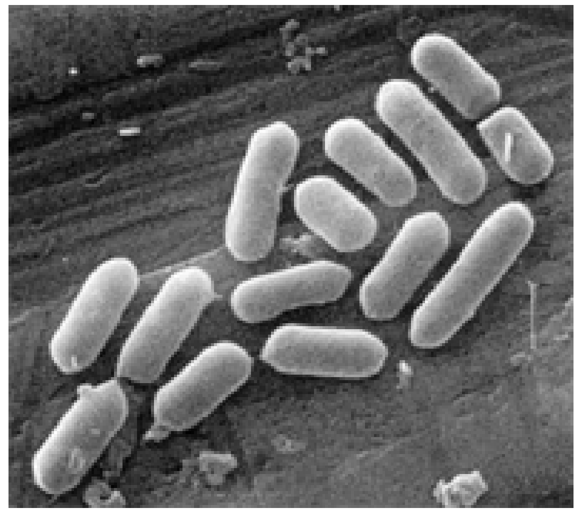
Appendix B

Bear Creek Bacteria Assessment

Prepared by
Oregon Department of Environmental Quality

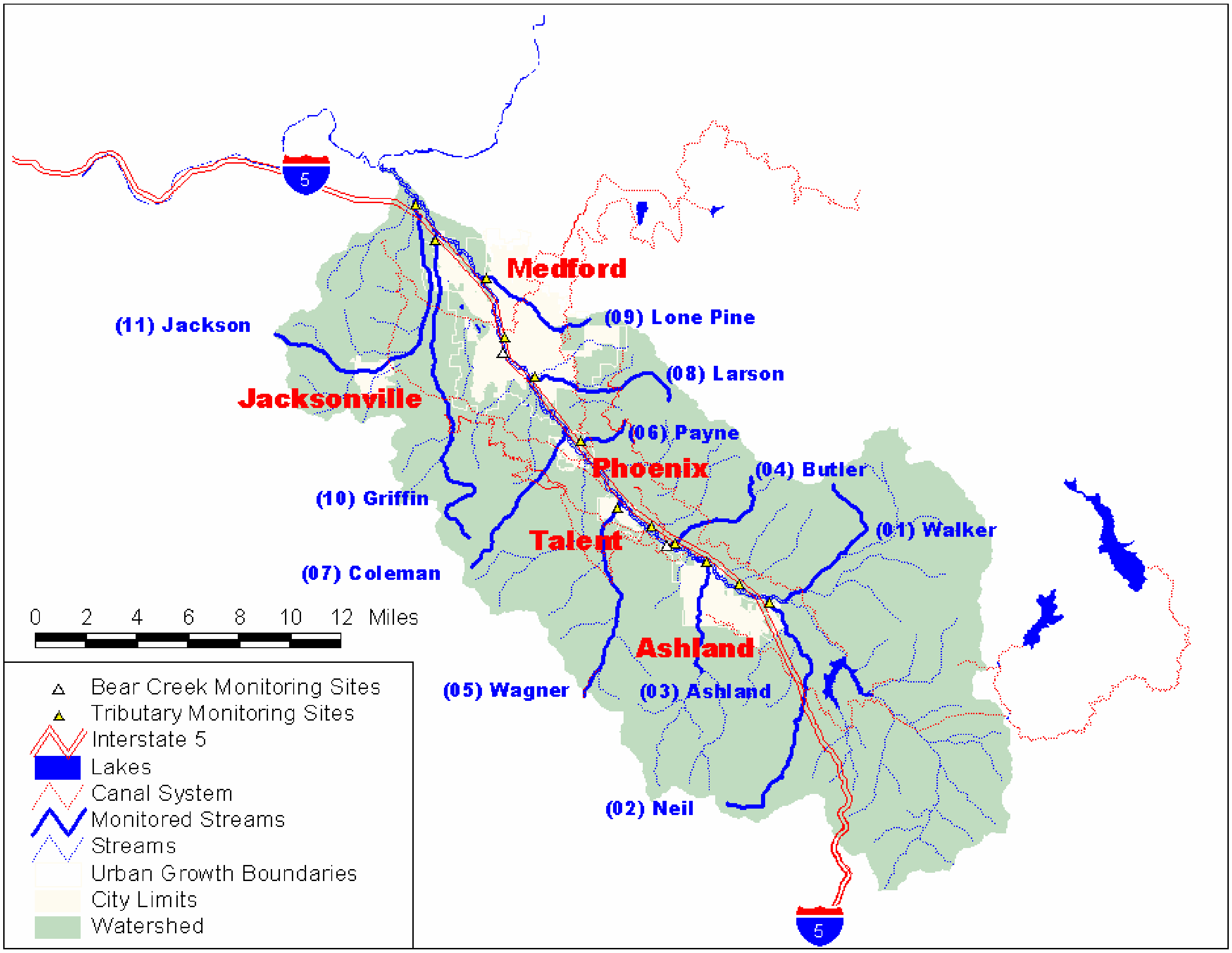
Bacteria in
Bear Creek



Oregon Department
Of Environmental Quality
Western Region August 2006

Collection of Field Data

Map 1



Sampling Locations

Map 1 shows the location of tributaries sampled for bacteria. Each tributary was sampled near it's mouth. Map 1 also shows the location of the existing flow-discharge gages, maintained by the US Geological Survey.

Sampling Frequency

Samples taken from the tributaries were taken on a monthly basis during the non-irrigation season (Nov-Mar) and twice-monthly during the irrigation season (Apr-Oct). Tributary samples used in this analysis were taken between February of 1995 and October of 1998.

The Bear Creek mainstem was sampled over many years at irregular time intervals. The fecal coliform numbers reported at the "Medford gage" are actually from multiple locations no more than one quarter-mile from the gage. None of the values associated with the Medford gage are taken out of the impoundment behind the old Jackson Street Dam. Bacterial data exists going back to October of 1967, but only data taken between June of 1990 and October of 2001 is presented in this document.

Numbers associated with the “Ashland Gage’ are also taken from multiple locations within one quarter-mile of that gage. The period of data presented in this document was also taken between June of 1990 and October of 2001 and was also taken at irregular intervals.

Bacterial Indicator
Samples were taken by the Oregon Department of Environmental Quality, The US Bureau of Reclamation and the Rogue Valley Council of Governments. Over the period analyzed, several bacterial indicators were used by these agencies. To allow comparison, only samples enumerated by the Fecal Coliform method are presented. The Fecal Coliform data presented may have been analyzed using either the membrane filter or MPN test-tube method.

Flow Measurements
Instantaneous staff gage readings were recoded at the same time and place as the bacteria samples from the tributaries. Each of these staff gages had individual rating curves established at each location.

The two mainstem gage sites (Map 1) recorded daily average flows.

Results and Data

Concentration vs. Loading
All bacterial data is reported as a concentration – the number of bacteria per unit volume. This can confound the comparing of data across the landscape or across time. Stream environments have two unrelated factors that can change – the number of bacteria present and the amount of water in the stream. A high amount of bacteria in a large volume of water can result in a concentration of exactly the same value as a smaller amount of bacteria in a smaller volume of water. The concentration could be the same even if the amount of bacteria present was ten, or even a hundred times higher in the first sample.

If however, we also measure the amount of water present when we measure the bacteria present, we can eliminate one of those variables and calculate a bacterial *loading*. This loading can be compared with other loadings across months years or locations, and gives an absolute value to the actual number of bacteria that were present. The units of bacterial loading are “Colony Forming Units/Day”.

Loading in Bear Creek Tributaries
Relative Magnitudes

Figure 1 shows the magnitude of bacterial loadings coming out of each of the tributary systems. These box plots are all constructed from data collected from Feb 1995 – Oct 1998. The total amount of bacteria coming out of each tributary system over this time period was converted to relative percentages and is presented in Figure 2.

The Ashland Wastewater Treatment Plant (WWTP) is shown here as if it were another tributary. This is to give a sense of this facilities bacterial contribution, compared to bacteria from non-point sources. The loading calculated out of the WWTP is significantly over-estimated. WWTP loading values are based on monthly-maximum bacteria levels rather than monthly-average values.

Figure 1

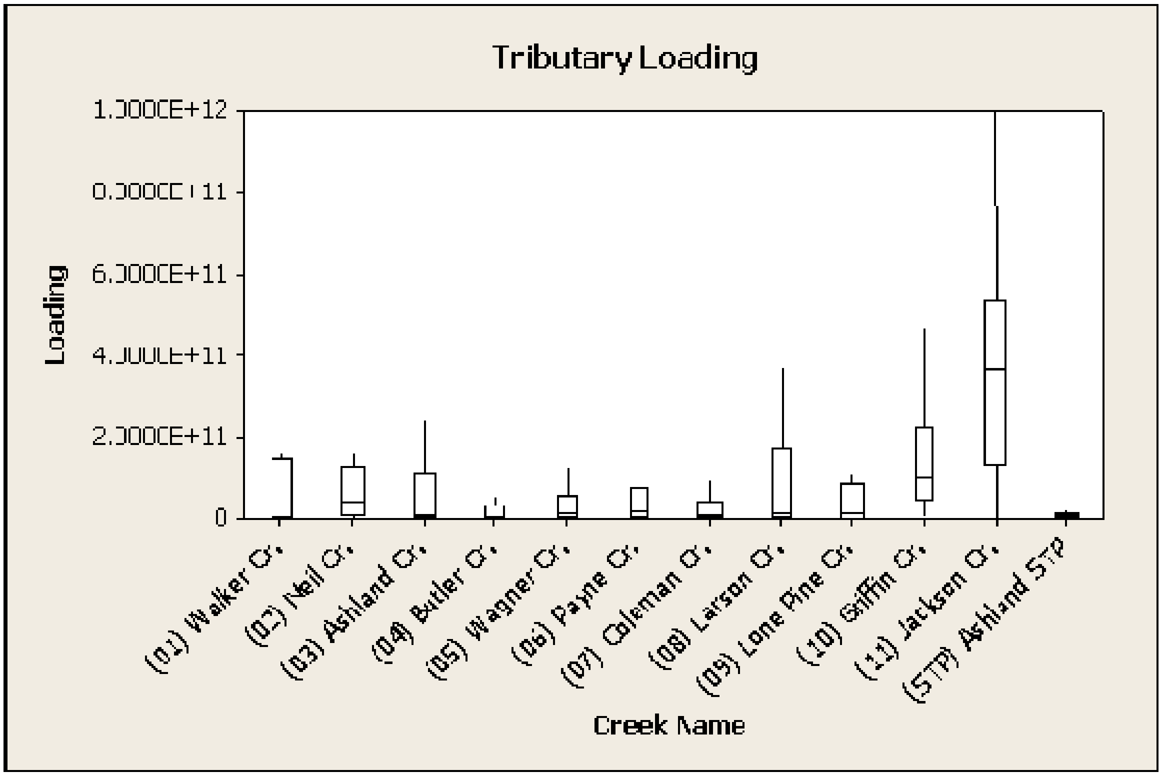
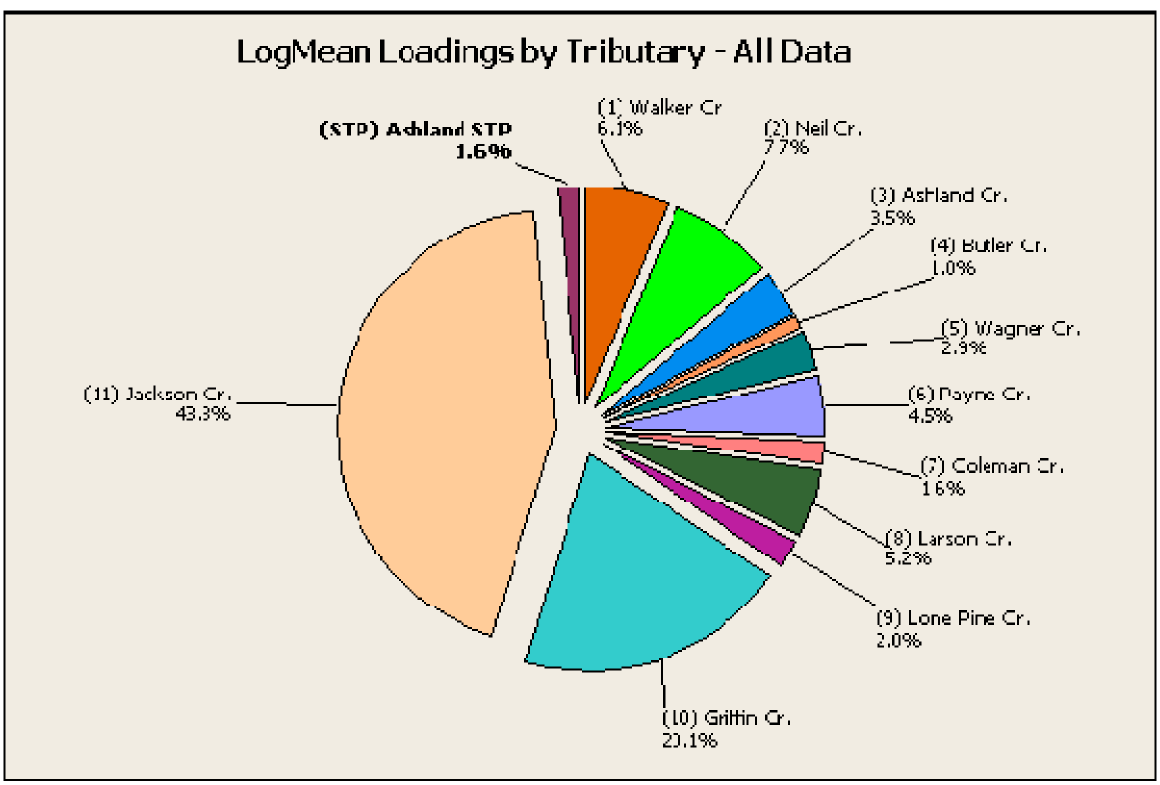


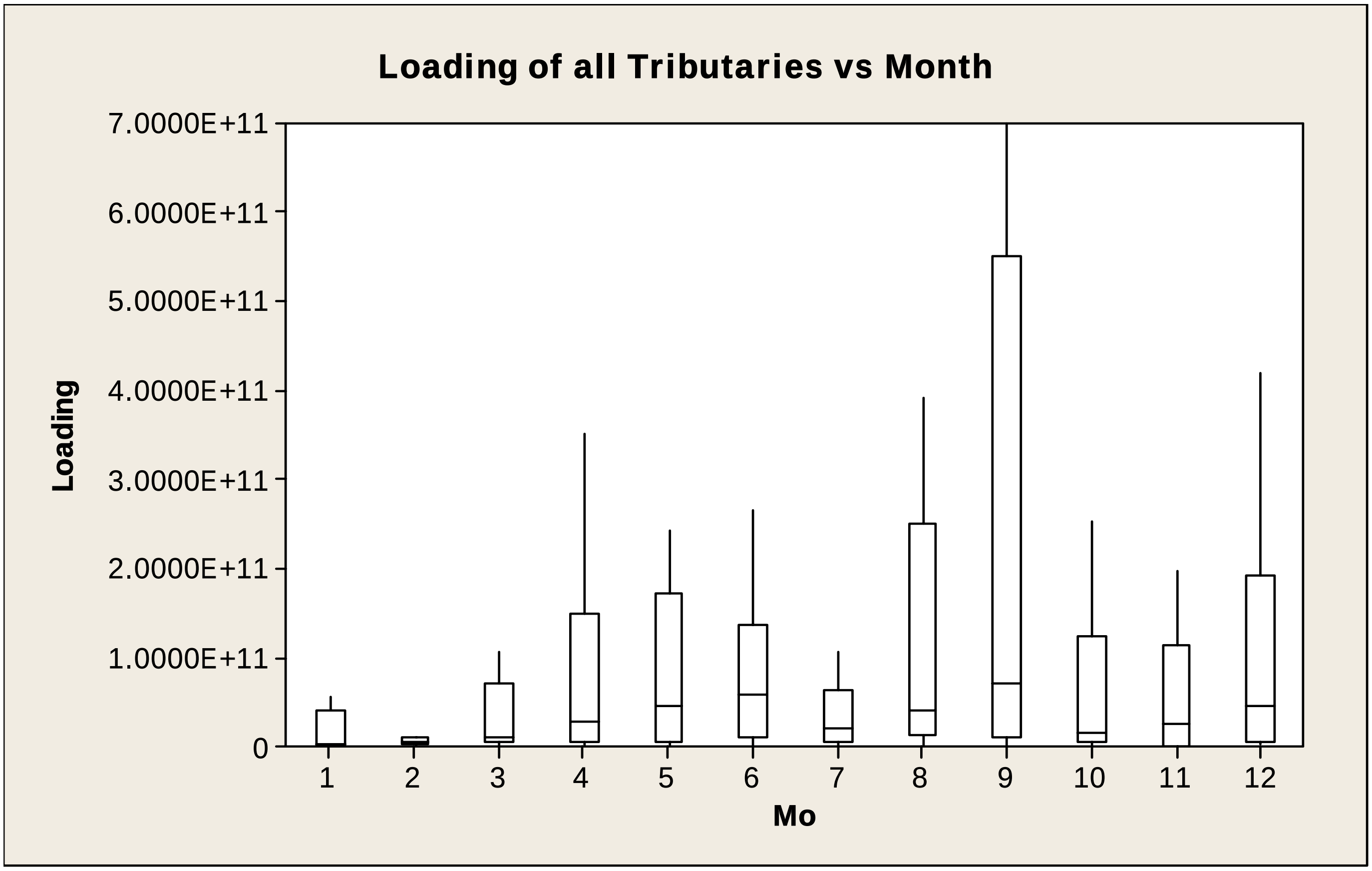
Figure 2



Loading in Bear Creek Tributaries
Monthly Patterns

All of the tributary loading data is grouped by month in Figure 3. Again, this is all tributary data collected from Feb 1995 – Oct 1998. WWTP data is not included here.

Figure 3

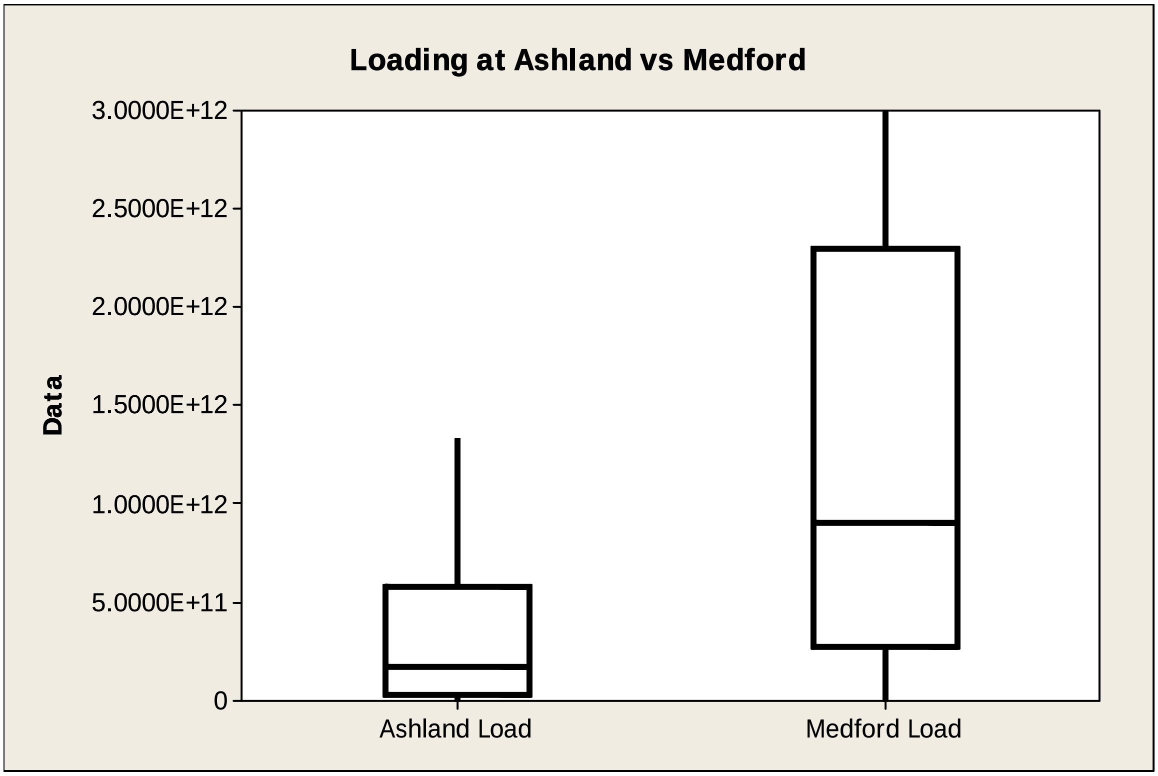


Loading in the Bear Creek Mainstem
Relative Magnitudes

The flow information derived from the two existing Bear Creek gages (Map 1), coupled with the bacterial samples taken near the gages allow loading values to be calculated. The Ashland gage has been in operation since 1990. The Ashland gage has 130 bacterial samples associated with it since it began recording flows. The Medford gage has taken discharge measurements since 1917, the bacterial sampling record goes back to 1967. Since 1990, 245 bacterial samplings can be associated with the Medford gage and converted into loadings. Figure 4 shows the relative magnitude of bacterial loadings at these two mainstem locations.

Bacterial samples taken at these two locations were not matched in time. Both areas were sampled at irregular intervals due to different sampling objectives. It is therefore unwise to attempt to construct a relative percentage of bacteria like that shown for the tributaries in Figure 2.

Figure 4


Loading at Ashland vs Medford
Data
3.0000E+12
2.5000E+12
2.0000E+12
1.5000E+12
1.0000E+12
5.0000E+11
0
Ashland Load
Medford Load

Loading in the Bear Creek Mainstem

Monthly Patterns

Monthly bacterial loading at the Ashland gage location (Figure 5 a) and at the Medford gage (Figure 5 b) location are shown below.

Figure 5a

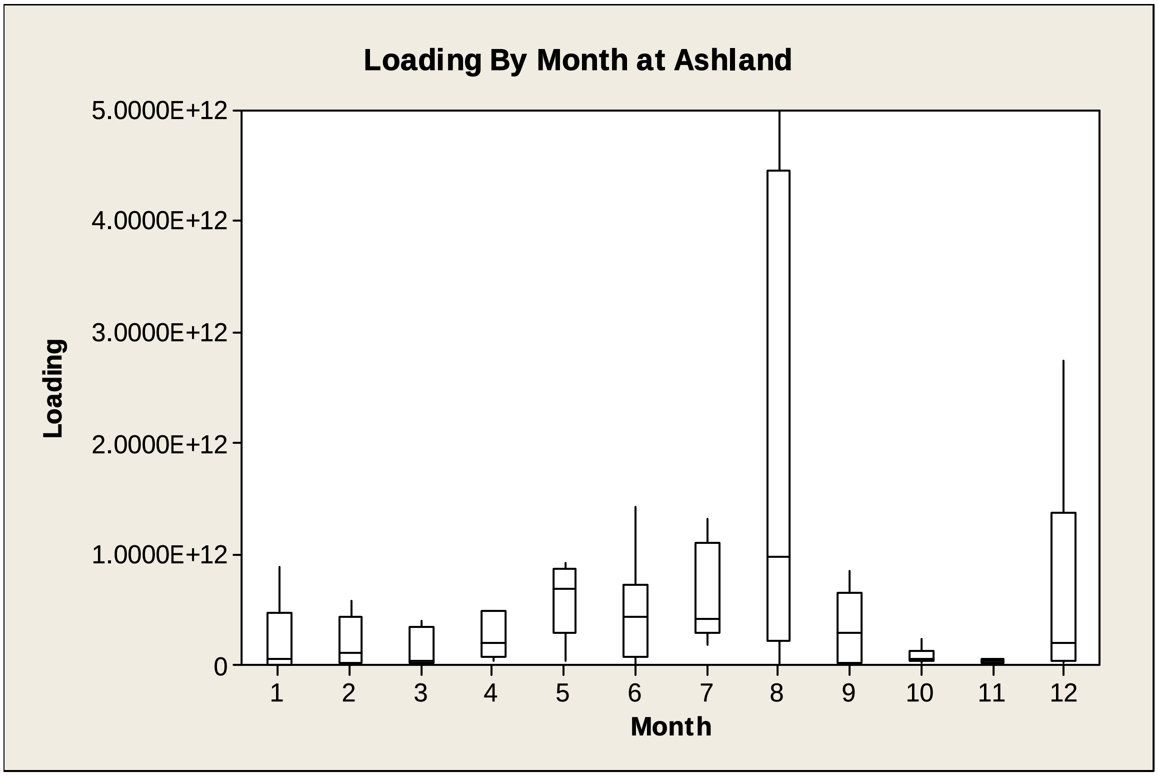
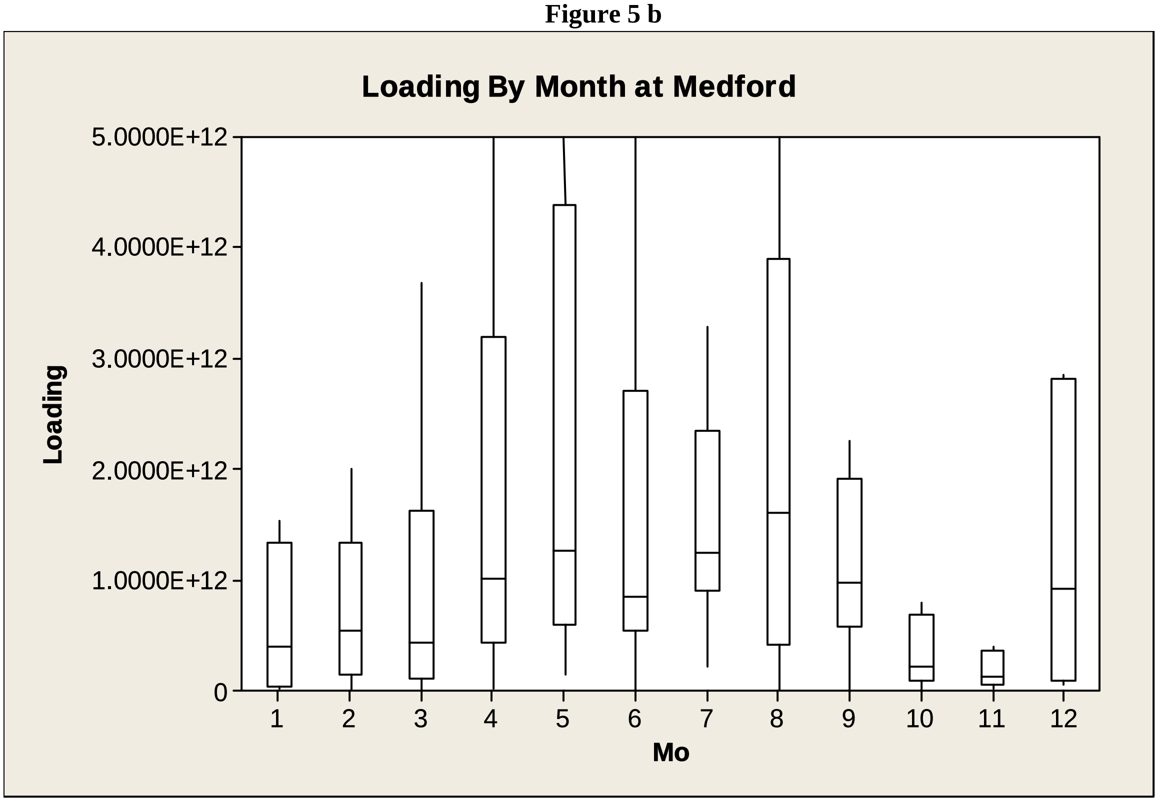


Figure 5 b



Additional Analysis at the Established Gage Locations

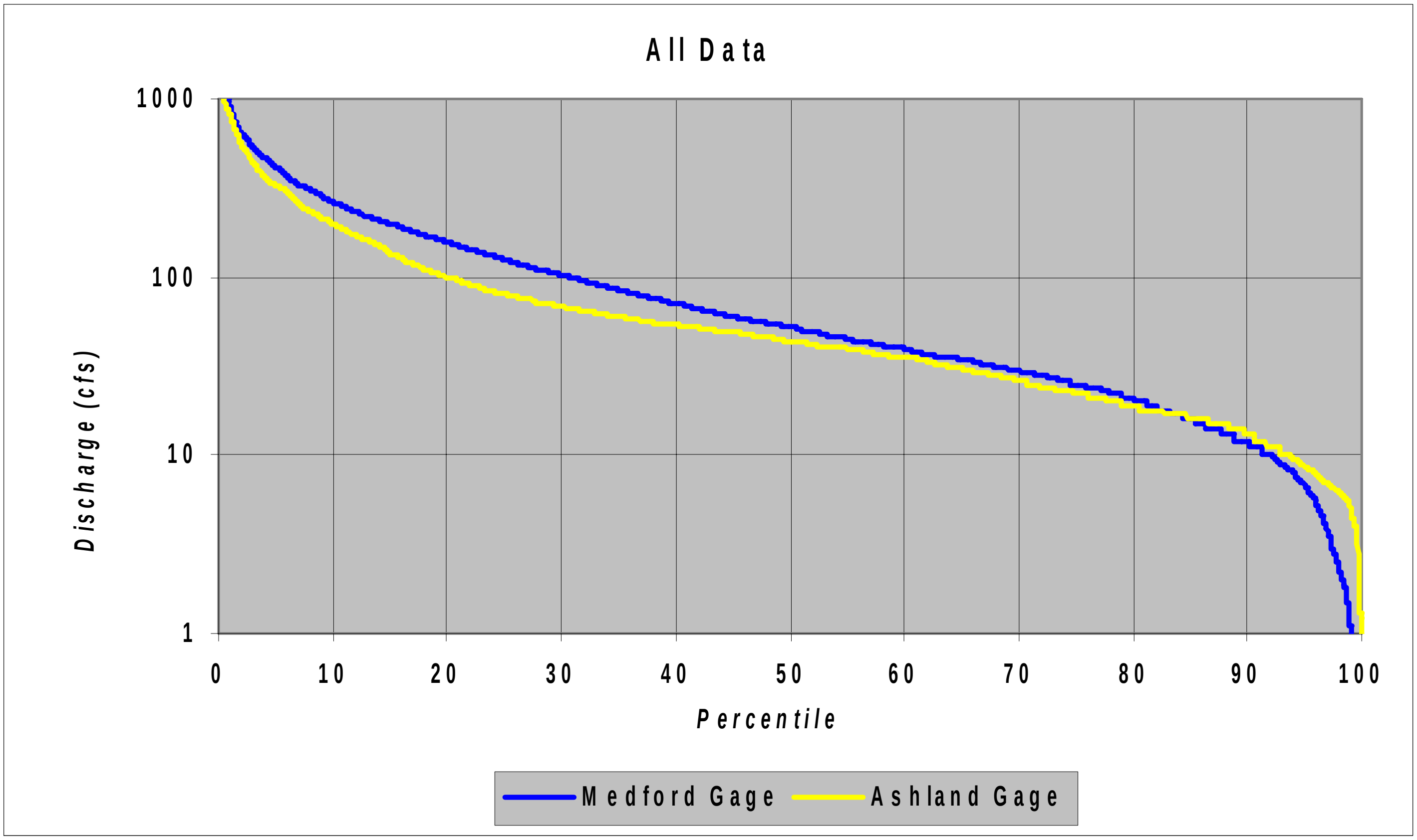
The long-term measurement of flow volume allows an additional analysis to be done with the bacterial loading data from the Ashland and Medford gage locations. Long term flow data can be used to construct *flow duration* curves, and this allows the bacterial loading to be examined as *load durations*.

Flow Duration Curves

Flow duration cures are constructed by taking all of the discharge readings from a location, and sorting them in high-to-low order (y-axis). The x-axis is the percentile rank of each flow. This cumulative frequency of discharges is also called a flow duration curve. The flow duration curves constructed for the Medford and Ashland gages are shown in Figure 6. These duration curves were constructed using the **entire** period of record for each gage. For Medford, this goes back to 1917.

Flow duration curves give a quick reference to how usual or unusual a given discharge reading is. For example, one can quickly answer the question - How often is flow in Bear Creek over 100 cfs? At the location of the Ashland gage, flow is above 100 cfs 20% of the time. At the Medford gage location, flow is above 100 cfs about 31% of the time.

Figure 6



Load Duration Curves

Load duration cures are an extension of the flow duration curves concept. Instead of plotting flow along the Y-axis, bacterial loading is plotted. The x-axis is the percentile occurrence (sometimes called the reoccurrence interval) of the flow when the bacterial sample was taken. This can have applications in helping to track the source of high bacterial numbers. If most standard exceedances occur at the high-flow end of the curve, nonpoint pollution from storm runoff is implicated. If most standard exceedances occur at the low-flow end of the curve, point source runoff with inadequate dilution is implicated.

Figure 7 shows a series of load duration curves for the Ashland gage site. Figure 7a is for all Ashland gage bacterial loading data, 7b is for bacterial loading data only from the wet season (December – May) and 7c is the data from only the dry season (July-October). Data from June and November was not used for either the wet or dry season graphs as these are month of transition and can be either wet or dry.

Figure 8 follows the same pattern for Medford data from the Medford gage site. Figure 8a is all data, Figure 8b is for wet season data and Figure 8c is for dry season data.

As an aid, each graph shows a curve (thick black line) which correspond to the state water quality standard for Fecal Coliform bacteria. Simply put, if a data point is above this line, it is above the 200 cfu/100 ml standard and if it is below the line, it is below the standard. The second line (thinner and dotted) corresponds to values that are ten times the state standard (2000 cfu/100mls). While this has no regulatory effect, it give a quick visual reference as to whether loading levels were slightly above the standard or significantly higher.

Figure 7a

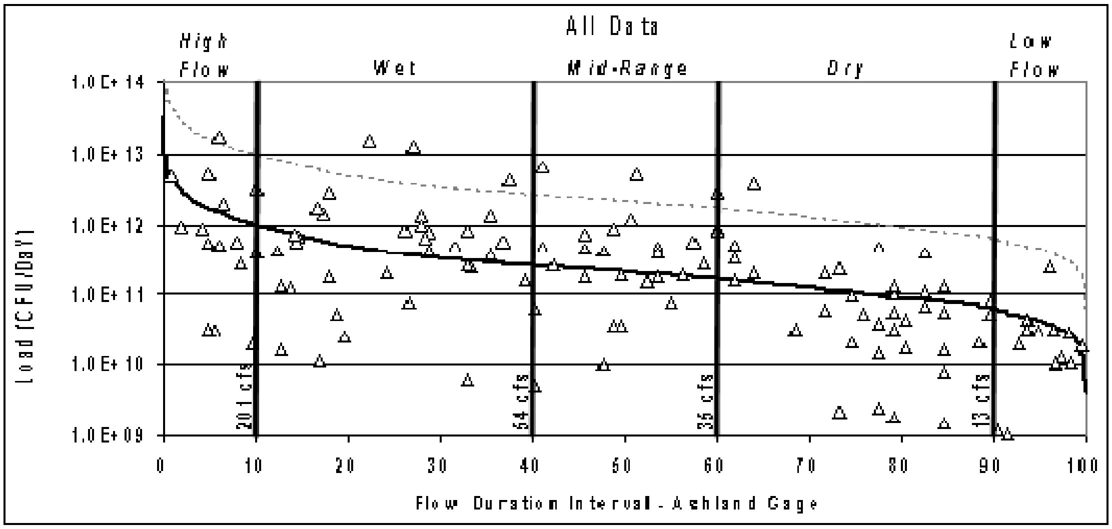


Figure 7 b

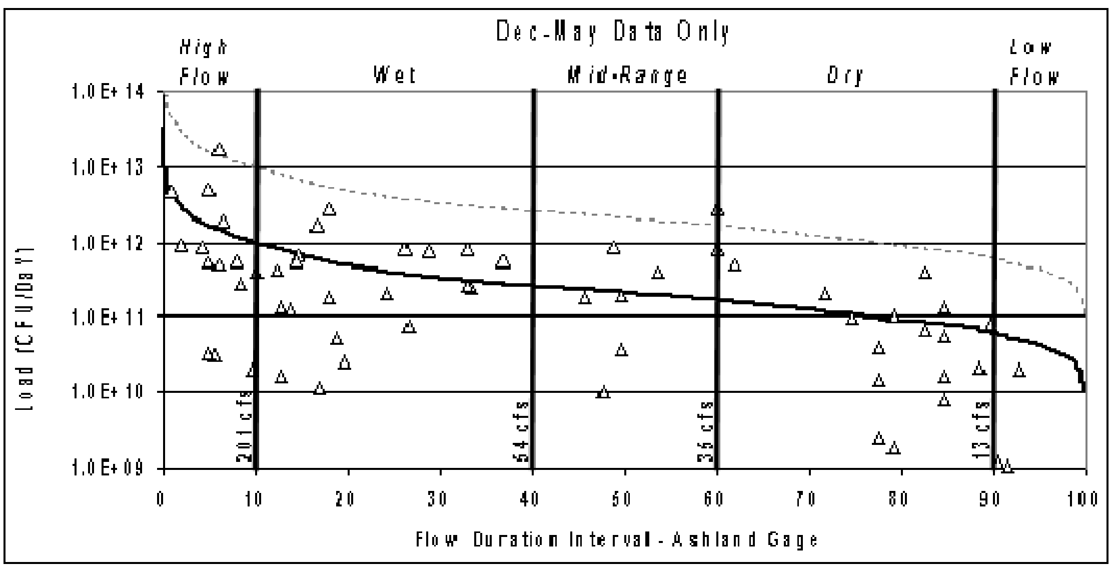


Figure 7c

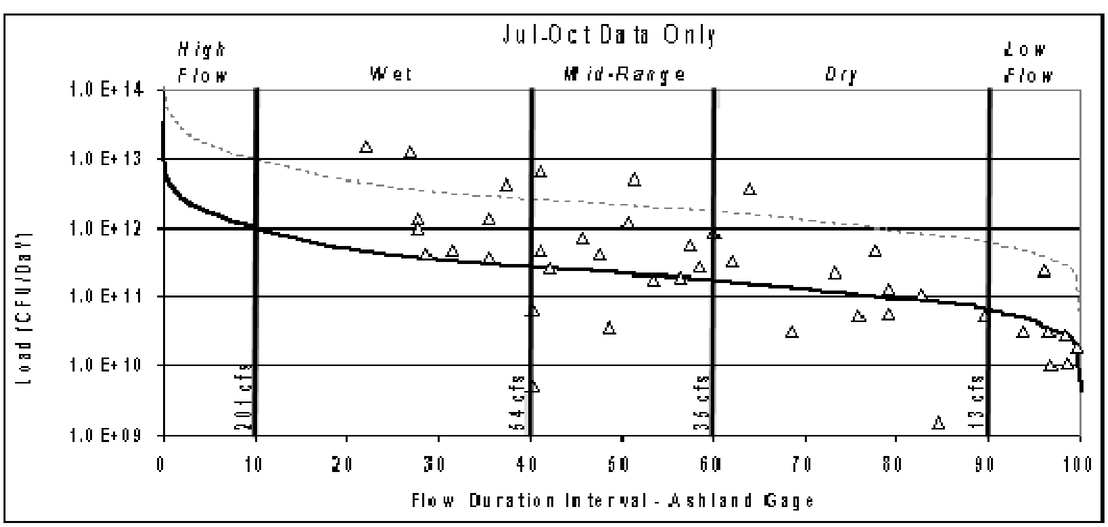


Figure 8a

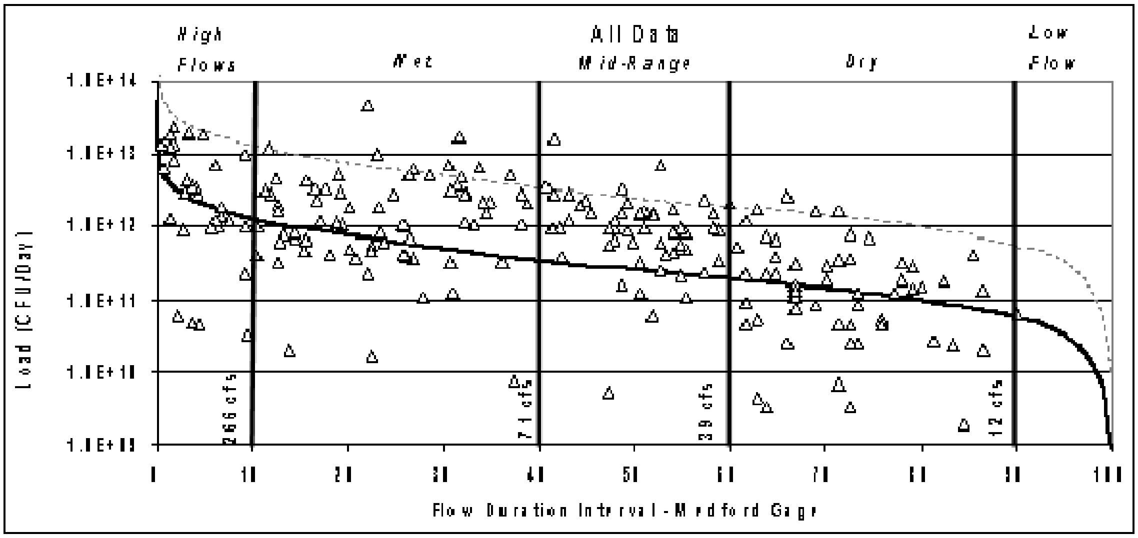


Figure 8b

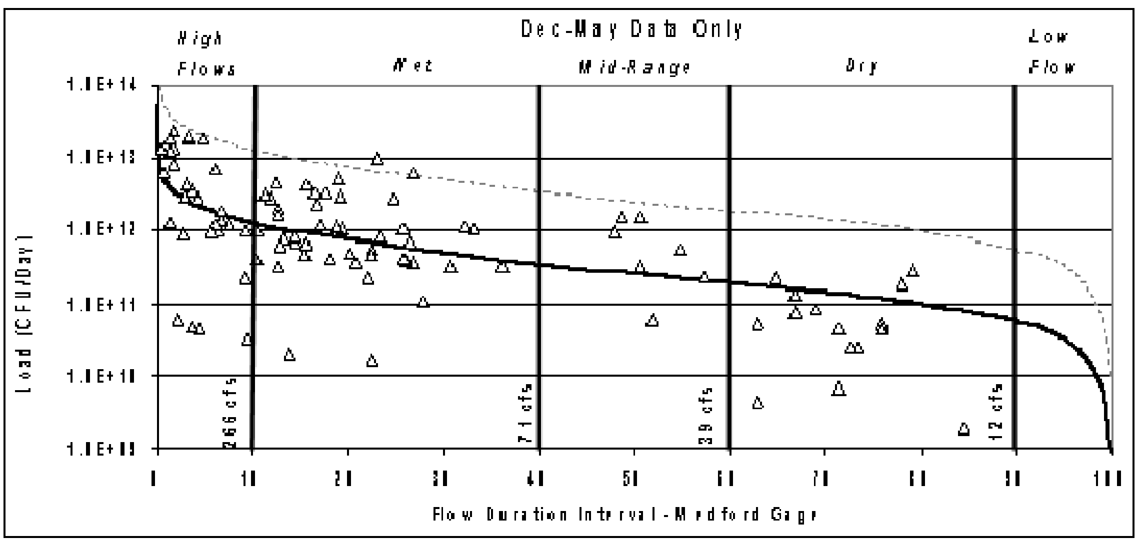
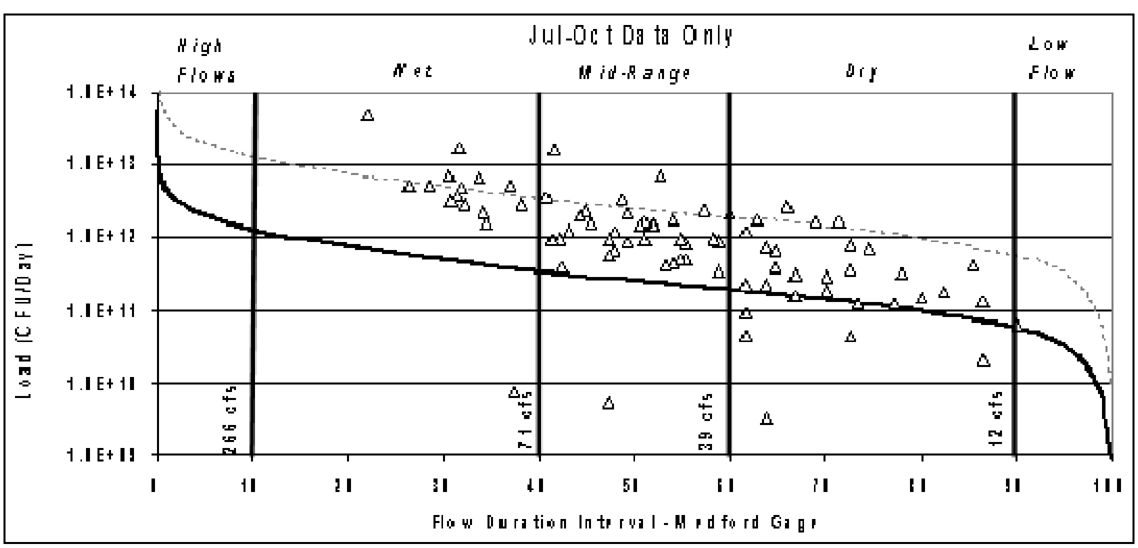


Figure 8c



Standards Exceedance Table

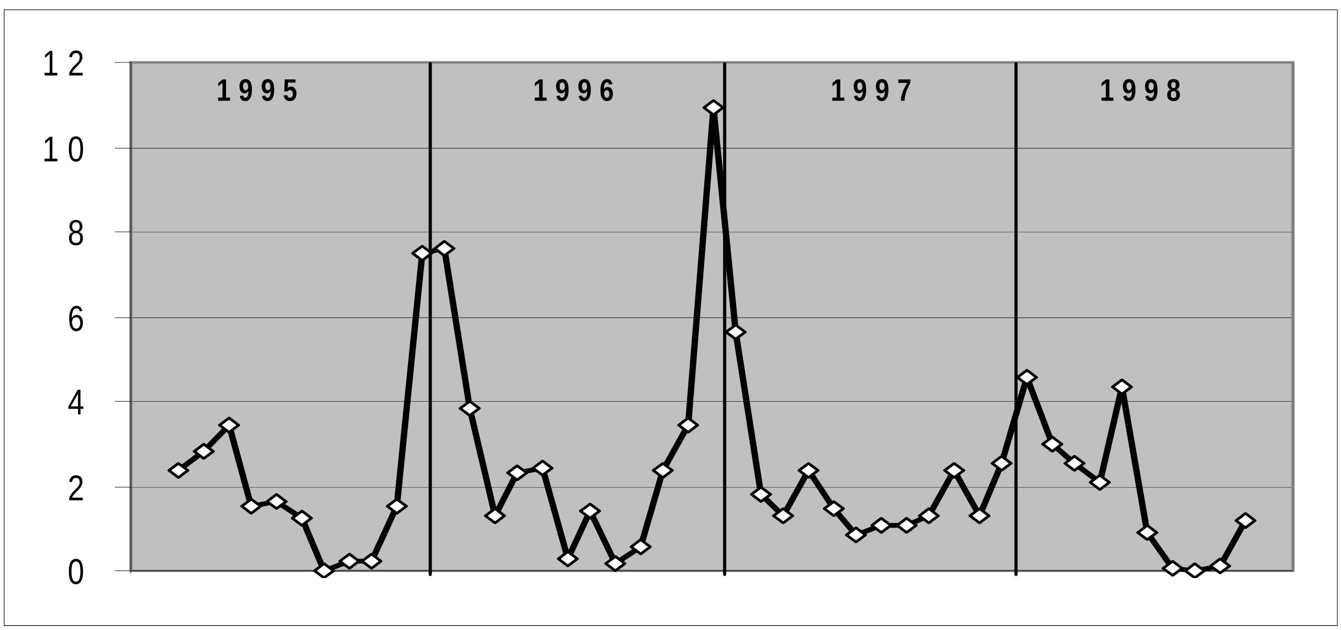
Table 1 is a simple tabulation of when mainstem bacterial levels were above the state standard of 200 cfu/100 mls at the Ashland and Medford gage locations. The numbers 7-8-9-10 refer to the months of the dry season, 12-1-2-3-4-5 refer to the months of the wet season, and 6,11 refer to June and November considered transitional months for precipitation.

Table 1

	7-8-9-10			12-1-2-3-4-5			6-11		
	Dry Below	Dry Above	Pct Above	Wet Below	Wet Above	Pct Above	Trans Below	Trans Above	Pct Above
Ashland	27	15	**35.7**	53	12	**18.5**	20	3	**13.0**
Medford	33	79	**70.5**	96	38	**28.4**	23	25	**52.1**

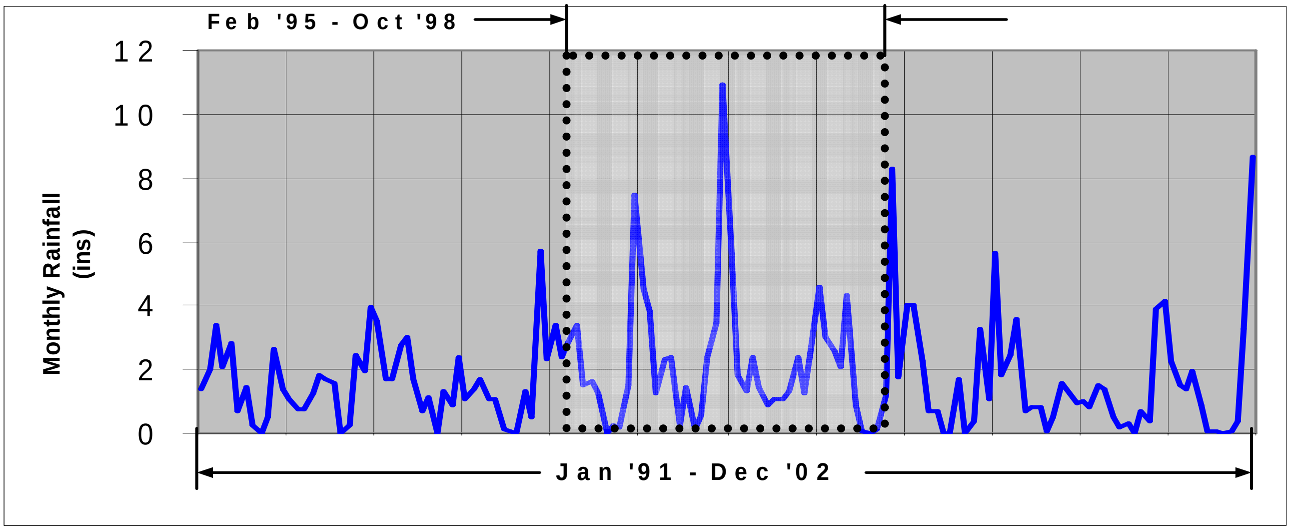
Weather Data
All rainfall data shown in this document was collected at the Oregon State Extension Research Station in Central Point. Monthly rainfall totals (in inches) during the time the tributaries were sampled are shown in Figure 9.

Figure 9



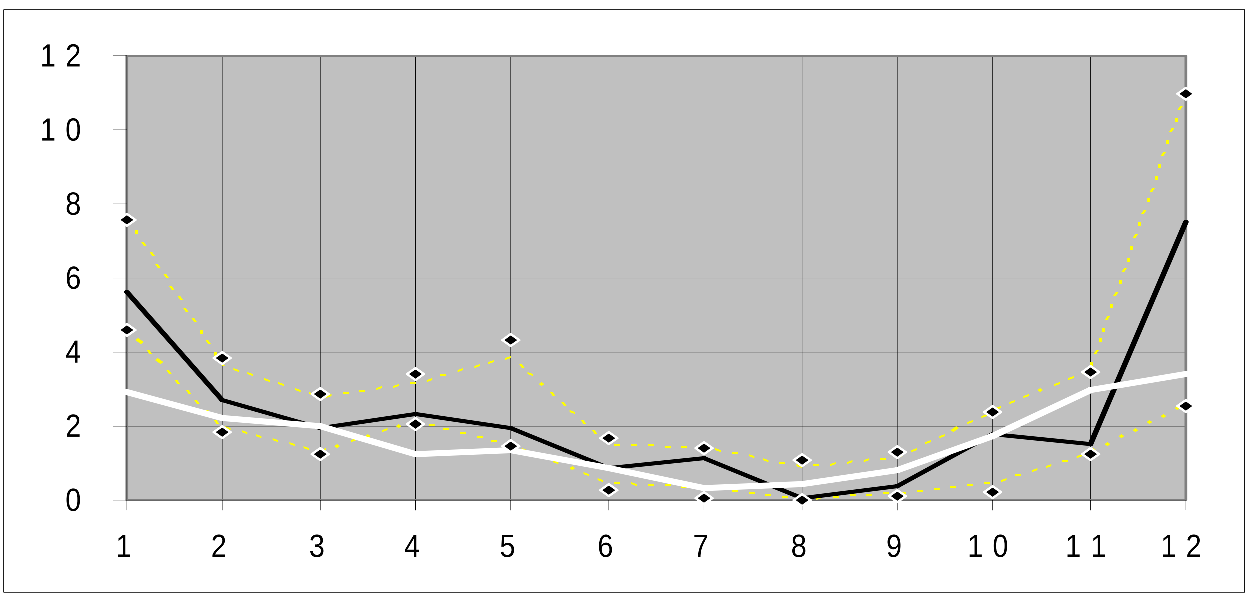
A longer period of rainfall, roughly matching the time of comparison for the two mainstem locations is shown in Figure 10.

Figure 10



Comparison of rainfall during the tributary study period with long term rainfall averages are shown in Figure 11. The tributary study period (1995-1998) monthly rainfall medians are shown as the black line, the 75th and 25th percentiles are shown as dashed yellow lines. The thick white line is the long term (1937-2003) average monthly rainfall amounts.

Figure 11



Discussion

Point Source Bacteria
Bacteria levels coming out of the Ashland treatment plant are very low, compared to bacteria coming from non-point sources. This is true regardless of season.

Tributaries – Temporal Variability
The behavior of typical bacteria pollution follows certain well-established patterns. Fecal material accumulates in the watershed and is carried into streams and rivers during rainfall events. With the dry summers of the Rogue Valley, this could be expected to produce a pattern of low bacterial numbers in the summer, high values in the rainy season with the highest values during the first fall storm freshets. Indeed, this pattern is common in watersheds west of the Oregon Cascade Mountains.

Figure 3 shows that bacteria numbers coming out of tributary systems exhibit quite a different behavior. The highest numbers occur in summer months which are also the driest months (Figures 9 and 11). Bacteria amounts during the classic high-level months of December through March are much lower than would normally be expected. A slight spike occurs in April - May, but these levels are still much lower than levels during the height of summer "dry" conditions.

One practice occurring in the Bear Creek valley that would seem to explain this pattern is the high level of irrigation used in the valley's agricultural areas. Summer-long irrigation is equivalent to multiple storm, only the timing of the water application is different. Fecal material that would normally accumulate during non-rainfall periods, is mobilized by water deposited by irrigation.

This might also explain the smaller spike in April - May. Normally, fecal material accumulates all summer long and is mobilized during the first rainfall events in the fall. In Bear Creek, material accumulates during a pseudo-summer time period (dryer times between the end of the winter storms and the beginning of irrigation season), and moves off in a slug from a pseudo-fall freshet (the beginning of irrigation season). This offset in timing fits how water is used in the Bear Creek Valley.

Tributaries – Spatial Variation
The tributary systems exhibit marked differences in their contribution of bacteria. Figure 1 shows that bacteria levels coming from Jackson Creek are literally head and shoulders above any other tributary. The Jackson Creek 25th percentile values are above the 75th percentile values of every other system, except for Griffin and Larson Creeks.

The pattern of where bacteria is found also suggests a connection to the irrigation system in the Bear Creek Valley. If one could follow a gallon of water down the valley, it would be quite a trip. Water from Bear Creek is diverted into miles of canals or applied directly from the mainstem onto fields through pumps and sprinklers. The efficiency of water use had grown steadily. A vast majority of the water used reaches its intended target of growing plants. But no process is 100% effective. Excess runoff may run through additional fields, animal pastures, along roadside ditches or even detour through urban stormwater pipes and culverts before it finds its way bact to a tributary or the Bear Creek mainstem. This whole process might happen several times as the water makes it's way down the valley.

Fecal material is highly soluble. As water moves down-valley, it picks up and carries whatever bacteria it finds along with it. The farther down the system, the more bacteria in the water. And this is what is seen. The bulk of irrigation return water coming from the west side of the valley winds up in either Jackson or Griffin Creeks.

Mainstem Sites – Temporal Variability
Figure 5a shows that the pattern of bacteria levels seen at the Ashland gage site is quite similar to the patterns seen in the tributaries. High summer levels, much lower fall/winter levels. Even the slight "spike" in May is there.

Figure 5b shows that the variability in Bear Creek from month–to-month is less than that at the Ashland site or in the tributaries. It also shows that the numbers are generally higher in magnitude, no matter what time of the year. Being farther down the valley, this is not unexpected. More and more bacteria enter the system as lands below the Ashland gage contribute bacteria. The demand for irrigation withdrawal changes from day-to-day, even from hour-to-hour. As the ebb and flow of water demand changes the timing of return water "slugs" returning to the mainstem, the pattern seen upstream gets less and less distinct.

Mainstem Sites – Spatial Variability
Figure 4 shows that, in the aggregate, the Bear Creek mainstem bacteria loading at the Medford gage site is generally more the 50% higher than that seen at the Ashland gage site.

Load Duration Curves
The load duration curves (Figures 7 a,b,c for the Ashland site and Figures 8 a,b,c for the Medford site) give a similar picture as to the timing of high bacterial levels. The seasonal groupings of data show the same general trend – high levels in the dry season and lower levels in the wet season. It is also clear that high bacteria levels occur throughout the year and are not confined to only dry or wet conditions.

Standards Exceedance Table
This is probably the simplest of all ways to show when bacteria levels are high (Table 1). A simple grouping of when bacteria levels are above or below the state bacteria standard. This simplistic analysis agrees very well with the methods already used. The Medford site exceeds the state standard about twice as often as the Ashland site. Both sites have roughly twice the number of violations during the dry season (July -October) then they do during the wet season (December-May).

Conclusions
The distribution of bacteria throughout the Bear Creek Valley as well as the timing of those levels is intimately tied to the movement of irrigation water throughout the valley. It should be emphasized that the irrigation system does not create bacteria, it simply transports it. Reducing the amounts of irrigation return water available for moving fecal material will reduce bacteria levels in Bear Creek tributaries and the mainstem. But proper manure management is also at issue. The amounts of manure that are vulnerable to contact with irrigation return water must also be reduced. The classic bacteria reduction goal of "keeping the manure out of the water while keeping the water out of the manure" still applies. This is an important goal because numerous types of bacteria are quite harmful to human and animal health.

The historic monitoring data examined in this report sheds some light on the timing and location of high bacterial levels in the valley. It also suggests the mechanism of what drives those dynamics. Different management measures will be required in different parts of the valley, and different methods will be required at different times of the year. In the world of effective management, one size does not fit all.

The historic data give some information on how things have worked. Additional data must be collected so that progress can be measured and management measure can be continually refined. Only on-going assessment will prove that progress has been made in reducing bacteria levels in the Bear Creek Valley.