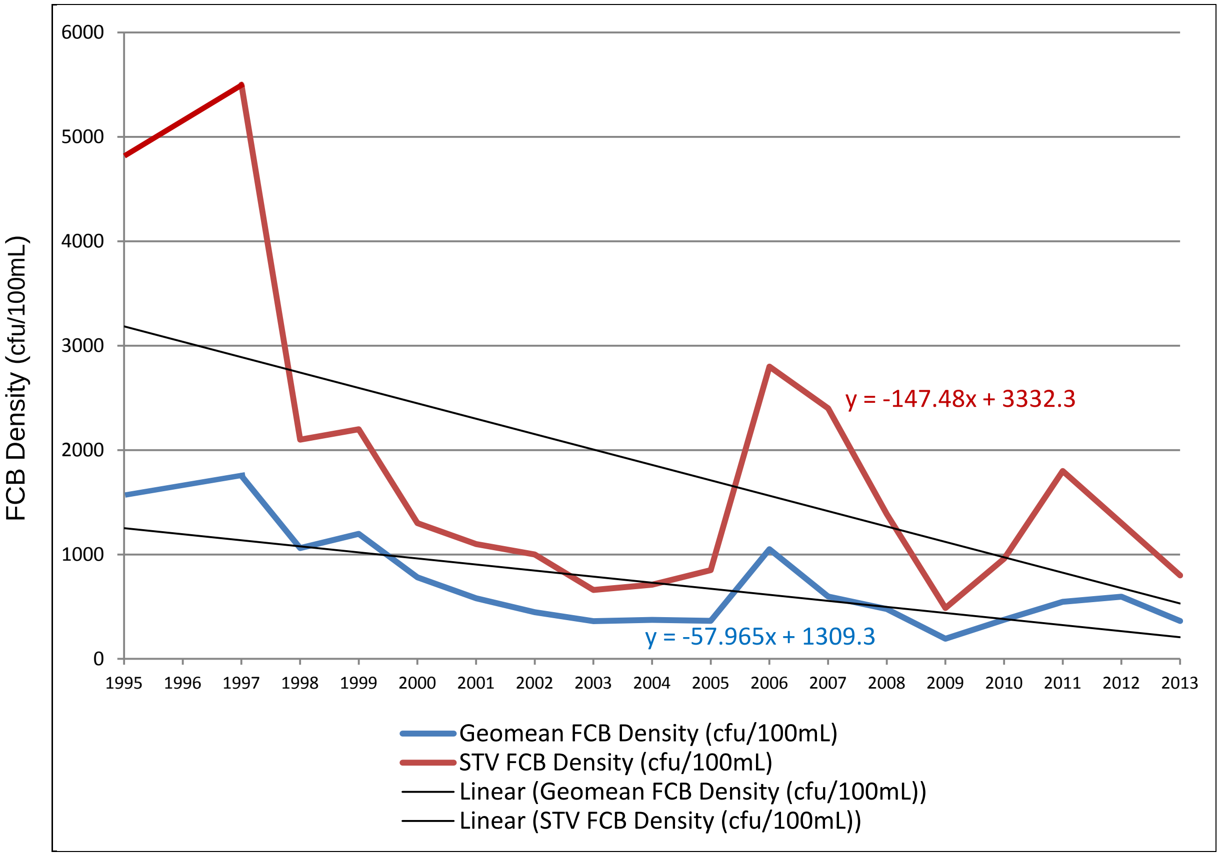

Figure 8 Irrigation season geomean and STV FCB densities: 1995-2013

The 2013 FCB concentrations are significantly (K-S = 2.34, $p < 0.001$) less than those of 1995. Using the linear trend equations given in Figure 8, the geomean (blue) and STV (red) FCB densities have decreased 83.8% and 83.4%, respectively, during the past 19 years. Even with this substantial decrease, the data did not meet the *Granger Drain Fecal Coliform Bacteria TMDL*'s final target of full compliance with the State's WQS in the 2012 irrigation season. That year's actual geomean and STV FCB densities were still 2 and 3 times greater than the State's criteria of 100 and 200 cfu/100mL, respectively. Thus, a new target date for full compliance with State standards is required by the "adaptive management" section of the TMDL.

According to the linear trend equations given in Figure 8, the State water quality geomean FCB criterion (100 cfu/100mL) is projected to be met in the 2014 irrigation season. However, the STV FCB criterion (200 cfu/100mL) is projected to be met in the 2016 irrigation season. Consequently, the TMDL's new target date for full compliance with State WQS for bacteria is the 2016 irrigation season. This is 4 years later than the original target.

Since its inception in 1996, the RSBOJC has: (1) prohibited livestock in waterways; (2) required a 20-ft. no-till buffer zone between crops and waterways; (3) enforced a maximum of 300 NTU in irrigation return flows; and (4) prohibited illicit connections to waterways. Correspondingly, this has resulted in over a 95% reduction in TSS discharges via the Granger Drain to the Yakima River since 1996.

Turbidity is the principal water quality parameter measured by the RSBOJC for estimating the amount of TSS in irrigation return water. Figures 9 and 10 (below) illustrate the linear correlations between $\log_{10}$ TSS concentrations and $\log_{10}$ turbidity values during the irrigation and non-irrigation seasons, respectively, at site #24 for the combined years of 1997 - 2012.

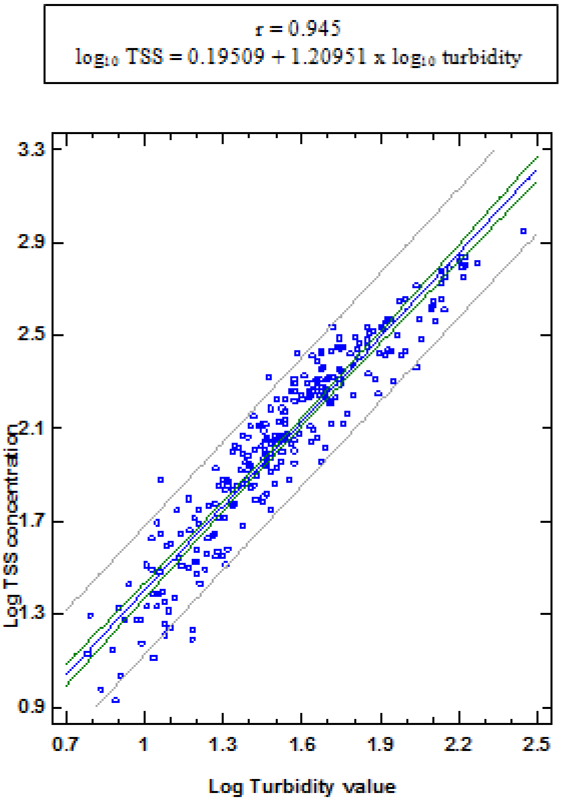

Figure 9 Log_{10} TSS vs. $\log_{10}$ turbidity: 1997-2012 irrigation seasons

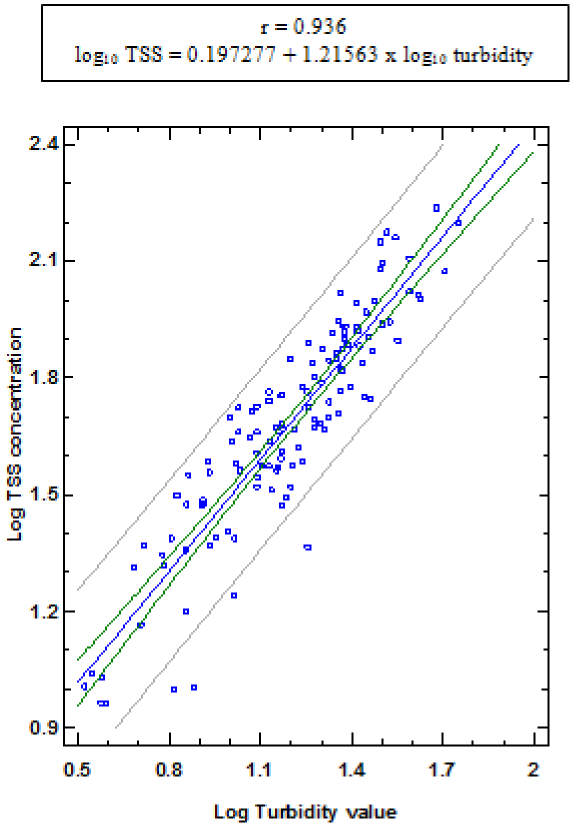

Figure 10 Log_{10} TSS vs. $\log_{10}$ turbidity: 1997-2012 non-irrigation seasons

Correlation coefficient (r) values range from 0 to 1 and represent the strength of correlations, with values greater than 0.8 reflecting strong correlations. Correlation coefficients less than 0.2 reflect weak (poor) correlations. The correlation between TSS and turbidity during both seasons at site #24 is very strong ($r > 0.9$).

Although correlation coefficients (r) are a measure of the correlation strength, the coefficient of determination (r^2) is a predictive measure of the amount of variability in one parameter that is determined by another parameter. Squaring the correlation coefficient for Figure 9 determined that 89.3% of the variability in TSS during the irrigation seasons was associated with turbidity. Figure 10 determined that 88.0% of the variability in TSS during the non-irrigation seasons was associated with turbidity. Because of the year-round very strong correlation between turbidity values and TSS concentrations, turbidity was determined to be an excellent surrogate for measuring TSS concentrations.

Various studies have also shown a strong correlation between FCB and turbidity (McSwain, 1977; Christensen, 2001; Rasmussen and Ziegler, 2003). Some of those studies have determined that when FCB is strongly correlated with turbidity, bacteria sources are predominantly associated with overland runoff and/or resuspension of bacteria-laden sediments (Lawrence, 2012).

Figures 11 and 12 illustrate the linear correlations between $\log_{10}$ FCB concentrations and $\log_{10}$ turbidity values during the irrigation and non-irrigation seasons, respectively, at site #24 for 1997 - 2012.

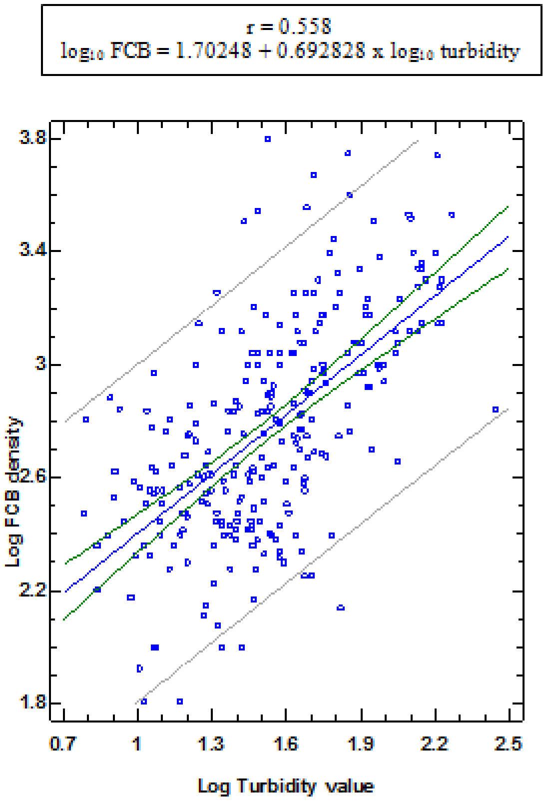

Figure 11 Log_{10} FCB vs. $\log_{10}$ turbidity: 1997-2012 irrigation seasons

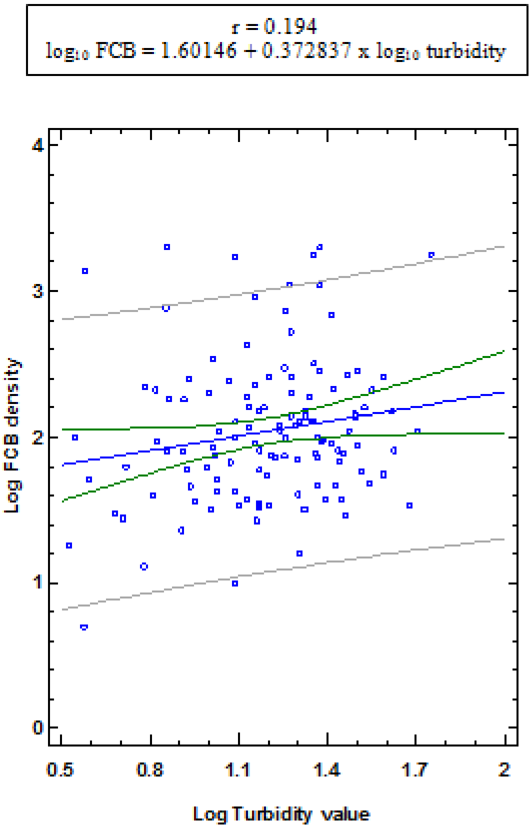

Figure 12 Log_{10} FCB vs. $\log_{10}$ turbidity: 1997-2012 non-irrigation seasons

For the combined 1997 – 2013 years, Granger Drain turbidity and FCB concentrations are moderately correlated (r = 0.558) during the irrigation seasons, and only weakly correlated (r = 0.194) during the non-irrigation seasons. Squaring the correlation coefficient for Figure 11 determined that 31.1% of the variability in FCB during the irrigation seasons was associated with turbidity. Whereas, Figure 12 shows that only 3.8% of the variability in FCB during the non-irrigation seasons was associated with turbidity. This dichotomy suggests that the predominant FCB sources are different between the two agricultural seasons.

Lawrence (2012) found a similar seasonal FCB dichotomy between storm flows and dry weather flows for the Chattahoochee River near Norcross, Georgia. That study concluded that two different sources of *E. coli* bacteria exist. The low correlation between FCB and turbidity during dry weather was associated with point sources. However, the high correlation between FCB and turbidity during wet weather was associated with non-point sources (surface runoff).

Overland runoff has historically been the predominant non-point source of irrigation season bacteria in the Granger Drain due to that season's comparatively stronger correlation between FCB and turbidity. Whereas, the weak correlation during the non-irrigation season suggests a different predominant source of FCB pollution that has no association with turbidity (e.g. illicit sanitary connections, subsurface irrigation drainage, failing septic tanks, direct discharge by animals, and potentially point source discharges).

In addition to the combined 1997 – 2013 data, there appears to have been a dramatic shift in annual FCB sources. Table 1, below, presents the annual irrigation season r^2 values for linear regressions between $\log_{10}$ FCB and $\log_{10}$ turbidity values from 1997 to 2013. The r^2 values ranged from 0.010 in 2013 to 0.672 in 2000 and showed no easily discernible pattern.

Although the tabularized annual r^2 values were highly variable, a definite linear downward trend appears when observing a graphical representation of the same data (Figure 13, below). Based on the linear equation, the annual irrigation season r^2 values have decreased 72% (from 0.477 to 0.134), where x = 1 (for 1997) and x = 17 (for 2013). In 1997, approximately 48% of the FCB pollution in the mainstem Granger Drain was determined by turbidity; however, by 2013, only 13% of the FCB pollution was determined by turbidity. The decreasing trend in r^2 values suggests a shift away from overland runoff as being the predominant source of FCB pollution during the irrigation season.

Table 1. Irrigation season linear regression r^2 values between $\log_{10}$ FCB densities and $\log_{10}$ turbidity values: 1997 - 2013

Year	N	r^2 value
1997	16	0.224
1998	34	0.600
1999	13	0.651
2000	15	0.672
2001	14	0.436
2002	13	0.250
2003	28	0.182
2004	32	0.120
2005	14	0.041
2006	27	0.228
2007	25	0.535
2008	28	0.161
2009	28	0.461
2010	27	0.081
2011	27	0.363
2012	14	0.173
2013	14	0.010

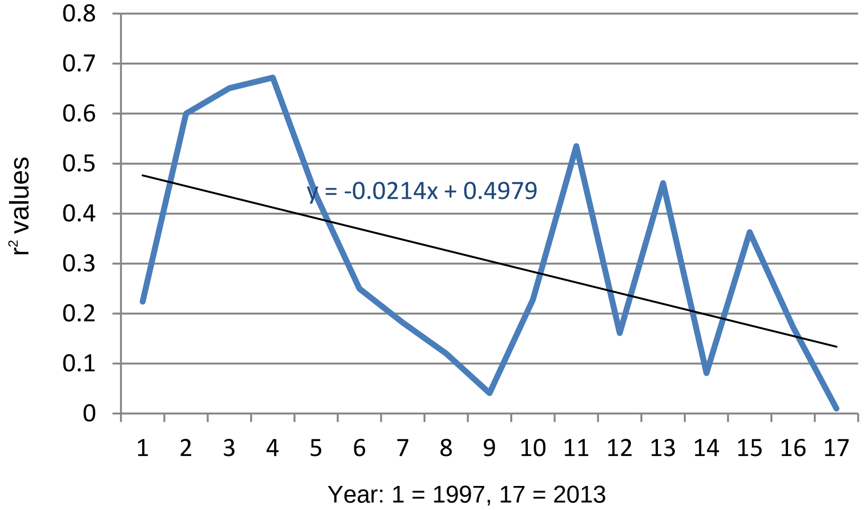

Figure 13 Irrigation season linear regression r^2 values between $\log_{10}$ FCB densities vs. $\log_{10}$ turbidity values: 1997 - 2013

The shift in FCB sources also acknowledges that previously hypothesized predominant FCB source (irrigation return waters) and the corresponding BMPs for mitigating both TSS and FCB in overland runoff were correct and effective. Those BMPs should remain in place throughout the Granger Drain watershed to prevent back-sliding. However, the majority of future TMDL BMP efforts should now be directed at discovering and mitigating pseudo-point sources of FCB pollution. Pseudo-point sources are those legally classified as non-point sources, but which have characteristics of point sources. They include subsurface tile drainage, failing septic tanks, direct deposition by animals, and illicit sanitary connections.

Adaptive Management Monitoring

From September 2011 through November 2013, the RSBOJC conducted adaptive management monitoring (AMM) throughout the Granger Drain watershed in order to locate FCB hotspots. The monitoring was required because the TMDL’s final target limit (compliance with State water quality FCB criteria in the 2012 irrigation season) was most likely not going to be met. The AMM utilized the surrogate bacteria species of *E. coli* and the Colilert®/Quantitray® analysis methodologies (IDEXX) to allow for greater efficiency of limited resources.

Sixty-one sampling sites (Figure 14, below) were specifically chosen by the RSBOJC to help track the sources of greatest bacterial contamination in the various tributaries to the Granger Drain. Subsequent BMP implementation would then be first directed at those sources in order to maximize mitigation efficiency. All distances specified in the later tributary descriptions are approximate.

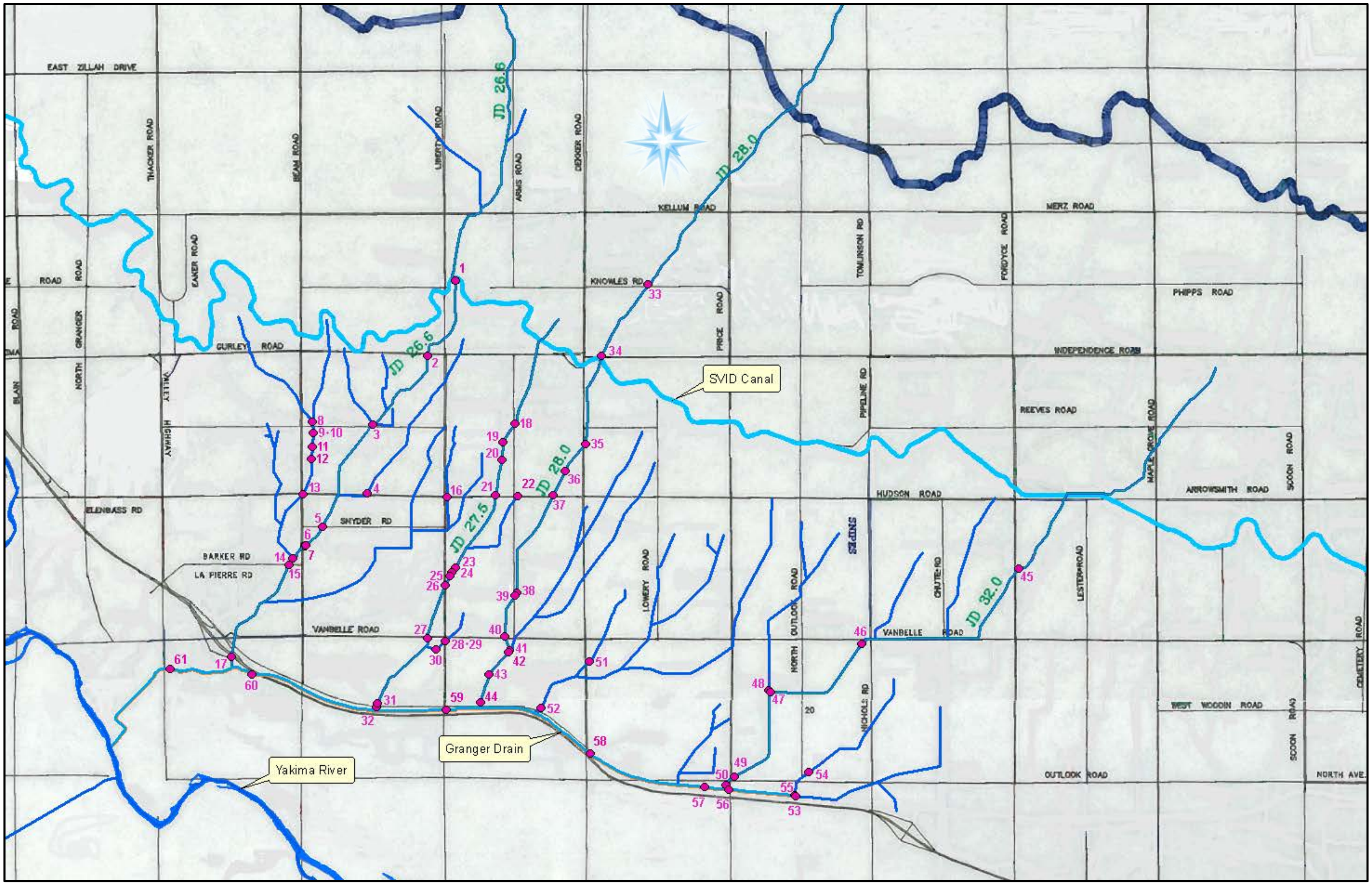

Figure 14 Adaptive management monitoring sites along mainstem Granger Drain and its tributaries

Table 2 presents the sampling site interchange guide between the original RSBOJC site ID numbers and the present AMM site ID numbers.

Table 2. AMM sampling site interchange guide

AMM Site ID	RSBOJC Site ID	Sampling Site Descriptions (In order from upstream to downstream)
JD 26.6		
1	1.1	JD 26.6, just downstream of SVID Canal in undershoot
2	1.25	JD 26.6, just south of Gurley Rd., just west of Liberty Rd., downstream of site 1
3	1.5	JD 26.6, just south of Nelson Rd., between Liberty and Beam Rds., downstream of site 2
4	1.75	DR 25 tributary, confluence is downstream of site 3
5	2	JD 26.6, just north of Snyder Rd., downstream of site 4, upstream of wetlands
6	WL1E	JD 26.6 side pipe, effluent from NW wetland
7	WL1F	JD 26.6 side pipe, effluent from SE wetland
8	2.54	DR 25 tributary, manhole just north of Nelson Rd.
9	2.55	DR 25 tributary, manhole south of Nelson Rd.
10	2.53A	DR 25 side pipe, 2” PVC, new manhole in pasture south of Hudson Rd., downstream of site 8
11	2.53B	DR 25 tributary, new manhole in pasture south of Hudson Rd., downstream of site 8
12	2.52	DR 25 tributary, east of Beam Rd., between Hudson and Nelson Rds., downstream of sites 9 & 10
13	2.51	DR 25 tributary, manhole in SE corner of intersection of Hudson and Beam Rds., downstream of site 11
14	2.5	DR 25 tributary, north of Barker Rd., west of Beam Rd., downstream of site 12
15	2.75	JD 26.6, just north of Barker Rd., west of Beam Rd., downstream of site 5, downstream of wetlands and discharges from site 13
16	7.8	DR 25 tributary, confluence is downstream of site 14
17	3	JD 26.6, east of Shell Gas Station, downstream of site 14 and discharges from site 15
JD 27.5		
18	5.3	JD 27.5, just west of Arms Rd, due east of end of Nelson Rd.
19	5.31	JD 27.5, just west of Arms Rd, south of Nelson Rd, at Gate #2, downstream of site 17
20	5.32	JD 27.5, just west of Arms Rd, at Gate #3, downstream of site 18
21	6	JD 27.5, just north of Hudson Rd, at Gate #4, downstream of site 19
22	5.4	DR 2 tributary, manhole at NE corner of Arms and Hudson Rds., confluence downstream of site 20.
23	6.1	JD 27.5, north end of open canal, west of Liberty Rd, downstream of site 20 and discharges from site 21
24	6.15	JD 27.5 side pipe, coming from Moore residence at 951 Liberty Rd, downstream of site 22
25	6.2	JD 27.5 side pipe, coming from Sander’s residence at 931 Liberty Rd, downstream of site 22
26	6.3	JD 27.5, just west of Liberty Rd., downstream of site 25
27	7	JD 27.5, just south of Van Belle Rd., downstream of site 26
28	7.7A	DR 2 tributary, manhole at 460 Liberty Rd.
29	7.7B	DR 2 side pipe, from west into manhole at site 28
30	7.6	DR 2 tributary, vineyard manhole, downstream of sites 28 & 29
31	7.1	JD 27.5, just north of Yakima Valley Highway (YVH), downstream of site 27 and discharges from site 30
32	7.4	JD 27.5, between YVH and railroad tracks, downstream of site 31
JD 28.0		
33	9.1	JD 28.0, just north of Knowles Rd., halfway between Dekker and Price Rds.
34	10	JD 28.0, just south of Independence Rd., downstream of site 33
35	10.3	JD 28.0, just west of Dekker Rd., downstream of site 34
36	10.4	JD 28.0, west of Dekker Rd., downstream of site 35
37	11	JD 28.0, just north of Hudson Rd., between Dekker and Arms Rds., downstream of site 36
38	11.1	JD 28.0, just east of Arms Rd., downstream of site 37
39	11.2	JD 28.0, just west of Arms Rd., downstream of site 38
40	11.3	JD 28.0, west of Arms Rd., just north of Van Belle Rd., downstream of site 39
41	11.53	JD 28.0, south of Van Belle Rd., west of Brien Rd., downstream of site 40
42	11.51	DR 2 tributary, confluence is downstream of site 41
43	11.6	JD 28.0, just north of YVH and west of Brien Rd., downstream of site 41 and discharges from site 42
44	11.7	JD 28.0, immediately north of YVH, downstream of site 43
JD 32.0		

45	32.1	JD 32.0, just east of Fordyce Rd., just before going subterranean
46	32.2	JD 32.0, just south of Van Belle Rd., west of Nichols Rd, downstream of site 45
47	22.1	JD 32.0, west of N. Outlook Rd., downstream of site 46
48	22.15	DR 2 tributary, immediately north of 90 degree bend between Price and N. Outlook Rds., south of Van Belle Rd, confluence is downstream of site 47
49	32.3	JD 32.0, just north of Outlook Rd., immediately east of Price Rd., downstream of site 47 and discharges from site 48
50	32.4	JD 32.0, just north of YVH, downstream of site 49
DR 2-3		
51	DR-2	DR 2 tributary, between Wellner and Van Belle Rds., just east of Dekker Rd.
52	12.1	DR 2 tributary, just north of YVH, between Dekker and Arms Rds.
DR 2-7		
53	DR-4	DR 2 tributary, from east into beginning of Granger Drain
DR 2-6		
54	32.5	DR 2 tributary, manhole in driveway at 41 “D” Street, Outlook, WA
55	DR-5	DR 2 tributary, from north into beginning of Granger Drain, downstream of site 54
Mainstem Granger Drain		
56	22.4	Granger Drain, just upstream of the JD 32.0 confluence, downstream of discharges from sites 53 and 56
57	32.7	Granger Drain, just south of 160 W. Outlook Rd., downstream of site 56
58	32.6	Granger Drain, YVH and east of Luther Rd., downstream of site 57
59	13	Granger Drain, YVH and Liberty Rd., downstream of site 58
60	8	Granger Drain, just east of Bagley Rd., north of Cherry Rd., downstream of site 59
61	24	Granger Drain, at the sheep barns, downstream of site 60

Table 3 presents the latitude and longitude coordinates for all of the AMM sampling sites.

Table 3. AMM sampling site latitude and longitude coordinates

AMM Site ID	Lat	Long	AMM Site ID	Lat	Long	AMM Site ID	Lat	Long
1	46.382608	-120.144755	22	46.360786	-120.135732	43	46.342402	-120.140182
2	46.375153	-120.149039	23	46.353481	-120.145037	44	46.339607	-120.141321
3	46.368121	-120.157173	24	46.352935	-120.145504	45	46.353104	-120.061687
4	46.361096	-120.158011	25	46.352598	-120.145857	46	46.345576	-120.084723
5	46.357680	-120.164676	26	46.351638	-120.146554	47	46.340522	-120.098480
6	46.355842	-120.167118	27	46.346233	-120.149215	48	46.340685	-120.098774
7	46.355666	-120.167256	28	46.345904	-120.146581	49	46.331847	-120.103879
8	46.368382	-120.166078	29	46.345904	-120.146581	50	46.331027	-120.105160
9	46.366912	-120.166114	30	46.345151	-120.148098	51	46.343731	-120.125279
10	46.365913	-120.166076	31	46.339538	-120.156617	52	46.338995	-120.132523
11	46.365913	-120.166076	32	46.339191	-120.156877	53	46.329901	-120.094918
12	46.364685	-120.166190	33	46.382396	-120.116344	54	46.332353	-120.092965
13	46.361051	-120.167542	34	46.375123	-120.123301	55	46.329925	-120.094959
14	46.354496	-120.169007	35	46.366066	-120.125740	56	46.330579	-120.104798
15	46.353832	-120.169656	36	46.363317	-120.128777	57	46.330817	-120.108347
16	46.360691	-120.146243	37	46.360860	-120.130528	58	46.334326	-120.125271
17	46.344399	-120.178134	38	46.350861	-120.135942	59	46.339022	-120.146524
18	46.368212	-120.136013	39	46.350528	-120.136244	60	46.342654	-120.175218
19	46.366264	-120.137889	40	46.346348	-120.137708	61	46.338300	-120.132738
20	46.364467	-120.138115	41	46.344925	-120.137137			
21	46.360877	-120.139007	42	46.344799	-120.137169			

Description of sampling locations and seasonal geomean bacteria densities

DR 2-7

DR 2-7 is the first tributary that enters the upstream end of the mainstem Granger Drain. The drainage is subsurface and begins 2,700 ft north of Outlook Rd. and 270 feet west of the Snipes Mountain Canal. It flows directly south for 2,000 feet at which point it jogs southwest for 2,500 feet where it passes underneath Outlook Rd. At Outlook Rd. the drain receives additional flows from another tributary that enters from the southeast. From Outlook Rd., DR 2-7 flows southwest for 1,700 feet and then west for 1,400 feet to where it discharges into the open mainstem Granger Drain at **Site 53** (nd; 491). For each site in this section, the two values in parentheses are the respective irrigation and non-irrigation season geomean *E. coli* densities. The letters "nd" means no data was collected.

DR 2-6

DR 2-6 is a small subsurface tributary that begins at a point approximately 3,900 feet north of Outlook Rd. and 710 ft east of Nichols Rd. It flows south for 600 feet and then southwest for 1,200 feet to where it crosses Nichols Rd. From the road it continues southwest for another 1,180 feet and then jogs due west for 720 feet. At this point the drain flows again southwest for 1,450 feet to **Site 54** (nd; 1) which is located in the community of Outlook. From this site, DR 2-6 continues southwesterly for 90 feet to where it crosses North Outlook Rd. After crossing the road, the drain continues in the same direction for 400 feet to where it goes underneath Outlook Rd. From Outlook Rd. the drain flows directly south for 540 feet to **Site 55** (nd; 1,203.3) which is its outfall into the Granger Drain, immediately downstream from the outfall of DR 2-7 (above).

JD 32.0

JD 32.0 is the first major tributary of the Granger Drain and is located at RM 4.98. It begins as an open drainage in a field 1,200 feet north of Independence Rd., halfway between Maple Grove Rd. and Scoon Rd. After flowing south and crossing Independence Rd., it goes subsurface for 550 feet and then resurfaces. The drain then continues southwest for 2,770 feet to Reeves Rd., whereupon it continues for another 700 feet until it crosses Maple Grove Rd. at approximately 600 feet south of Reeves Rd.

From Maple Grove Rd., the open drainage continues southwest for 900 feet where it then jogs south for 480 feet and then southwest for 1,400 feet to the SVID Canal. Upon reaching the canal, JD 32.0 turns west and flows 1,580 feet to where it crosses the canal. Depending on the season, the drainage flows either enter the SVID canal or pass underneath. During the irrigation season, upstream flow in JD32.0 is discharged into the SVID Canal. However, during the non-irrigation season, flows pass underneath and continue southwest 3,450 feet to **Site 45** (1,413.6; nd) on Fordyce Rd. After crossing the road, JD 32.0 goes subsurface in a southwest direction for 3,000 feet to Vanbelle Rd.

JD 32.0 continues west parallel to Vanbelle Rd. for 4,200 feet to a **Site 46** (461.1; nd) which is 370 feet west of Nichols Rd., where it resurfaces. The open drainage now flows 2,350 feet southwest and then jogs directly west for 900 feet to N. Outlook Rd. After crossing N. Outlook Rd., it continues flowing west for another 1,245 ft to **Site 47** (344.8; nd), which is just upstream of the outfall of a long (7,000 feet) DR 2-5 tributary at **Site 48** (157.6; nd) that enters from the north. From the confluence with the DR 2-5 tributary, JD 32.0 turns directly south for 2,350 feet and then southwest for 1,560 feet to **Site 49** (261.3; 613.1) on Price Rd. After crossing Price Rd., JD 32.0 continues southwest for 210 feet to Outlook Rd., then directly south for 260 feet to **Site 50** (648.8; nd) on Yakima Valley Highway, and an additional 150 feet to its outfall into the Granger Drain.

DR 2-4

DR 2-4 is a small (0.67 mile) subsurface drainage that begins at a point 500 feet west of Price Rd. and 180 feet north of Wellner Rd. and discharges into the Granger drain at RM 4.64. No sampling was made of this drainage.

DR 2-3

DR 2-3 is a long (2.73 miles) drainage which is primarily subsurface. It begins as an open drainage on the south side of Hudson Rd. about halfway between North Outlook Rd. and Price Rd. It flows south for 650 feet and then goes subsurface for another 1,100 feet. DR 2-3 then flows southwest for 2,400 feet to a point 220 feet east of Price Rd. and 1,300 feet north of Van Belle Rd. Here the subsurface drainage jogs south once again for 280 feet and then southwest for 470 feet to Price Rd. The drain then flows south along the east side of Price Rd. for 800 feet to the intersection of Price and Van Belle Rds.

From the intersection, DR 2-3 flows southwest for 2,100 feet and then west for 1,200 feet to a point 1,300 feet north of Wellner Rd. and 2,600 feet east of Dekker Rd. The drain, still subsurface, then jogs northwest for 300 feet and then west for 1,300 feet to its confluence with its second tributary (open drainage) that comes in from the northeast. From the confluence, DR 2-3 is an open drainage that flows southwest for 1,800 feet to its confluence with its first tributary (open drainage) that comes in from the northeast. It then flows 3,500 feet south to **Site 52** (517.2; 396.8), which is is located on the north side of the Yakima Valley Highway. The drain then passes underneath the highway and then southwest for another 300 feet to its outfall into the Granger Drain at RM 3.47. **Site 51** (nd; 52.1) was located on DR 2-3's first tributary, approximately 130 feet east of Dekker Rd. and 860 ft.feet south of Van Belle Rd. From this site, the tributary flows southwest for 800 feet to its confluence with the mainstem DR 2-3.

JD 28.0

JD 28.0 is the second major tributary of the Granger Drain and is located at RM 3.07. The tributary begins 1,650 feet above (north) of the P9R Lateral (pump station 9 right lateral) and 200 feet west of Maires Rd. The drain flows southwest until it crosses the P9R canal and then continues another 2,900 feet until it forms a series of small ponds at a site located 1,500 ft. west of Maires Rd. and 1,400 ft. northeast of N. Outlook Rd. From the ponds, the open drain continues southwest for 2,000 feet where it crosses N. Outlook Rd. and then afterwards for 1,100 feet to the Roza Canal.

JD 28.0 flows underneath the Roza Canal and then continues southwest for 3,000 feet to N. Price Rd. After crossing the road, the tributary goes subsurface for a distance of 2,000 feet southwest to Kellum Rd. at a point 1,300 feet west of N. Price Rd. After passing underneath Kellum Rd., the drain resurfaces and continues southwest for 2,600 feet to a point 500 feet north of Knowles Rd. and halfway between N. Price Rd. (east) and Dekker Rd. (west). From here, JD 28.0 goes subsurface and continues southwest 660 feet to **Site 33** (275.5; nd) at Knowles Rd. and then an additional 3,100 feet to **Site 34** (616.2; nd) at Independence Rd. and immediately north of the SVID Canal.

Year-round, JD 28.0 passes underneath the SVID Canal and continues flowing southwest 1,900 feet to Dekker Rd. and then directly south 1,400 feet (parallel to Dekker Rd.) until it passes underneath Isaacs Rd. The subsurface drain continues south for 600 feet to **Site 35** (1,565.1; 9.6) on Dekker Rd.and then jogs southwest for 1,400 feet to **Site 36** (1,119.9; nd) and then another 1,000 feet to **Site 37** (410.6; 17.1) on Hudson Rd. From Hudson Rd., JD 28.0 continues southwest for 2,500 feet to Arms Rd. where it resurfaces. The drain then jogs south for 1,600 feet to **Site 38** (1,643.0; 228.2) which is located approximately 3,300 feet north of VanBelle Rd.

After passing under Arms Rd. to **Site 39** (1,643.0; nd), the open drainage continues southwest for 670 feet and then jogs south for 1,000 feet to **Site 40** (1,553.1; nd) on VanBelle Rd. It then passes underneath Vanbelle Rd. and 540 feet to **Site 41** (nd; 344.8) just upstream of **Site 42** (nd; 59.4) which is the outfall of DR 2-2 that enters from the east. JD 28.0 flows southwest 1,200 feet to **Site 43** (nd; 146.7) and then another 1,100 feetto **Site 44** (1,365.0; 58.5) on the Yakima Valley Highway. From here, JD 28.0 flows directly south 170 feet to its outfall into the Granger Drain approximately 170 feet east of Liberty Rd.

JD 27.5

JD 27.5 is the third major tributary entering the Granger Drain and is located at RM 2.32. The drain begins on the immediate north side of the SVID Canal (1,500 feet west of Dekker Rd. and 600 feet north of Gurley Rd.). The tributary begins subsurface and flows southwest underneath (year-round) the SVID Canal and then underneath Gurley Rd. From Gurley Rd., the drainage continues southwest for 2,700 feet where it crosses Arms Rd. (near the eastern terminus of Nelson Rd.). On the west side of Arms Rd. at **Site 18** (39.1; nd) the tributary resurfaces and continues to flow southwest for 860 feet to **Site 19** (24.3; nd) which is located at a point 600 feet south of Nelson Rd. and 500 feet west of Arms Rd. The drainage then flows south for 650 feet to **Site 20** (31.8; nd) and then southwest for 1,300 feet to **Site 21** (837.0; nd) which is on the north side of Hudson Rd. and 780 feet west of Arms Rd.

After Site 21, JD 27.5 flows subsurface in a southwest direction for 1,100 feet, then as an open drainage for 950 feet, and then once again goes subsurface for 250 feet to the where a smaller (0.61 mile) subsurface DR 2-1 tributary enters from the east. The tributary begins at **Site 22** (12.7; nd) near the intersection of Hudson Rd. and Arms Rd. JD 27.5 flows southwest from the tributary's confluence for 800 feet to **Site 23** (448.8; nd), then 230 feet to **Site 24** (520; nd), then 150 ft to **Site 25** (2,252.5; nd), and finally 380 feet to **Site 26** (398.6; nd) which is on the west side of Liberty Rd. and just upstream of where the drainage resurfaces. The open drainage flows southwest for 2,100 feet to **Site 27** (290.9; nd) which is located immediately south of Van Belle Rd. and then 320 feet south to its confluence with a smaller 2,100 feet DR 2-1 tributary.

The DR 2-1 subsurface drainage tributary begins in a field at a point 620 feet east of Liberty Rd. and 880 feet north of Van Belle Rd. **Site 28** (nd; 5,630) and **Site 29** (nd; 241,960) are located on the

DR 2-1 tributary at a distance of 850 feet upstream from its confluence with JD 27.5. **Site 30** (nd; 1,658) is located downstream of the two previous sites and 370 feet from the confluence with JD 27.5. From the above confluence, JD 27.5 flows southwest for 2,900 feet to **Site 31** (316.4; 18.5) which is just 150 feet north of the drainage's outfall into the Granger Drain at **Site 32** (238.2; nd).

JD 26.6

JD 26.6 is the fourth (and last) major tributary entering the Granger Drain and is located at RM 1.23. The drainage begins subsurface under an AFO at a point approximately 880 feet west of N. Arms Rd. and 3,500 feet north of E. Zillah Dr. It flows southeast for 2,400 feet to N. Arms Rd. and then south parallel to the road for 640 feet. From here, JD 26.6 flows southwest for 550 feet to where it crosses E. Zillah Dr. and then south for 6,000 feet to its confluence with a small (0.95 mile) DR 25 subsurface tributary at a point 250 feet north of Kirks Rd. and 1,300 feet west of N. Arms Rd.

From the confluence above, JD 26.6 flows southwest for 3,200 feet to **Site 1** (90.5; nd) which is just south of the SVID Canal. The upstream flow in JD 26.6 is discharged into the SVID Canal during the irrigation season. But during the non-irrigation season, its flow passes underneath the canal and is allowed to flow downstream toward the Granger Drain. The minor irrigation season bacteria density found at Site 1 is not representative of bacteria pollution from upstream sources. It only represents bacteria pollution that began immediately downstream of the SVID Canal.

At Site 1, JD 26.6 resurfaces and flows southwest approximately 3,300 feet to Gurley Rd. where **Site 2** (1,773.3; nd) is located. The drainage then flows southwest for 2,800 feet to its confluence with a small (0.42 mile) subsurface DR 25 tributary that enters from the northwest. JD 26.6 then flows southwest for another 750 feet to **Site 3** (866.4; nd) which is located just upstream of its confluence with another small (0.59 mile) subsurface DR 25 tributary that also comes in from the northwest. No AMM sampling was made of the two above DR 25 tributaries.

The open drainage then flows southwest of Nelson Rd. for 2,000 feet, where it goes subsurface. From there JD 26.6 continues south for 1,000 feet to Hudson Rd. After passing underneath the road, it confluences with a long (1.5 mile) subsurface DR 25 tributary that enters from the east. **Site 4** (2,419.6; nd) is located 1,200 feet east of the confluence, on the north side of Hudson Rd. The tributary passes adjacent to an AFO in its upstream reach and by residences in its lower reach.

From the confluence, JD 26.6 resurfaces and flows southwest for 1,300 feet to **Site 5** (488.4; nd). Site 5 is located 75 feet north of Snyder Rd. and 735 feet east of Beam Rd. and is used by this report to represent upstream conditions of the RSBOJC's wetlands project. Then, 980 feet downstream of that site are located the two wetland outfalls. **Site 6** (261.3; nd) is the outfall from the west wetland. **Site 7** (143.8; nd) is the outfall from the east wetland. Approximately 100 feet downstream to the southwest from the wetland outfalls, JD 26.6 passes underneath Beam Rd. (halfway between Snyder Rd. and Barker Rd.).

JD 26.6 then continues 530 feet southwest to **Site 14** (2,419.6; nd) which is the outfall of a large and complex subsurface DR 25 tributary system that enters from the northwest. The upstream portions of the DR 25 tributary system are located just south of the SVID Canal and are composed of two legs: one 1,300 feet north of Gurley Rd. (2,200 feet west of Beam Rd.) and the other 1,200 feet north of Gurley Rd. (920 feet east of Beam Rd.). The two DR 25-2 tributary legs combine at **Site 8** (3,639.7; 20) which is located on Nelson Rd. (contamined by sanitary sewage) at a point 390 feet east of Beam Rd.

The combined tributary flow continues for 400 feet to the south to **Site 9** (nd; 682). Approximately 500 feet further south is located a mahole which has inside of it two pipes: **Site 10** (1,396; 48,392) is a 2”-PVC pipe that is an illicit sanitary connection, and **Site 11** (6,867; 86) is the upstream DR 25 inflow to the manhole. Another 430 feet to the south is **Site 12** (5,475;158) which represents the combined DR 25 flow from the all of the above sites. The combined flow goes 620 feet south and 770 feet southwest to **Site 13** (nd; 3,654) near the intersection of Hudson Rd. and Beam Rd. From there the subsurface drainage flows southwest 900 feet, then south for 1,170 feet, and finally 850 feet to its confluence with JD 26.6 at **Site 14** (2,419.6; nd).

280 feet downstream (southwest) of Site 14 is **Site 15** (866.4; nd) which is on the north side of Barker Rd. approximately 540 feet west of Beam Rd. The site represents the combined flow of upstream JD 26.6 plus the complex DR 25 tributary system. JD 26.6 then continues southwest for 1,740 feet to the confluence of yet another large (2.16 mile) complex subsurface DR 25 tributary system. **Site 16** (461.1; nd) is located in the upper reach of the tributary system at the intersection of Hudson Rd. and Liberty Rd.

From the above confluence, JD 26.6 flows 1,450 feet to a point where it goes subsurface and passes underneath Interstate 82. The tributary continues underground for 1,080 feet to **Site 17** (501.7; 143) which is located just of a Shell gasoline station (1221 Bailey Ave.). At this point, JD 26.6 resurfaces and continues southwest for 895 feet to its outfall into the Granger Drain.

Mainstem Granger Drain

The Granger Drain is a large open irrigation return drain that is located between the Yakima Valley Highway and I-82. It runs from east to west and parallels the highways. The drain begins collecting irrigation return flows from DR 2-7 (Site 53) and DR 2-6 (Site 55), which represent the headwaters of the Granger Drain. From the confluence of those initial tributaries, the mainstem drain flows 2,500 feet to west to **Site 56** (228.2; nd) and then 900 feet to **Site 57** (nd; 235.9). The latter site represents the combined flow of the headwaters and the JD 32.0 tributary.

The drain continues for 4,500 feet to **Site 58** (1,046.2; nd) which represents the combined flow of DR 2-4 and everything upstream. Still further downstream (6,000 feet) is **Site 59** (1,203.3; nd) which represents the combined flow of everything upstream plus DR 2-3 and JD 28.0 tributaries. Approximately 7,500 feet downstream is **Site 60** (238.2; nd) which represents the combined flow of everything upstream and the JD 27.5 tributary. The last AMM sampling site on the Granger Drain is **Site 61** (583.0; 75.1) and represents everything upstream plus the JD 26.6 tributary.

The Granger Drain ultimately terminates at its outfall on the Yakima River after continuing for 4,250 feet further downstream and passing around the southern edge of the city of Granger. Table 4 lists the tributaries that discharge into the Granger Drain along its 5.53 mile length.

Table 4 Mainstem Granger Drain outfall and tributaries

Tributary or Outfall	Description	Shore	River Mile
Outfall	at Yakima River	n/a	0
JD 26.6	Open ditch	North	1.23
JD 27.5	Culvert	North	2.32
JD 28.0	Open ditch	North	3.13
DR 2-3	Open ditch	North	3.47
DR 2-4	Culvert	North	4.64
JD 32.0	Culvert	North	5.04
DR 2-6	Culvert	North	5.53
DR 2-7	Culvert	East	5.53

AMM overview

The AMM consisted of sampling for the FCB surrogate of *E. coli.* using a laboratory procedure that proven reliable by the RSBOJC in a previous study. Bacteria densities in the Granger Drain watershed ranged from 1 to 241,960 MPN during the AMM study. The highest individual bacteria density was found at Site 29 and was purported to be due to sanitary sewage. The largest geomean *E. coli* densities are presented in Table 5.

Table 5 AMM sites of severe bacteria pollution within Granger Drain watershed

Site ID	Sub-basin	Description	Geomean *E. coli* Density (mpn)
4	JD 26.6	DR 25 tributary, confluence is downstream of site 3	2,419.6
8	JD 26.6	DR 25 tributary, manhole just north of Nelson Rd.	3,639.7
10	JD 26.6	DR 25 side pipe, 2” PVC, new manhole in pasture south of Hudson Rd., downstream of site 8	48,392.0*
11	JD 26.6	DR 25 tributary, new manhole in pasture south of Hudson Rd., downstream of site 8	6,867.0
12	JD 26.6	DR 25 tributary, east of Beam Rd., between Hudson and Nelson Rds., downstream of sites 9 & 10	5,475.0
14	JD 26.6	DR 25 tributary, north of Barker Rd., west of Beam Rd., downstream of site 12	2,419.6
25	JD 27.5	JD 27.5 side pipe, coming from Sander’s residence at 931 Liberty Rd., downstream of site 22	2,252.5
29	JD 27.5	DR 2A side pipe, from west into manhole at site 28	241,960.0*
* Non-irrigation season value			
Shaded cells represent sites with known sanitary sewage input			

During the AMM sampling, several sampling sites throughout the Granger Drain watershed were found to be contaminated by sanitary sewage due to illicit sanitary connections. This supports the conclusions of the prior discussion regarding r^2 values which hypothesized a shift away from overland runoff as being the predominant source of FCB pollution during the irrigation season. The illicit sanitary connections were subsequently capped because the RSBOJC has a strict policy that prohibits sanitary sewage from being discharged into its canals and drains. These situations are excellent examples of bacteria pollution that is not associated with overland runoff and which are referred to as “pseudo-point sources”.

Table 6 presents the *E. coli* (surrogate for FCB) geomean and STV values and their corresponding percent reductions needed for the four major drainage tributaries during the irrigation season. The percent reductions represent the amount of decrease needed for the *E. coli* bacteria to achieve compliance with State WQS if they were numerically equivalent to FCB.

Table 6 Irrigation season *E. coli* densities (MPN) and needed reductions

Waterbody	Geomean	Geomean % reduction needed*	STV	STV % reduction needed*	Estimated total % reduction needed*
JD 32.0	426.3	76.5	1,413.6	85.9	81.2
JD 28.0	993.1	89.9	1,938.9	89.7	89.8
JD 27.5	247.3	59.6	2,419.6	91.7	75.6
JD 26.6	271.7	63.2	1,450.0	86.2	74.7

* "Estimated total % reduction needed" was based on both geomean and STV % reductions having equal weight.

Table 7 presents the *E. coli* geomean and STV values and their corresponding percent reductions needed during the non-irrigation season.

Table 7 Non-irrigation season *E. coli* densities (MPN) and needed reductions

Waterbody	Geomean	Geomean % reduction needed*	STV	STV % reduction needed*	Estimated total % reduction needed*
JD 32.0	613.1	83.7	613.1	67.4	75.5
JD 28.0	66.6	0	344.8	42.0	21.0
JD 27.5	18.5	0	18.6	0	0
JD 26.6	473.5	78.9	18,350.1	98.9	88.9

* "Estimated total % reduction needed" was based on both geomean and STV % reductions having equal weight.

During the irrigation season, the greatest bacteria reduction is needed in the JD 28.0 sub-basin (89.8%) followed by the JD 32.0 sub-basin (81.2%). However, during the non-irrigation season, the greatest bacteria reduction is needed in the JD 26.6 sub-basin (88.9%) followed by the JD 32.0 sub-basin (75.5%). The discovery and capping of the illicit sanitary connections in the JD 26.6 sub-basin resulted in approximately a 20% reduction in bacteria densities. Even with this substantial reduction, the fact that the remaining non-irrigation season FCB densities are high suggests that direct discharges of sanitary sewage or manure are still occurring.

In the JD 27.5 sub-basin similar illicit sanitary connection repairs resulted in approximately an 80% reduction in bacteria densities. So great was the reduction, that the sub-basin is now in compliance with State water quality bacteria criteria during the non-irrigation season. The continued high bacteria densities in the sub-basin during the irrigation season suggest that irrigation return water still contains manure.

RSBOJC constructed wetland project

In 2002, the RSBOJC contructed a 16,300 m^2 wetlands pilot project site located at the intersection of Snyder Rd. and Beam Rd. It is composed of two separate cells, north and south, which receive water independently from JD 26.6. The cells were originally planted with cattails (*Typha* sp.) and soft stem bulrush (*Scirpus* sp.), but presently contain a much more complex mix of vegetation. Hydraulic retention time is approximately 8 days.

The constructed wetland treatment system was sampled in order to determine if it had an effect on bacteria pollution. The upstream geomean FCB density was 223 cfu/mL, while the geomean FCB densities in the west and east wetland's effluent were 261 and 144 cfu/100mL, respectively. Although it appears that the west wetland increased in bacteria and the east wetland decreased, a Kolmogorov-Smirnov test determined that neither wetalnd significant changed FCB densities in the water passing through them (K-S = 0.7817; p = 0.574).

AFO-related data

Three sets of AMM sampling sites were situated in close proximity to animal feeding operations (AFOs). Sites 33 and 34 are located upstream and downstream of a large AFO that is located adjacent (west-side) to JD 28.0 and just north of the SVID Canal. Sites 34 and 35 are located upstream and downstream of a large AFO that is located adjacent (east-side) to JD 28.0 and immediately downstream of the SVID Canal. Sites 45 and 46 are located upstream and downstream of a large AFO that is located over directly a subterranean portion of JD 32.0 immediately north of Van Belle Rd.

Table 8 presents the bacteria data collected with reference to AFOs.

Table 8 AFO-related AMM bacteria data

Site ID	Sub-basin	Description	Irrigation Season Geomean *E. coli* density (mpn)	Non-irrigation Season Geomean *E. coli* density (mpn)
33	JD 28.0	Upstream	275.5	no data
34		Downstream	616.2	no data
34	JD 28.0	Upstream	616.2	no data
35		Downstream	1,565.1	9.6
45	JD 32.0	Upstream	1,413.6	no data
46		Downstream	461.1	no data

At the two JD 28.0 AFOs, the irrigation season data suggests that bacteria concentrations increase between the upstream to downstream sampling sites. However, not enough data was collected to statistically prove that suggestion. The third AFO appears to show a decrease in bacteria pollution in JD 32.0, but once again, since only one sample was collected at each site, there is not enough data to allow a valid statistical evaluation.

Conclusions and Recommendations

The landowners in the Granger Drain watershed, especially dairies, have done a commendable job in reducing FCB pollution that is discharged into the Granger Drain. From 1995 to 2013, the irrigation season geomean and STV FCB concentrations have decreased by 83.8% and 83.4%, respectively. Due to the overwhelming correlation between FCB and TSS, the original *Granger Drain Fecal Coliform Bacteria TMDL* and the earlier *Lower Yakima River Suspended Sediment and DDT TMDL* recommended BMPs that reduce turbidity in irrigation return flows as the best means of pollution prevention.

The successful implementation of BMPs directed at reducing FCB in sediment has resulted in a shift in the predominant sources of bacteria during the irrigation season. Sources not associated with sediment in irrigation return flows, such as sanitary sewage and/or other pseudo-point sources, now appear to be responsible for a greater portion of the FCB pollution problem in the Granger Drain. The shift is supported by a 72% reduction in the coefficient of determination (r^2) values between turbidity and FCB concentrations during the 1997 to 2013 irrigation seasons. However, the watershed's landowners should not regard the implementation of BMPs directed at irrigation return flows as completed. Bacteria concentrations could possibly increase (backslide) if irrigation return flow BMPs are withdrawn or not maintained.

The shift in the predominant sources is also supported by the fact that the AMM sampling sites with the greatest bacteria pollution contained sanitary sewage from illicit connections. When found, those connections were corrected in a timely manner. The RSBOJC should continue to examine the entire Granger Drain drainage system, since they will undoubtedly find additional illicit sanitary sewage connections.

The AMM sampling data indicates that the JD 26.6 and JD 32.0 sub-basins contain suspiciously high *E. coli* concentrations, especially at Sites 4, 21, 50, and 52. The RSBOJC may want to conduct further sampling near these sites in order to determine the source(s) of the high bacteria.

This report finds no conclusive evidence for or against the proposition that dairy facilities are still associated with excessive bacteria pollution in the JD 28.0 and JD 32.0 sub-basins. In order to make a valid conclusion based on statistical analysis, additional data needs to be collected. However, the AMM data still indicates that a minor amount of irrigation runoff of *E. coli* is still occurring.

Future BMP implementation should specifically include subsurface drainage systems. Tile drains have often been found to contain high amounts of bacterial pollution. Tile drainage is a pseudo-point source and represents a direct hydrologic connectivity to waters of the State, which potentially could require NPDES coverage. Ecology acknowledges that irrigation return flow is generally exempted from NPDES permitting by the Clean Water Act. However, this exemption only applies to discharges composed "entirely" of irrigation return water.

Based on the AMM trend analysis, the *Granger Drain Fecal Coliform Bacteria TMDL*'s new target date for full compliance, in all sub-basins, with the State water quality bacteria criteria is anticipated beginning with the 2016 irrigation season.

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Appendix A

Site ID	Date	*E. coli* density (mpn)	*E. coli* geomean density (mpn)
JD 26.6			
1	6/27/2013	90.5	
2	6/20/2012	2,419.6	1,773.3[e]
2	6/20/2012	1,299.7	
3	6/20/2012	866.4	
4	6/20/2012	2,419.6	
5	5/1/2012	1,600*	488.4[e]
5	5/29/2012	82*	
5	6/20/2012	488.4	
5	6/25/2012	440*	
5	7/24/2012	74*	
5	8/21/2012	210*	
5	9/18/2012	150*	
5	10/16/2012	290*	
5	4/30/2013	660*	
5	5/28/2013	150*	
5	6/24/2013	670*	
5	7/23/2013	370*	
5	8/20/2013	56*	
5	9/17/2013	78*	
5	10/15/2013	81*	
6	5/1/2012	200*	261.3[e]
6	5/29/2012	940*	
6	6/25/2012	740*	
6	7/24/2012	54*	
6	8/21/2012	190*	
6	9/18/2012	64*	
6	10/16/2012	88*	
6	4/30/2013	140*	
6	5/28/2013	68*	
6	6/24/2013	1,100*	
6	7/23/2013	4,800*	
6	8/20/2013	120*	
6	9/17/2013	1,300*	
6	10/15/2013	110*	
7	5/1/2012	680*	143.8[e]
7	5/29/2012	730*	
7	6/25/2012	370*	
7	7/24/2012	120*	
7	8/21/2012	330*	
7	9/18/2012	42*	
7	10/16/2012	210*	
7	4/30/2013	65*	
7	5/28/2013	550*	
7	6/24/2013	140*	
7	7/23/2013	94*	
7	8/20/2013	16*	
7	9/17/2013	73*	
7	10/15/2013	46*	
35	11/15/2012	9.6	
8	4/10/2012	5,475[c]	3,639.7[e]
8	10/4/2012	2,419.6[c]	
8	10/22/2013	20[b]	
9	1/22/2013	682	
10	4/10/2012	1,396[c]	
10	10/22/2013	48,392[c]	
11	4/10/2012	6,867[d]	
11	10/22/2013	86[b]	
12	4/10/2012	5,475[c]	
12	10/22/2013	158[b]	
13	4/10/2012	3,654	
14	10/4/2012	2,419.6	
15	6/20/2012	866.4	
16	10/3/2012	461.1	
17	4/26/2012	410.6	501.7[e]
17	6/20/2012	613.1	
17	10/25/2012	143	
JD 27.5			
18	8/29/2012	39.1	
19	8/29/2012	24.3	
20	8/29/2012	31.8	
21	6/20/2012	2,419.6	837.0[e]
21	6/20/2012	1,203.3	
21	8/29/2012	201.4	
22	10/3/2012	12.7	
23	4/24/2012	520	448.8[e]
23	8/29/2012	387.3	
24	4/24/2012	520	
25	4/24/2012	488[c]	2,252.5[e]
25	7/12/2012	2,419.6[c]	
25	8/29/2012	9,678.4[c]	
26	4/24/2012	488	398.6[e]
26	8/29/2012	325.5	
27	8/29/2012	290.9	
28	4/9/2012	5,630[d]	
29	4/9/2012	241,960[a]	
30	4/9/2012	1,658[d]	
30	5/22/2012	45.5[b]	24.7[e]
30	10/3/2012	13.4[b]	
31	4/26/2012	307.6	316.4[e]
31	8/29/2012	325.5	
31	10/25/2012	18.5	
32	8/29/2012	238.2	
JD 28.0			
33	9/8/2011	275.5	
34	6/20/2012	980.4	616.2
34	8/9/2012	387.3	
35	9/8/2011	1,413.6	1,565.1
35	8/9/2012	1,732.9	
61	1/4/2012	180*	101.0[f]

Site ID	Date	*E. coli* density (mpn)	*E. coli* geomean density (mpn)		Site ID	Date	*E. coli* density (mpn)	*E. coli* geomean density (mpn)
36	8/9/2012	1,119.9			61	1/9/2012	141.4	
37	8/9/2012	410.6			61	1/11/2012	230*	
37	11/15/2012	17.1			61	1/24/2012	98*	
38	8/9/2012	1,643			61	2/14/2012	63*	
38	11/15/2012	228.2			61	2/21/2012	30*	
39	8/9/2012	1,643			61	3/7/2012	100*	
40	8/9/2012	1,553.1			61	4/10/2012	100	
41	11/15/2012	344.8			61	4/25/2012	860	633.1[e]
42	11/15/2012	59.4			61	4/26/2012	1,413.6	
43	11/15/2012	146.7			61	5/8/2012	1,300	
44	4/26/2012	2,419.6	1,365.0[e]		61	5/23/2012	1,000	
44	8/9/2012	770.1			61	6/5/2012	1,500	
44	10/25/2012	39.7	58.5[f]		61	6/20/2012	1,000	
44	11/15/2012	86.2			61	7/2/2012	490	
JD 32.0					61	7/18/2012	1,300	
45	5/15/2012	1,413.6			61	7/31/2012	390	
46	5/15/2012	461.1			61	8/15/2012	700	
47	5/15/2012	344.8			61	8/28/2012	300	
48	5/15/2012	157.6			61	9/12/2012	640	
49	5/15/2012	261.3			61	9/26/2012	210	
49	12/13/2012	613.1			61	10/10/2012	100	
50	4/26/2012	648.8			61	10/25/2012	63.8	62.6[f]
DR 2-3					61	10/30/2012	52	
51	10/25/2012	52.1			61	11/19/2012	43	
52	4/26/2012	517.2			61	11/27/2012	67	
52	10/25/2012	396.8			61	12/12/2012	34	
DR 2-7					61	12/13/2012	42.8	
53	12/13/2012	491			61	12/26/2012	37	
DR 2-6					61	1/10/2013	320*	
54	12/13/2012	1			61	1/22/2013	88*	
55	12/13/2012	1,203.3			61	2/5/2013	55*	
Mainstem Granger Drain					61	2/19/2013	27*	
56	5/15/2012	228.2			61	3/6/2013	88*	
57	12/13/2012	235.9			61	4/9/2013	120*	
58	4/26/2012	1,046.2			61	4/23/2013	460*	328.7[e]
59	8/9/2012	1,203.3			61	5/7/2013	800*	
60	4/26/2012	238.2			61	5/21/2013	500*	
					61	6/4/2013	1,000*	
					61	6/18/2013	350*	
					61	7/1/2013	320*	
					61	7/16/2013	350*	
					61	7/30/2013	470*	
					61	8/13/2013	420*	
					61	8/27/2013	180*	
					61	9/10/2013	120*	
					61	9/24/2013	170*	
					61	10/8/2013	100*	

[a] broken sewer line upstream

[b] after repair completed

[c] suspected illicit sanitary discharge

[d] mainstem drainage mixed with sanitary discharge

[e] irrigation season

[f] non-irrigation season

* fecal coliform bacteria measured as cfu/100mL

Appendix B. Glossary, acronyms, and abbreviations

303(d) List: Section 303(d) of the federal Clean Water Act requires Washington State periodically to prepare a list of all surface waters in the state for which beneficial uses of the water – such as for drinking, recreation, aquatic habitat, and industrial use – are impaired by pollutants. These are water quality-limited water bodies (ocean waters, estuaries, lakes, and streams) that fall short of state surface water quality standards and are not expected to improve within the next two years.

Best management practices (BMPs): Physical, structural, or operational practices that, when used singularly or in combination, prevent or reduce pollutant discharges.

Clean Water Act: A federal act passed in 1972 that contains provisions to restore and maintain the quality of the nation's waters. Section 303(d) of the Clean Water Act establishes the TMDL program.

Fecal coliform (FC): That portion of the coliform group of bacteria which is present in intestinal tracts and feces of warm-blooded animals as detected by the product of acid or gas from lactose in a suitable culture medium within 24 hours at 44.5 plus or minus 0.2 degrees Celsius. Fecal coliform bacteria are "indicator" organisms that suggest the possible presence of disease-causing organisms. Concentrations are measured in colony forming units per 100 milliliters of water (cfu/100mL).

Geometric mean: A mathematical expression of the central tendency (average) of multiple sample values. A geometric mean, unlike an arithmetic mean, tends to dampen the effect of very high or low values, which might bias the mean if a straight average (arithmetic mean) were calculated. This is helpful when analyzing bacteria concentrations, because levels may vary anywhere from 10 to 10,000 fold over a given period. The calculation is performed by either:

1. Taking the nth root of a product of n factors, or
2. Taking the antilogarithm of the arithmetic mean of the logarithms of the individual values.

Load allocation: The portion of a receiving water's loading capacity attributed to one or more of its existing or future sources of nonpoint pollution or to natural background sources.

National Pollutant Discharge Elimination System (NPDES): National program for issuing and revising permits, as well as imposing and enforcing pretreatment requirements, under the Clean Water Act. The NPDES permit program regulates discharges from wastewater treatment plants, large factories, and other facilities that use, process, and discharge water back into lakes, streams, rivers, bays, and oceans.

Parameter: Water quality constituent being measured (analyte). A physical, chemical, or biological property whose values determine environmental characteristics or behavior.

Pollution: Such contamination, or other alteration of the physical, chemical, or biological properties, of any waters of the state. This includes change in temperature, taste, color, turbidity, or odor of the waters. It also includes discharge of any liquid, gaseous, solid, radioactive, or other substance into any waters of the state. This definition assumes that these changes will, or are likely to, create a nuisance or render such waters harmful, detrimental, or injurious to (1) public health, safety, or welfare, or (2) domestic, commercial, industrial, agricultural, recreational, or other legitimate beneficial uses, or (3) livestock, wild animals, birds, fish, or other aquatic life.

Reach: A specific portion or segment of a stream.

Stormwater: The portion of precipitation that does not naturally percolate into the ground or evaporate but instead runs off roads, pavement, and roofs during rainfall or snow melt. Stormwater can also come from hard or saturated grass surfaces such as lawns, pastures, playfields, and from gravel roads and parking lots.

Total maximum daily load (TMDL): A distribution of a substance in a water body designed to protect it from exceeding water quality standards. A TMDL is equal to the sum of all of the following: (1) individual wasteload allocations for point sources, (2) the load allocations for nonpoint sources, (3) the contribution of natural sources, and (4) a Margin of Safety to allow for uncertainty in the wasteload determination. A reserve for future growth is also generally provided.

Total suspended solids (TSS): The suspended particulate matter in a water sample as retained by a filter.

Turbidity: A measure of water clarity. High levels of turbidity can have a negative impact on aquatic life.

Wasteload allocation: The portion of a receiving water’s loading capacity allocated to existing or future point sources of pollution. Wasteload allocations constitute one type of water quality-based effluent limitation.

Watershed: A drainage area or basin in which all land and water areas drain or flow toward a central collector such as a stream, river, or lake at a lower elevation.

Critical condition: When the physical, chemical, and biological characteristics of the receiving water environment interact with the effluent to produce the greatest potential adverse impact on aquatic biota and existing or designated water uses. For steady-state discharges to riverine systems, the critical condition may be assumed to be equal to the 7Q10 (see definition) flow event unless determined otherwise by the department.

Acronyms and abbreviations

Following are acronyms and abbreviations used frequently in this report.

BMP	best management practice
Ecology	Washington State Department of Ecology
EPA	U.S. Environmental Protection Agency
GIS	Geographic Information System software
ND	no data
NPDES	National Pollutant Discharge Elimination System
TMDL	total maximum daily load (water cleanup plan)
USGS	United States Geological Survey

Units of Measurement

°C	degrees centigrade
cfs	cubic feet per second
cms	cubic meters per second, a unit of flow.
dw	dry weight
ft	feet
g	gram, a unit of mass
kcfs	1000 cubic feet per second
kg	kilograms, a unit of mass equal to 1,000 grams.
kg/d	kilograms per day
km	kilometer, a unit of length equal to 1,000 meters.
l/s	liters per second (0.03531 cubic foot per second)
m	meter
mg	million gallons
mgd	million gallons per day
mg/d	milligrams per day
mg/Kg	milligrams per kilogram (parts per million)
mg/L	milligrams per liter (parts per million)
mg/L/hr	milligrams per liter per hour
mL	milliliters
mmol	millimole or one-thousandth of a mole. A mole is an S1 unit of matter.
ng/g	nanograms per gram (parts per billion)
ng/Kg	nanograms per kilogram (parts per trillion)
ng/L	nanograms per liter (parts per trillion)
pg/g	picograms per gram (parts per trillion)
pg/L	picograms per liter (parts per quadrillion)
psu	practical salinity units
s.u.	standard units
ug/g	micrograms per gram (parts per million)
ug/Kg	micrograms per kilogram (parts per billion)
ug/L	micrograms per liter (parts per billion)
um	micrometer
uM	micromolar (a chemistry unit)
umhos/cm	micromhos per centimeter
us	microsiemens per centimeter
uS/cm	microsiemens per centimeter, a unit of conductivity
ww	wet weight