Carson River:

Phase I
Total Maximum Daily Loads for Total Phosphorus

FINAL
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Bureau of Water Quality Planning
Nevada Division of Environmental Protection
Department of Conservation and Natural Resources

Table of Contents

Appendices

List of Tables

List of Figures

Executive Summary

Section 303(d) of the Clean Water Act requires each state to develop a list of water bodies that need additional work beyond existing controls to achieve or maintain water quality standards, and submit an updated list to the Environmental Protection Agency (EPA) every two years. The Section 303(d) List provides a comprehensive inventory of water bodies impaired by all sources. CFR (Code of Federal Regulations) 40 Part 130.7 require states to develop TMDLs (Total Maximum Daily Loads) for the waterbody/pollutant combinations appearing in the 303(d) List.

The Nevada 2002 303(d) List identifies Total Phosphorus, Total Suspended Solids, Turbidity, Temperature, Total Iron and Total Mercury as parameters of concern for the Carson River. This document will present TMDLs for only Total Phosphorus. All of these 303(d) Listings were based upon ambient water quality monitoring conducted at 15 different sampling points established by the Nevada Division of Environmental Protection. The data indicates that annual average total phosphorus concentration exceeds the standard of 0.1 mg/L at all but two of the sampling points. Analysis also indicates that, in general, phosphorus levels increase in the downstream direction.

This TMDL report includes a discussion of the following categories:

- Problem Statement
- Source Analysis
- Target Analysis
- Pollutant Load Capacity and Allocation
- Future Needs

Through the use of equations and load duration curves, the defined TMDLs and load allocations vary with flow thereby addressing the EPA requirement to consider seasonal variations and critical flow conditions in the TMDL process.

This document presents a “phased” approach to the Carson River TMDLs. A phased approach is used in situations where data needed to determine the TMDL and associated load allocations are limited, but enables the adoption and implementation of a TMDL while collecting additional information (“*Guidance for Water Quality Based Decisions—The TMDL Process”* (#EPA 440/4-91-001, April 1991)). The phased or adaptive management approach enables states to use available information to establish interim targets, begin to implement needed controls and restoration actions, monitor waterbody response to these actions, and plan for future TMDL review and revision. As part of the phased approach, a number of future needs have been identified for further refinement of the Total Phosphorus TMDL:

- Evaluate how nitrogen may be contributing to water quality impairment
- Evaluate water quality data collected by the Conservation Districts and the USGS
- Assess physical condition and relate characteristics such as the percentage of riparian vegetation or percentage of incised banks within a reach to the degree of water quality impairment or lack of biological integrity
- Determine if updates to the nitrogen or phosphorus standards are warranted

As time and resources allow, the Nevada Division of Environmental Protection will address these needs and update the TMDLs as appropriate.

Carson River Total Maximum Daily Loads – Total Phosphorus

1.0 Introduction

The primary goal of the Clean Water Act (CWA) is to restore and maintain the chemical, physical and biological integrity of the Nation's waters. CWA Section 303(a) requires each state to adopt water quality standards that include beneficial uses of the waters and criteria to protect the uses. These standards must be approved by the U.S. Environmental Protection Agency (USEPA).

Section 303(d) of the CWA requires each state to develop a list of water bodies that need additional work beyond existing controls to achieve or maintain water quality standards, and submit an updated list to the EPA every two years. The Section 303(d) List provides a comprehensive inventory of water bodies impaired by all sources. The Nevada 2002 303(d) List identifies Total Phosphorus (TP), Total Suspended Solids (TSS), Turbidity, Temperature, Total Iron and Total Mercury as parameters of concern for the Carson River. A draft 2004 list was submitted to the USEPA for approval in February 2005. The draft 2004 303(d) list reports the same impairment as the 2002 list for the Carson River.

Section 303(d) also requires states to develop Total Maximum Daily Loads (TMDLs) for the waterbody/pollutant combinations appearing in the 303(d) list. The TMDL process provides an organized framework to develop watershed-based solutions for 303(d) listed waters. This document will present TMDLs for Total Phosphorus only. TMDLs for TSS and turbidity are being developed separately. No schedule has been set for temperature, iron and mercury.

1.1 Total Maximum Daily Load (TMDL) Defined

TMDLs are an assessment of the amount of pollutant a water body can receive and not violate water quality standards. Also, TMDLs provide a means to integrate the management of both point and nonpoint sources of pollution through the establishment of waste load allocations for point source discharges and load allocations for nonpoint sources. For pollutants other than heat, TMDLs are to be established at levels necessary to attain and maintain the applicable narrative and numerical water quality standards with consideration given to seasonal variations and a margin of safety.

To achieve the necessary pollutant reductions, wasteload allocations for point source discharges are implemented through National Pollutant Discharge Elimination System (NPDES) permits for point source discharges. Nonpoint source (NPS) TMDLs can be implemented through voluntary or regulatory nonpoint source control programs, depending on the state. In Nevada, participation in programs to control nonpoint source pollution is voluntary, which lends a degree of uncertainty as to whether pollutant reductions attributed to load allocations can be achieved. As development in the Carson River Basin continues, however, nonpoint source pollution generated by urban sources and discharged through stormwater runoff will be managed through the NPDES Stormwater Program.

While each TMDL report is unique, many contain similar elements. Following is a discussion of the typical components that may appear in a TMDL based upon USEPA guidance (October 1999).

1.1.1 Problem Statement: Describes the key factors and background information that characterize the nature of the impairment, such as chemical water quality, biological integrity, physical condition, etc.

1.1.2 Source Analysis: Identifies known loading sources (both point and nonpoint sources) by location, type, frequency, and magnitude to the extent possible. Characterizing nonpoint sources can be difficult and often requires significant financial resources.

1.1.3 Target Analysis: Identifies those future conditions needed for compliance with the water quality standards and for support of the beneficial use. The target analyses clarifies whether the ultimate goal of the TMDL is to comply with a numeric water quality criterion, comply with an interpretation of a narrative water quality criterion, or attain a desired condition that supports meeting a specified designated use.

1.1.4 Pollutant Load Capacity and Allocation: Identifies the waterbody loading capacity. The loading capacity is the maximum amount of pollutant loading a waterbody can assimilate without violating the TMDL target. The allowable loadings are then distributed or "allocated" among the significant sources of the pollutant.

A margin of safety is included in the analysis to account for uncertainty in the relationship between pollutant loads and the water quality of the receiving water. It can also be stated that the margin of safety is to account for uncertainties in meeting the water quality standards when the target and TMDL are met. Additionally, consideration needs to be given to seasonal variations and critical conditions. The general equation describing the TMDL with the allocation and margin of safety components is given below:

TMDL = Sum of WLA + Sum LA + Margin of Safety (Eq. 1)

Where:

Sum of WLA = sum of wasteload allocations given to point sources
Sum of LA = sum of load allocations given to nonpoint sources

According to the CFR 130.2(i), TMDLs need not be expressed in pounds per day when alternative means are better suited for the waterbody problem. In recent years some states have utilized (and USEPA has approved) a load duration curve analysis to establish target load reductions.

1.1.5 Load Duration Curves and a Phased Approach to TMDL Adoption and Implementation

The State of Nevada is pursuing a phased approach to TMDL development and implementation for the Carson River using *Duration Curve Analysis*. A preliminary target for load reduction can be established, while continuing to collect information that will help determine the relationship between a water quality (WQ) standard and an aquatic beneficial use, such as cold-water fish. Using a phased Duration Curve Analysis as a "TMDL" provides the flexibility to conduct long-term physical, biological and chemical monitoring to establish a credible link between the appropriate water quality standard, the load reduction target and the Beneficial Use. By establishing this relationship, the "TMDL" will be a more meaningful tool in tracking improvements in water quality or *overall health* of the system as controls and restoration activities are implemented. The phased TMDL process is an adaptive management approach designed to help meet the *primary goal* of the Clean Water Act – to restore and maintain the chemical, physical and biological integrity of the Nation's waters.

1.2 Watershed Plan

Although not specifically required by the CWA, a plan to implement the TMDLs is often developed. Point source waste load allocations are managed through NPDES permits. In most states, including Nevada, the nonpoint source load allocations are addressed through voluntary compliance with assistance from the CWA Section 319 grant program.

In 2002, the USEPA began focusing the use of a portion of 319 NPS funds to the development of NPS TMDLs, development of TMDL or watershed-based implementation plans, and implementation of the plans. The watershed plans are intended to focus activities on measures that will reduce nonpoint source pollutant loads and restore impaired waters. Watershed-based plans developed with 319 funds must include nine elements: (1) pollution sources; (2) an estimate of load reductions needed; (3) description of NPS management measures needed; (4) technical, financial or regulatory needs to implement plan; (5) public education; (6) an implementation schedule for NPS management measures; (7) measurable milestones; (8) criteria for determining if load reductions are being met and WQ standards attained; and (9) a monitoring component. NDEP is currently working with the Carson Water Subconservancy District to develop a Watershed Plan for the Carson River that contains the nine key elements.

2.0 Background

2.1 Study Area

Although the headwaters of the Carson River originate in Alpine County, California, approximately 85% or 3360 square miles of the Carson River Watershed lies in Nevada (California DWR, 1991). The source of the East Fork is near Sonora Pass and the West Fork begins as several small streams that merge below Carson Pass near the Red Lake area along Highway 88. The two forks combine in Carson Valley and the main stem travels northeast through Carson City, Dayton Valley and is eventually impounded by Lahontan Reservoir. Flows from the reservoir are controlled for downstream irrigation in the Fallon area and the river terminates in the Carson Sink. Water is also diverted into the Stillwater Wildlife Management Area.

The predominant land use in the basin valleys is agriculture. However, the Minden-Gardnerville, Carson City and Dayton areas are experiencing extensive development. Ranch property is being sold and subdivided, forever changing the rural character of the Carson River Watershed. Increased population growth may have a significant impact on future water quality and the focus of nonpoint source pollution control programs.

2.2 Major Monitoring Stations and TMDL Sites

There are 15 sampling locations on the Carson River that are routinely monitored by NDEP (Figure 1). Bryant Creek water quality and the impacts of Leviathan Mine were addressed under a separate TMDL document, which was approved by EPA in November 2003. The Truckee Canal and Below Lahontan stations will be evaluated as part of a possible future TMDL for Lahontan Reservoir. All water quality data evaluated for this report can be provided electronically upon request.

Duration Curve Analysis was conducted at five of the remaining 12 sampling locations because of the proximity of the USGS Flow Gages to the monitoring sites. Table 1 outlines the "TMDL" sites, the corresponding reaches and USGS gaging stations. If the Load Duration Curve is exceeded at the selected site according to the target established for non-attainment, then the entire upstream reach will not meet the TMDL.

TABLE 1 "TMDL" Sites, Corresponding Reaches and USGS Gaging Stations for the Carson River

"TMDL" Site	Corresponding Reach upstream of TMDL Site and the Nevada Administrative Code (NAC) segments *within* TMDL Reaches	USGS Gaging Station
1 East Fork at Riverview	**No impairment** - Duration Curve developed to illustrate decline in water quality at downstream sites	Near Gardnerville # 10309000
2 West Fork at Paynesville, Ca.	**No impairment** - Duration Curve developed to illustrate decline in water quality at downstream sites	Woodfords # 10310000
3 Carson River at Mexican Gage	Mexican Gage to Stateline on both East and West Forks **445A.147, 445A.149, 445A.150, 445A.151, 445A.152, 445A.153, 445A.154**	Near Carson City # 10311000
4 Carson River at New Empire Bridge	New Empire to Mexican Gage **445A.155**	Deer Run Road # 10311400
5 Carson River at Weeks Bridge	Weeks to New Empire **445A.156, 445A.157**	Near Fort Churchill # 10312000

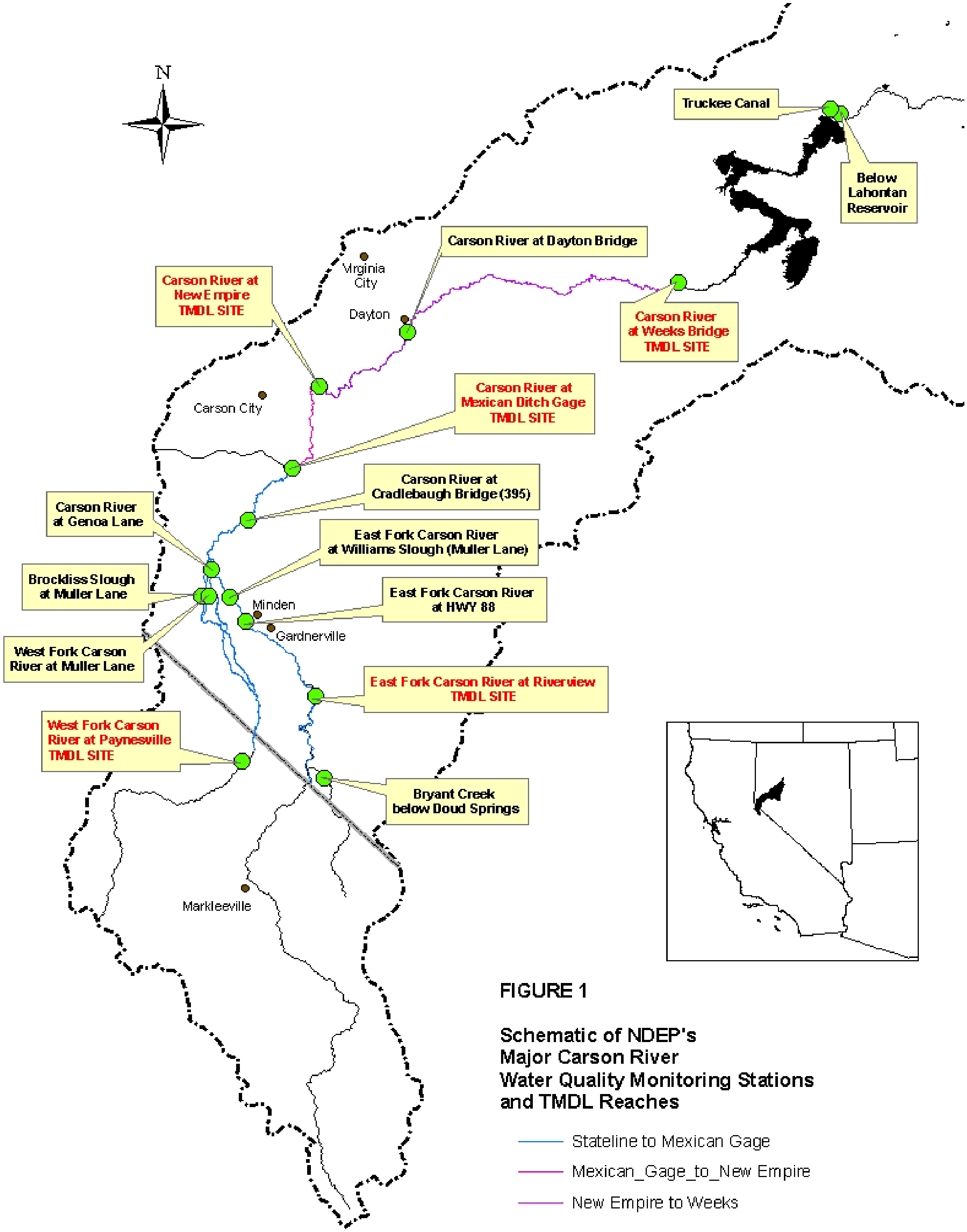


FIGURE 1

Schematic of NDEP's
Major Carson River
Water Quality Monitoring Stations
and TMDL Reaches

Stateline to Mexican Gage
Mexican_Gage_to_New Empire
New Empire to Weeks

2.3 Water Quantity

The highest stream flows at all USGS gaging stations in the Carson River Basin occur primarily during spring snowmelt. Summer low flows are usually exacerbated by agricultural diversions throughout the Carson basin. During the irrigation season (April through mid-October), flow diversions are managed by the Federal Watermaster, as dictated by the Alpine Decree. Mean monthly stream flow for the East Fork is shown in Figure 2. Charts for the other four Carson River gaging stations are provided in Appendix A.

The East Fork gage is located 4.5 miles downstream of Bryant Creek and 7 miles southeast of Gardnerville. The West Fork gage is located 0.6 miles southwest of Woodfords in Alpine County, California, approximately 3 miles from the Paynesville monitoring site. Discharge in the West Fork can be one-quarter to one-third of the flow in the East Fork. However, Brockliss Slough carries most of the flow in the West Fork. The channel designated as the West Fork on local maps is considered a return flow ditch that receives water from fields irrigated with water from the East Fork. Only a small portion of the West Fork river flow is diverted into the West Fork Ditch to meet downstream water rights. Urban runoff from a residential area may also be contributing to the discharge and pollutant load in the West Fork via the Rocky Slough.

The East and West Forks combine just upstream of the Genoa Lane Bridge on property managed by The Nature Conservancy. Brockliss Slough converges with the Main Stem of the river downstream of Genoa Lane and upstream of the Genoa Lakes Golf Course. The Carson City gage is two miles downstream of the confluence with Clear Creek and 3 miles upstream of Lloyds Bridge. The gage at Deer Run Road is 4 miles east of Carson City, just downstream of the bridge and approximately 32 miles from the gaging station near Fort Churchill. The Fort Churchill gage is 4.5 miles upstream of Weeks Bridge and approximately 10 miles from Lahontan Reservoir. At this point, the Carson River drains an area of 1302 mi^2.

The flow duration curve presented in Figure 3 is based on a percentage of the ranking of the East Fork near Gardnerville average daily stream flow rates between years 1890 and 2003. The plot illustrates the frequency (or likelihood) of a particular stream flow occurring. During this time period, daily stream flow rates ranged from a low of 11 cfs to a high of 17,000 cfs with an annual mean stream flow rate of 381 cfs. Flow duration curves for the other four gages are provided in Appendix B.

FIGURE 2 Mean Monthly Stream Flow (1890 - 2003) - East Fork Carson River near Gardnerville, NV USGS #10309000

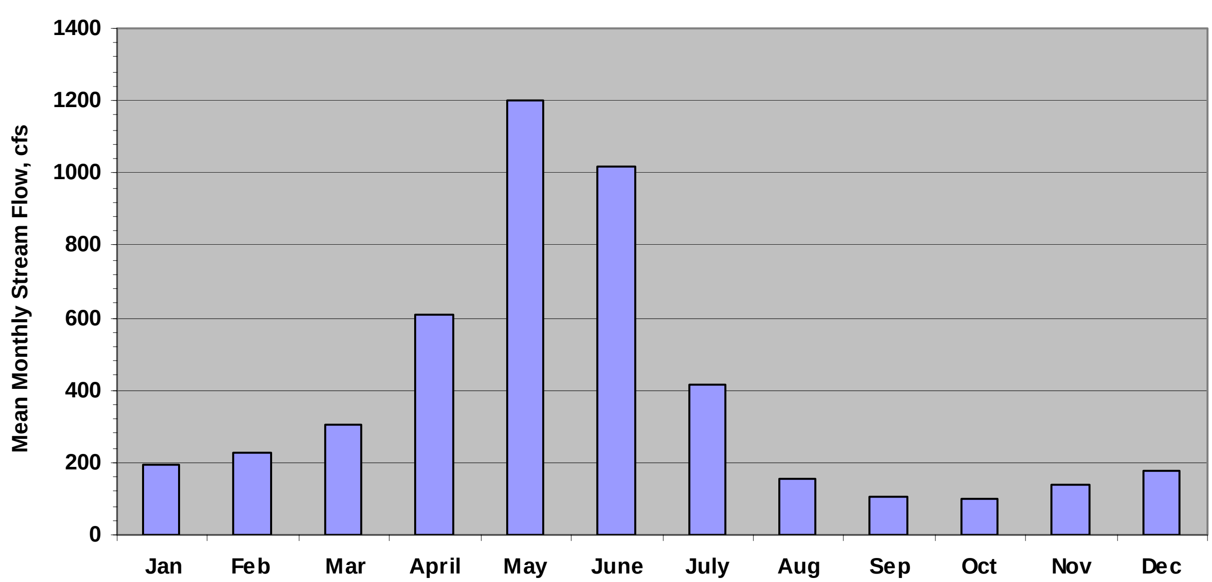
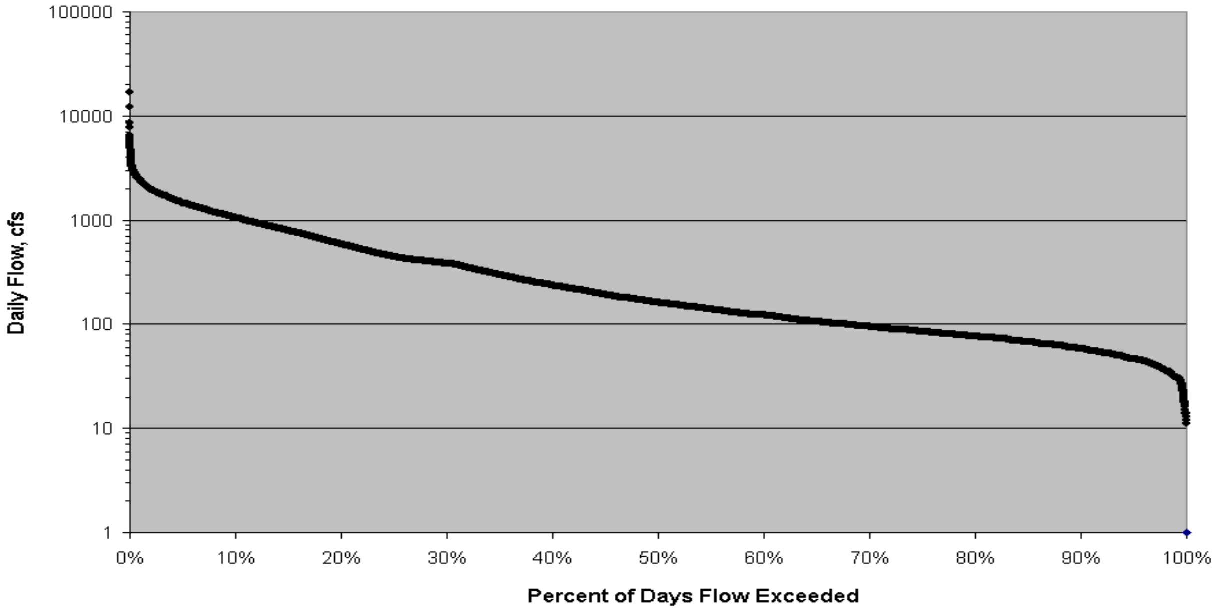


FIGURE 3 Flow Duration Curve (1890 - 2004) East Fork Carson River at Riverview USGS #10309000



2.4 Existing Water Quality Standards & Aquatic Beneficial Uses

The 2002 Nevada 303(d) List identifies TP, TSS, Turbidity, Temperature, Total Iron and Total Mercury as parameters of concern. This report will only present a phased TMDL for Total Phosphorus. TSS, Turbidity, Temperature, Total Iron and Total Mercury will be addressed at a later date in separate documents. Some discussion of TSS and Turbidity has been included because of the association of TP with sediment and particulate organic matter.

The existing water quality standards for TP, TSS and Turbidity are listed in Table 2 and are derived from the Nevada Administrative Code (NAC) Section 445A.147 through 445A.158. The control points listed in the NAC identify the downstream monitoring station of each reach. If a standard is exceeded at a control point, the entire reach is considered impaired. The beneficial uses for the Carson River are listed in NAC 445A.146 and includes *propagation of aquatic life*, *irrigation, watering of livestock, recreation involving contact with water, recreation not involving contact with water, industrial supply, municipal or domestic supply or both, and the propagation of wildlife.* The Upper Carson River Watershed, which extends from the stateline to the New Empire Bridge at Deer Run Road in Carson City, is described as a cold-water fishery. Species of major concern are also identified in Table 2. From New Empire down to Lahontan Dam, the system is considered a warm water fishery.

Currently, there is no evidence of a self-propagating trout population in the Carson River through Nevada (Nevada Division of Wildlife (NDOW), 2000). NDOW manages the Carson River as a “put and take” fishery, stocking non-native rainbow and brown trout annually. Fish population surveys performed since 1994 indicate that based on the small size of fish found and the overall low population densities, it is assumed stocked fish do not survive for longer than 1 or 2 years. There is also no evidence for wild rainbow trout reproduction based on the length of fish found. Anglers are expected to harvest 80 to 100% of the stocked trout. According to NDOW, high spring flows and excessive suspended sediment concentrations may also be contributing to poor trout survival. Anecdotal information indicates a stray native Lahontan Cutthroat trout (LCT) may be found in the East Fork Carson River in California (CA Fish & Game, 1995), but the indigenous fishery was severely degraded prior to 1900 (NDOW, 1999). Catfish were first planted in the Carson in the late 1870’s and stocking with non-native trout has been occurring since 1884. A low-density population of genetically pure LCT was found in the upper East Fork above

Carson Falls during a survey conducted in 1989 (CA Fish & Game, 2004), but more recent data is unavailable for this site. Impairment of river ecology is also evidenced by preliminary data from NDEP's Bioassessment Program, which indicates an overall low diversity and low abundance of Macroinvertebrates in Nevada's major basin streams. Specific watershed results will not be released until the QA/QC analysis is complete.

TABLE 2 Carson River Water Quality Standards for TP, TSS and Turbidity

NAC designated Reach	Control Point	TP, mg/L Annual Average	TSS, mg/L Single Value	Turbidity, NTU Single Value	Fish Species of Concern
445A.147 West Fork at stateline	WF at stateline	≤ 0.10	≤ 25	≤ 10	Rainbow & Brown Trout
445A.148 Bryant Creek near stateline	Bryant Creek near stateline	≤ 0.10	≤ 25	≤ 10	Rainbow & Brown Trout
445A.149 East Fork at stateline	EF at stateline	≤ 0.10	≤ 25	≤ 10	Rainbow & Brown Trout
445A.150 East Fork at stateline to Hwy 395	Hwy 395 (EF Riverview)	≤ 0.10	≤ 80	≤ 10	Rainbow & Brown Trout
445A.151 East Fork at Hwy 395 to Muller Lane	EF at Muller Lane	≤ 0.10	≤ 80	≤ 10	Rainbow & Brown Trout
445A.152 East Fork at Muller to Genoa Lane	Carson River at Genoa Lane	≤ 0.10	≤ 80	≤ 10	Catfish, Rainbow & Brown Trout
445A.152 West Fork at stateline to Genoa Lane	Carson River at Genoa Lane	≤ 0.10	≤ 80	≤ 10	Catfish, Rainbow & Brown Trout
445A.153 Carson River at Genoa Lane to Cradlebaugh Bridge	Cradlebaugh Bridge	≤ 0.10	≤ 80	≤ 10	Catfish, Rainbow & Brown Trout
445A.154 Carson River at Cradlebaugh Bridge to Mexican Ditch Gage	Mexican Ditch Gage	≤ 0.10	≤ 80	≤ 10	Rainbow & Brown Trout
445A.155 Carson River at Mexican Gage to New Empire	Near New Empire	≤ 0.10	≤ 80	≤ 10	Smallmouth Bass, Rainbow & Brown Trout
445A.156 Carson River at New Empire to Dayton Bridge	Dayton Bridge	≤ 0.10	≤ 80	≤ 50	Walleye, Channel Catfish & White Bass
445A.157 Carson River at Dayton Bridge to Weeks Bridge	Weeks Bridge	≤ 0.10	≤ 80	≤ 50	Walleye, Channel Catfish & White Bass
445A.158 Carson River at Weeks Bridge to Lahontan Dam	At Lahontan Dam	≤ 0.06	≤ 25	≤ 50	Walleye, Channel Catfish & White Bass

2.5 303(d) Listing

There are some major differences in the 1998 303(d) list compared to the 2002 list (Table 3). There are a greater number of reaches listed under the 2002 list exceeding the TSS standard compared to the 1998 list. The TSS standard is exceeded on three East Fork reaches according to the 1998 list, but these same reaches were not listed in 2002. The 1998 list document states that "TSS and turbidity exceedances are likely the result of record high flows in the Carson River in January 1997 during which damage to the river channel occurred." Turbidity exceedances are a problem during both time periods.

However, only 2 years of data was evaluated to create the 1998 list; 5 years worth of data was analyzed to produce the 2002 list. The evaluation method also changed. In 1998, impairments were reported if >25% of the samples exceeded the standard. In 2002, a water body was reported as impaired for the parameter in question if >10% of the samples exceeded the standard.

It is difficult to pinpoint the cause of the differences in standard violations between time periods. The change in exceedances may be an artifact of the amount of data evaluated, evaluation method, flow levels or the result of more particulate matter (sediment + organic) being moved downstream. The greater number of exceedances reported by the 2002 list may be the result of localized streambank erosion. There is only one difference in TP impairment between evaluation periods. The 2002 list reported the East Fork (EF) at Williams Slough site as impaired for TP; the 1998 list showed no impairment. A more detailed discussion of existing water quality related to total phosphorus will be provided in *Section 3.0 Total Maximum Daily Loads.* The draft 2004 303(d) list reports the same impairments for all sections of the river due to phosphorus as the 2002 list.

TABLE 3 Comparison of 1998 and 2002 303(d) Lists

<table>
<tr><th colspan="2">Reach and/or Sub-Reach</th><th>1998 Impairment</th><th>2002 Impairment</th></tr>
<tr><td colspan="2">EF Stateline to Hwy 395 (EF Riverview)</td><td>TSS, Turbidity</td><td>Turbidity</td></tr>
<tr><td rowspan="2">EF 395 to Muller Lane</td><td>EF Hwy 395 (EF Riverview) to Hwy 88</td><td>TSS, Turbidity</td><td>Turbidity</td></tr>
<tr><td>EF Hwy 88 to Muller Lane</td><td>TSS, Turbidity</td><td>TP, Turbidity</td></tr>
<tr><td colspan="2">EF Muller Lane to Genoa Lane</td><td>TP, Turbidity</td><td>TP, TSS, Turbidity</td></tr>
<tr><td colspan="2"></td><td></td><td></td></tr>
<tr><td colspan="2">Brockliss Slough above Carson River*</td><td>N/A</td><td>TP, Turbidity</td></tr>
<tr><td colspan="2"></td><td></td><td></td></tr>
<tr><td rowspan="2">Carson River at Genoa Lane to the WF at stateline</td><td>WF at Stateline to Muller Lane</td><td rowspan="2">TP, Turbidity</td><td>TP, Turbidity</td></tr>
<tr><td>West Fork Muller Lane to Genoa Lane</td><td>TP, TSS, Turbidity</td></tr>
<tr><td colspan="2"></td><td></td><td></td></tr>
<tr><td colspan="2">Carson River at Genoa Lane to Cradlebaugh Bridge</td><td rowspan="2">TP, Turbidity</td><td>TP, TSS, Turbidity</td></tr>
<tr><td colspan="2">Carson River at Cradlebaugh to Mexican Ditch Gage</td><td>TP, TSS, Turbidity</td></tr>
<tr><td colspan="2"></td><td></td><td></td></tr>
<tr><td colspan="2">Carson River at Mexican Ditch Gage to New Empire</td><td>TP, Turbidity</td><td>TP, Turbidity</td></tr>
<tr><td colspan="2">Carson River at New Empire to Dayton Bridge</td><td>TP</td><td>TP, TSS</td></tr>
<tr><td colspan="2"></td><td></td><td></td></tr>
<tr><td colspan="2">Carson River at Dayton Bridge to Weeks Bridge</td><td>TP</td><td>TP, TSS, Turbidity</td></tr>
</table>

* Brockliss Slough is considered a Tributary to the Carson River and enters the main stem of the river between Genoa Lane and Cradlebaugh Bridge. Therefore, the standards proscribed in regulation for the reach from Genoa to Cradlebaugh (NAC445A.153) are applied to Brockliss Slough.

2.6 Relationship between Water Quality and Historic Hydrologic and Geomorphic Modification

Hydrologic modification is described as a source of nonpoint pollution by EPA (Federal Register, 10/23/03) and includes channelization or flow alteration. EPA recognizes that such modifications can disrupt sediment supply and delivery, eliminate riparian habitat, change channel morphology and accelerate the delivery of pollutants to downstream areas. Projects that straighten, enlarge or relocate a stream channel may also require regular maintenance that will continually disturb the system (**http://www.epa.gov/owow/nps/hydro.html**).

In 1996, a consulting firm (Inter-Fluve, Inc) conducted a fluvial geomorphic assessment of the Carson River in cooperation with a number of organizations and agencies within the watershed. The general conclusion drawn by the consultants is that the stability of the Carson River is poor and in a "state of geomorphic transition, and that further changes in channel geometry and planform can be expected". They acknowledged that channel instability likely dates back to the initial use of the river by European settlers for irrigation and mining-related activities. In addition, efforts to control the large magnitude floods that occur periodically have resulted in levee construction and channelization. In 1965, the Bureau of Reclamation straightened approximately 70 out of the 114 miles of river between Stateline and Lahontan Reservoir. Channelization is cited as one of the principal reasons the Carson River is incised.

Grazing and numerous dams and diversions are additional factors cited by Inter-Fluve that have contributed to system degradation. Livestock trample streambanks and may browse heavily on riparian vegetation, limiting natural regeneration. Permanent dam structures accumulate sediment that is flushed out during high flows, adding to the pollutant load. Push-up dams are constructed from riverbed materials and are often washed downstream during spring runoff. During low flow conditions, several reaches are subject to substantial dewatering because of water diverted for agricultural use.

Based upon the existing observed physical condition, the water quality impairments in the Carson River may not *simply* be due to a direct discharge of some specified contaminant. *Multiple* disturbances to the river system, which began over a century ago, have altered form (meander pattern) and function, upsetting the balance between flow and sediment transport, disconnecting the river from its floodplain, lowering the water table and reducing pollutant assimilative capacity. Timber logged from the Upper East Fork Basin was transported down the Carson River to Empire City (top of Dayton Valley) to support Comstock mine construction. Floating logs down the Carson occurred over a 40-year time period, beginning in 1862 (NDWP, 1997). The largest drive was reported to be 4 miles long with logs stacked 8 feet high. Log drives would have had a tremendous impact on channel stability, by scouring the channel and destroying bank vegetation.

Hydrogeomorphic alteration and habitat loss are considered the primary reasons the cold-water fishery is impaired. The impacts of logging, mining and irrigation led to increased bed and bank erosion, and the subsequent decline in water quality, macroinvertebrate populations and fish propagation. In many reaches, the Carson River has down-cut; creating shallow, over-widened channels with vertical banks that lack appropriate vegetation. The river channel also lacks adequate pool and riffle structure necessary for trout reproduction and survival in many reaches. NDOW (2000) reports that downstream of the town of Minden, sand and silt dominate the river bottom substrate. Initial evaluation of the pebble count data collected as part of NDEP's Bioassessment Program supports NDOW's claim. The median percentage of substrate determined to be < 2 mm is 67 percent at sites located just above the confluence at Genoa Lane and just above Cradlebaugh Bridge compared to 32 percent at the upstream sites on the East and West Forks. Sand or silt embedded in gravel used as spawning habitat can prevent trout from digging nests (redds) and may suffocate eggs already deposited (EIFAC, 1965).

Changes to channel size and shape have occurred over the past 150 years. It is difficult to separate out the direct impacts from each occurrence because the physical changes have not been monitored. Over time, an incised stream will readjust at a lower base level, recreating a floodplain and establishing a new equilibrium. However, this new steady-state condition may be of less ecological value than what existed before the disturbance (Federal Interagency Stream Restoration Working Group, 1998). Continuous perturbations, such as mismanaged grazing in the riparian area or routine sand bar removal for conveyance will likely impede any readjustment, at least at the local reach level if not watershed-wide. Unchecked urban development in the floodplain, without buffer zones or conservation easements in place to preserve the riparian corridor, will also hinder significant improvements in physical condition, biological integrity and water quality. As integral parts of the river system, floodplains attenuate high flow, recharge groundwater, collect sediment and process nutrients. Building next to a river can prevent restoration of these functions, require costly artificial flood controls to protect new infrastructure and may introduce other water quality problems. According to EPA (1983), copper, lead and zinc were the most prevalent priority pollutants detected in urban runoff. Current water quality samples collected by NDEP indicate levels of these three constituents are below drinking water or aquatic life protection standards.

A more comprehensive discussion of the anthropogenic impacts on Carson River geomorphology is presented in the 1996 Inter-Fluve assessment report. The Upper Carson River Watershed Stream Corridor Condition Assessment (2004), sponsored by the Alpine Watershed Group and the Sierra Nevada Alliance, also presents a thorough examination of geomorphic process. These documents are available for review at NDEP.

3.0 Total Phosphorus TMDL

3.1 Problem Statement

The Carson River is impaired for Total Phosphorus downstream of the West Fork at Paynesville and the East Fork at Riverview, therefore requiring development of a "TMDL". Increases in phosphorus can cause excess algae growth, consumption of oxygen and subsequent death of aquatic life.

Table 4 summarizes the total phosphorus data as collected by NDEP for the period of record at each "TMDL" site. Data collected during this longer time period was used to develop the Target Load Duration Curves rather than the 5-year span used to develop the 2002 303(d) list. Only a partial data set was used to construct a load duration curve for New Empire, because the flow record (May 1979 - present) at the Deer Run Road gage is shorter than the water quality record.

TABLE 4 Summary of Total Phosphorus Data

Parameter	West Fork at Paynesville	East Fork at Riverview	Carson River at Mexican Gage	Carson River at New Empire	Carson River at Weeks
Annual Average Standard, mg/L	0.1 at stateline	0.1	0.1	0.1	0.1
Period of Record	7/68 - 5/04	6/68 - 5/04	9/75 - 5/04	6/68 - 5/04	6/68 - 5/04
# Samples	365	366	265	350	240
# Samples exceeding	4	21	242	331	175
% Samples exceeding	1	6	91	95	73
Average	0.030	0.045	0.218	0.361	0.152
Median	0.026	0.030	0.190	0.220	0.135
Minimum	0.000	0.007	0.070	0.060	0.040
Maximum	0.209	0.440	0.650	4.32	0.830

As listed in Table 4, exceedances generally increase moving downstream. This is illustrated by comparing Figures 5 and 6. A greater number of sample concentrations at Mexican Gage are above the standard compared to upstream at Riverview on the East Fork. The peak TP values observed are not always associated with increased flow; high concentrations can occur during other flow conditions. The relationship between TP and flow will be discussed in more detail in the next section. Time series plots for the other 3 sites are provided in Appendix C.

The East Fork at Riverview and West Fork at Paynesville sites do not require a TMDL because they are not impaired for TP. The Load Duration curves were developed for these sites to illustrate the decline in water quality between sites. <u>This document evaluates the total number of exceedances instead of annual averages</u> in order to assess the potential seasonal differences in concentration and loading.

FIGURE 4 East Fork Carson River at Riverview June 1968 - May 2004

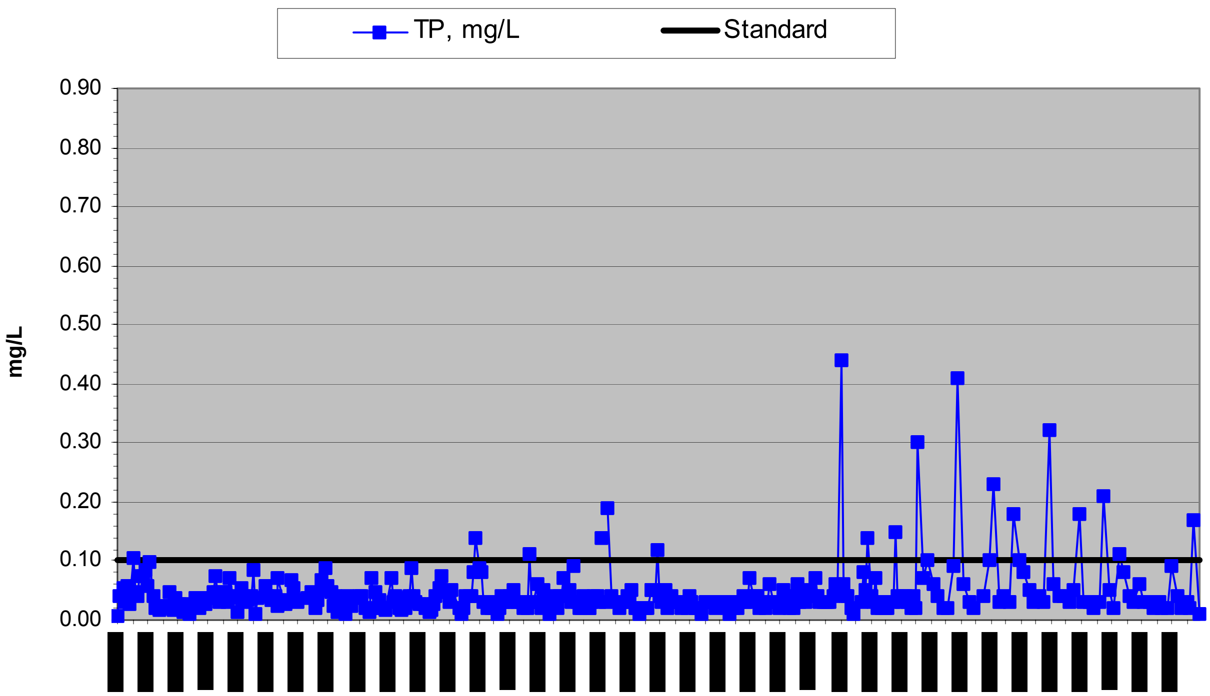
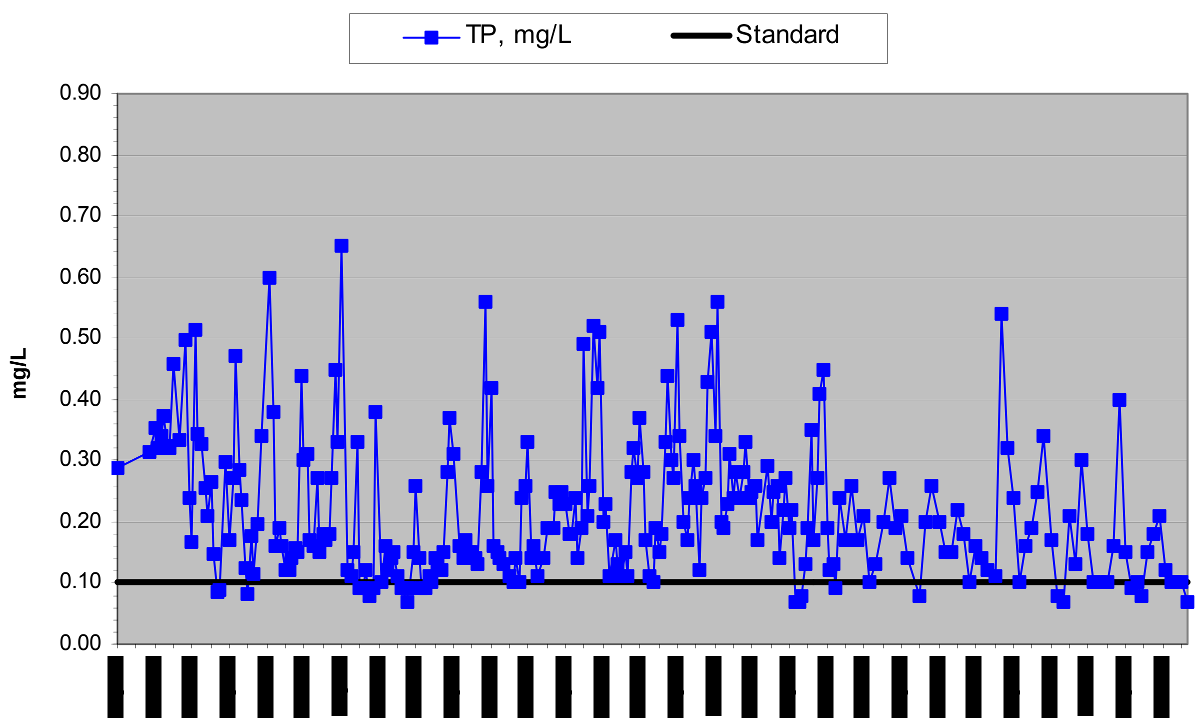


FIGURE 5 Carson River at Mexican Gage September 1975 - May 2004



3.2 Source Analysis

The degraded physical condition of the river system has led to a loss of biological integrity and exceedance of the water quality standards for TP, TSS and Turbidity in most Carson River Reaches. Inputs from agricultural return flow, grazing livestock, stream bank erosion and sediment, fertilizer or pet waste in urban runoff are all considered potential sources of phosphorus in the Carson River. Impacts are intensified because the system has a reduced capacity to assimilate, filter and process pollutants. Loss of floodplain, the associated lotic wetlands and riparian vegetation has eliminated the mechanisms that mitigate pollutant concentrations. Sediment being discharged from land damaged by fire or from erodible, high gradient tributaries to the East Fork in California may be contributing to the suspended solid loads and high turbidity (USFS, 1997). The Upper Carson River Watershed Assessment (2004) prepared for the Alpine Watershed Group and the Sierra Nevada Alliance also report that the East Fork "has significantly higher sediment transport than the West Fork". High phosphorus can be related to excessive sediment or total suspended solids because phosphorus binds selectively to fine particles as soil erodes (Sharpley, 1980). Phosphorus (P) may also be naturally-occurring due to local geology or released into the water column by organic matter decomposition. Phosphorus is also conserved within the system, unlike nitrogen, which can be permanently removed by denitrification. Phosphorus is recycled between organic and inorganic species and temporarily stored in algae, plants or sediment after uptake and adsorption. Characterizing the individual phosphorus sources for allocating loads can be a time and money intensive process; therefore, this TMDL document addresses only general contributions.

Point source discharges (treated effluent) were removed from the system in 1987; therefore current exceedances of the water quality standards can be considered the result of nonpoint source (NPS) pollution. Today, treated wastewater generated throughout the Basin is discharged to evaporation ponds or land applied to agricultural fields, public landscapes or golf courses. Effluent piped in from the Tahoe Basin, is used for irrigation or discharged to constructed wetlands in the northern part of Carson Valley. The USGS *Scientific Investigations Report 2004-5186* (Alvarez and Seiler, 2004) indicated that treated effluent used in Carson Valley may be contributing to the pollutant loads in the river through surface runoff from fields enriched with phosphorus during the irrigation season. Williams Slough drains fields irrigated with reclaimed water and flows into Ambrosetti Pond, which then discharges into the main stem Carson River between Genoa Lane and Cradlebaugh Bridge. Alvarez and Seiler (2004) report that on November 20, 2000, Ambrosetti Pond was the source for 42% of the phosphorus load leaving Carson Valley. On July 9, 2002, almost 11% of the phosphorus load measured at the Carson City gage was coming from Ambrosetti Pond. Organic matter decay and internal cycling (release of P from anoxic sediments) may also be contributing to the high phosphorus levels discharged from the pond. Some concern has been expressed regarding a leak flowing from Carson City's effluent storage reservoir in Brunswick Canyon and discharging into the river. The leak is temporary because NDEP may require the city to line the facility or recycle the discharge back into the reservoir. In addition, the average TP concentration decreases between New Empire and Weeks, suggesting the leak has minimal impact to the phosphorus concentration in the river downstream of the discharge.

Long-term P enrichment of the fields may be occurring because irrigation with treated effluent has been taking place since the late 1980's and soil adsorption sites may have become saturated over time (Alvarez and Seiler, 2004). The State of Nevada issues reuse permits that do not allow direct discharge to the river and require application rates be calculated based on nitrogen to reduce the potential for nitrate leaching. However, only managing for nitrogen may lead to the addition of more phosphorus than needed by the crop, an eventual increase in soil P and an increased risk of phosphorus export to surface waters (Pennsylvania State University, 1999; Sharpley et al., 1994). Sims et al. (1998) also discussed the loss of phosphorus from soils where over-fertilization has increased soil P above crop requirements. More investigation is needed to determine if phosphorus enrichment has actually occurred.

Figures 6 and 7 illustrate the increase in <u>average</u> sample phosphorus load and concentration as you move downstream from the East and West Fork Sites to New Empire in Carson City. Analysis of NDEP's water quality data indicates that a considerable portion of the total phosphorus load consists of orthophosphate (OP). The highest <u>average</u> concentrations of both OP and TP occur at New Empire (Figure 8). It should also be noted that the average TP concentrations at the upstream East and West

Fork sites are comprised of 50% OP (Figure 8), suggesting that the phosphorus flowing into Nevada is not just associated with sediment, but with a diffuse source that supplies the water column with dissolved or available P (albeit very low in concentration). The highest percentage of OP occurs October to December at most sites and may be related to the minimal nutrient uptake that occurs during the fall/winter months (Figure 9). Additional Seasonal Phosphorus bar charts are found in Appendix D. All five TMDL sites show a high percentage of orthophosphate (≥ 45%) regardless of season.

FIGURE 6 Carson River Seasonal Average Phosphorus Concentrations

Note: Values determined by averaging over the total number of samples collected.

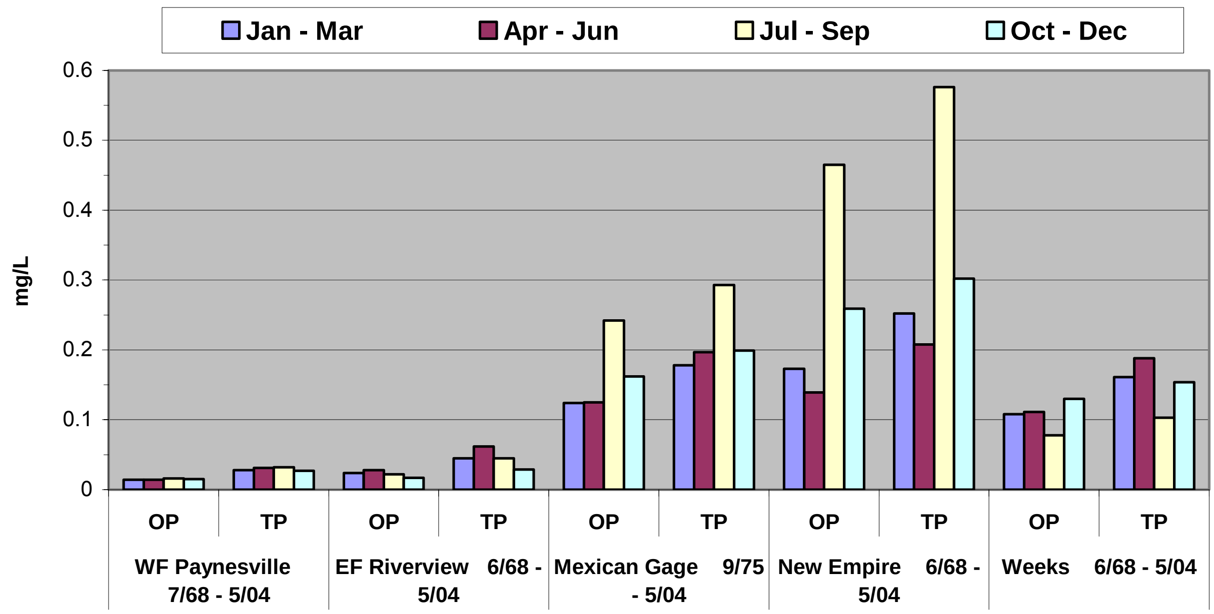


FIGURE 7 Carson River Seasonal Average Sample Loads

Note: Values determined by averaging over the number of samples collected within available flow record.

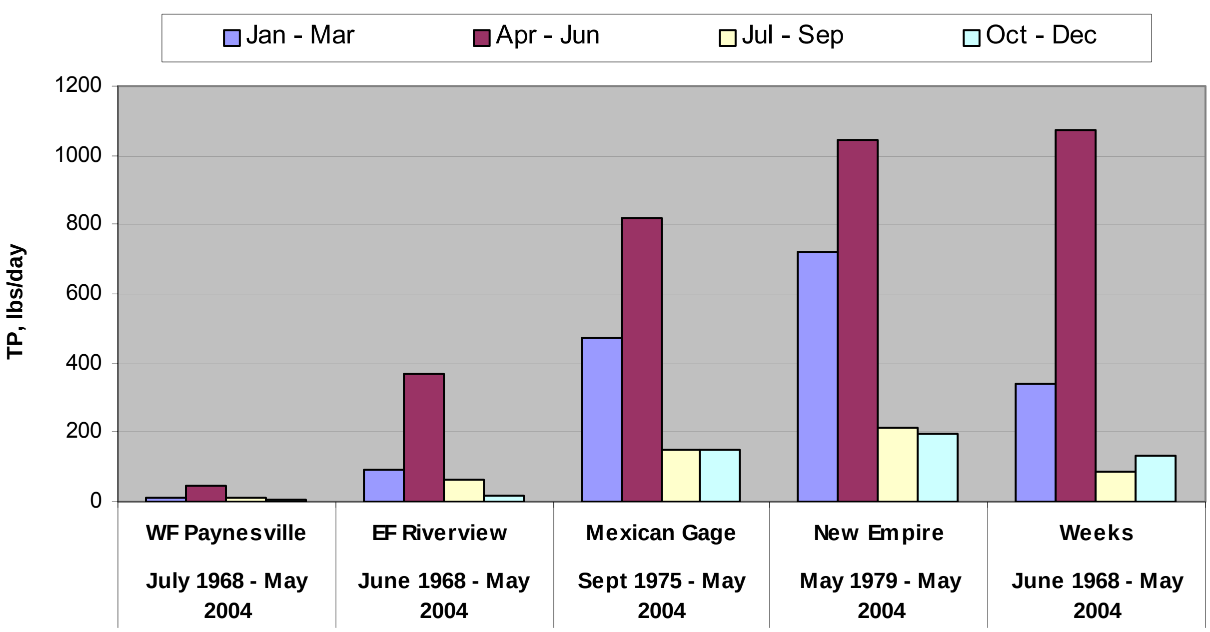


FIGURE 8 Carson River Average Phosphorus

Values determined by averaging over the total number of samples collected.

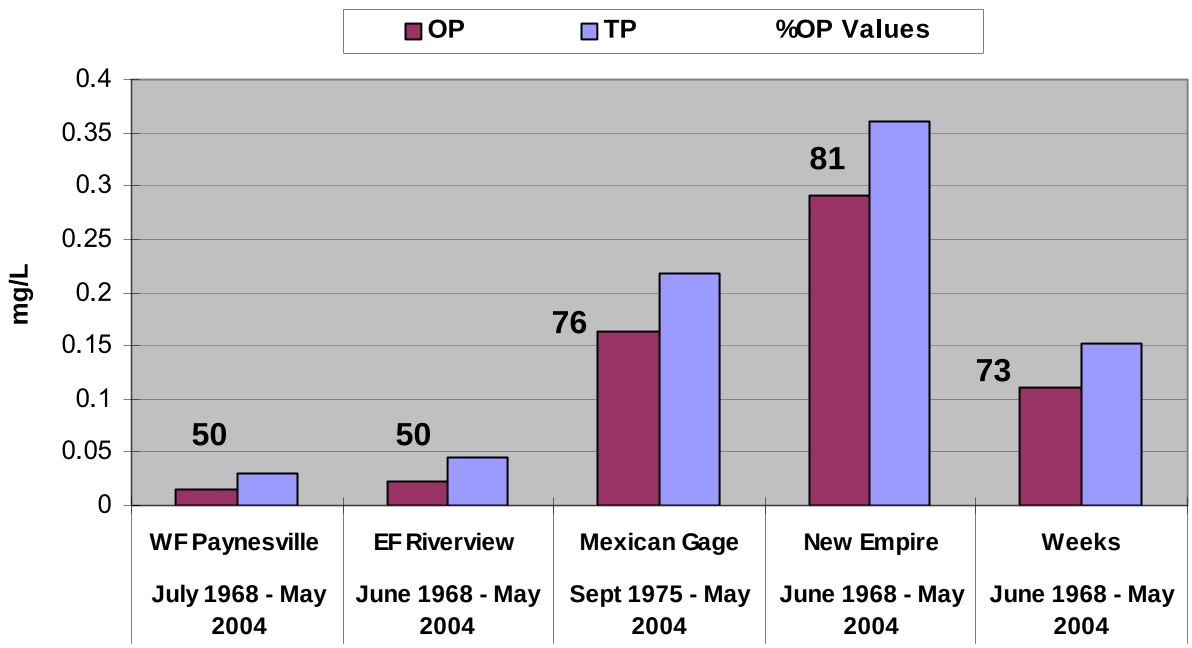


FIGURE 9 Carson River at New Empire Bridge

Seasonal Average Phosphorus June 1968 - May 2004

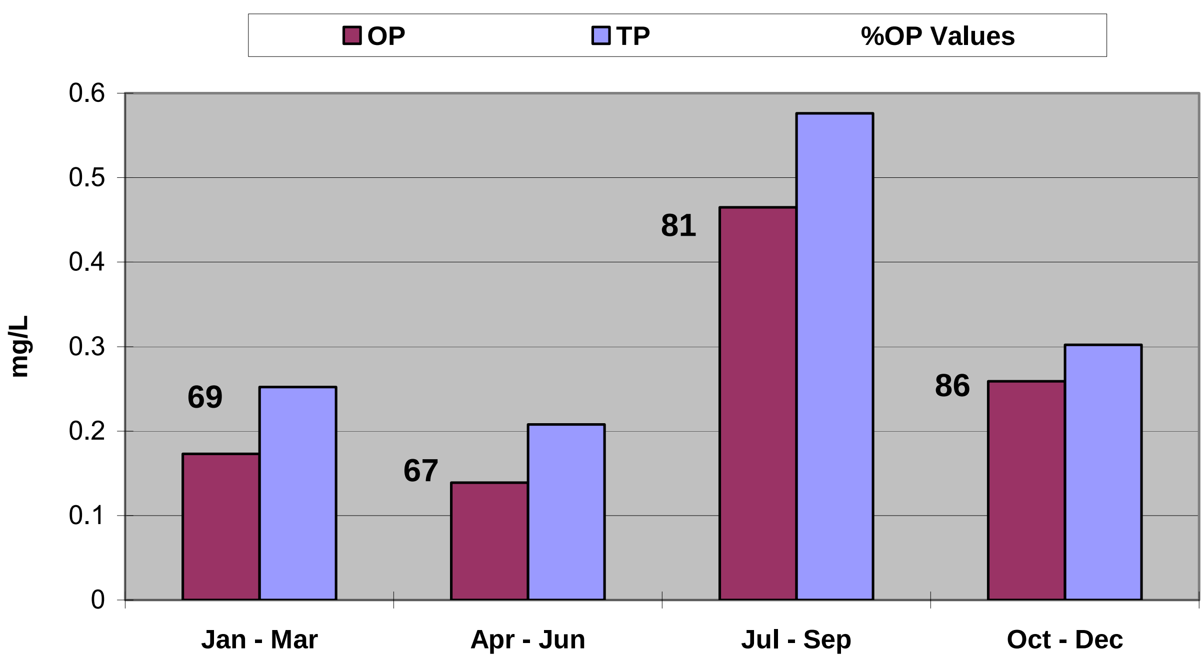


FIGURE 10 Carson River Period of Record
Distribution of Phosphorus

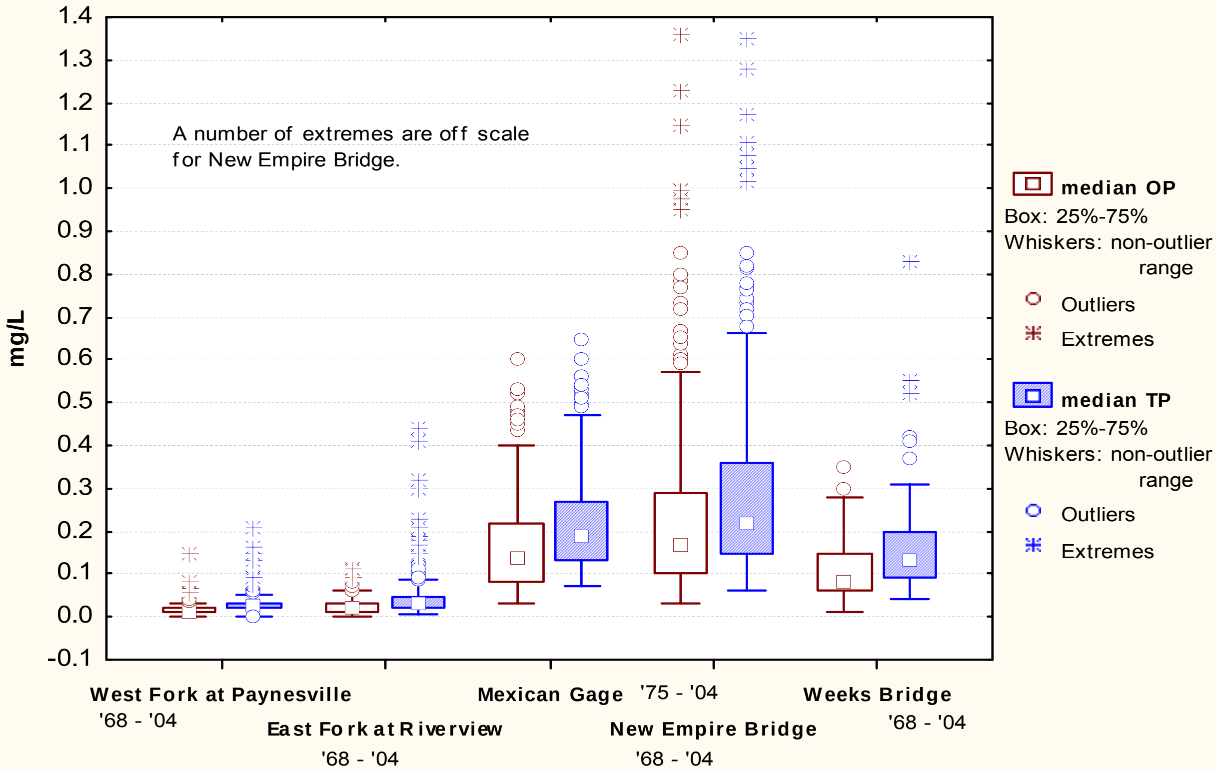
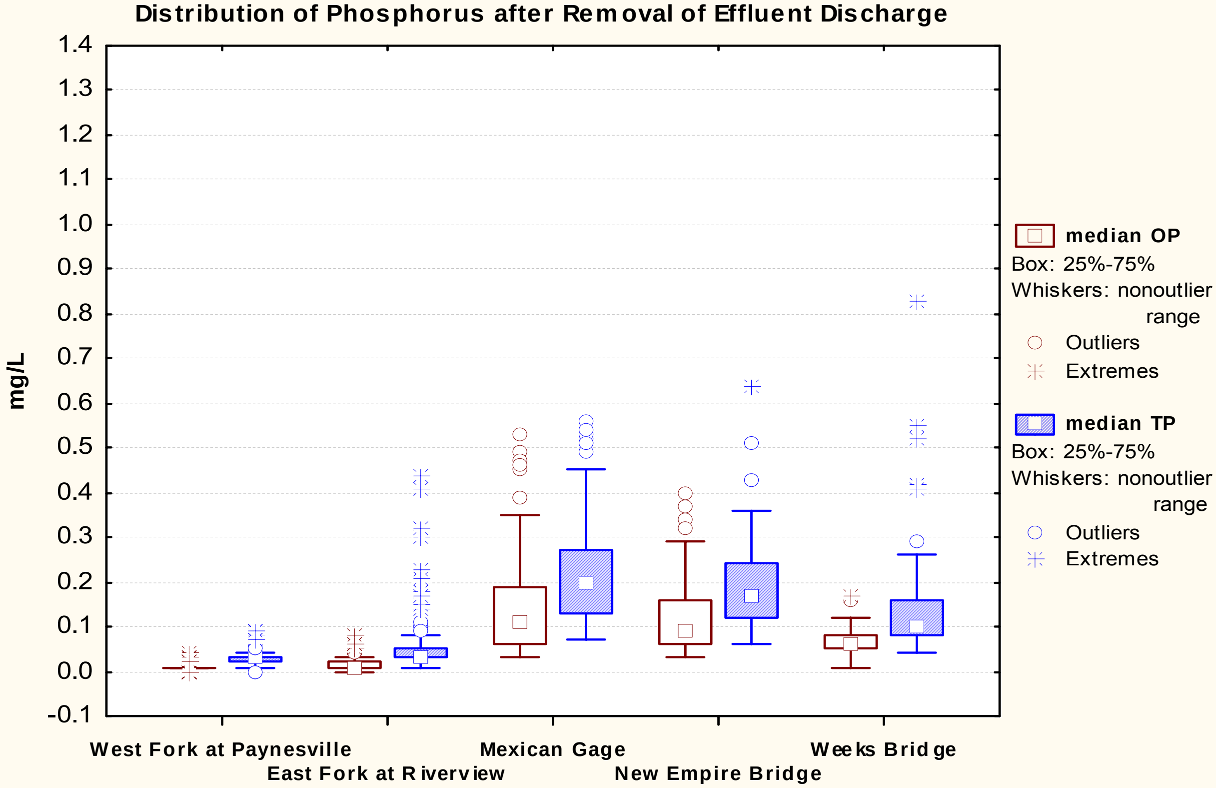


FIGURE 11 Carson River 1988 - 2004
Distribution of Phosphorus after Removal of Effluent Discharge



Box plots provide a simple method to summarize and compare the center, variability and skewness of a data set (Helsel and Hirsch, 1992). Figure 10 illustrates the change in the distribution of phosphorus concentration as you move downstream for the period of record at each TMDL site. Figure 11 illustrates the distributions after removal of the treated effluent discharges in 1987. The number of outliers and extremes at New Empire are reduced in addition to the range in concentration. The data still indicates an increase in OP and TP is occurring between the upstream sites and Mexican Gage and is attributed to a diffuse source.

Phosphorus levels have also declined at Weeks Bridge because all sewage effluent discharges to the Carson River in Nevada were terminated in 1987. It was considered important to look at all the historical data in order to remind the community of the changes that have occurred over the years due to variable conditions. Because of rapid urban development and a possible decrease in the area available for reuse, there is renewed discussion about discharging treated sewage effluent to the river again on a permanent basis. More advanced treatment may be required before NDEP would even consider the possibility. Potential impacts to Lahontan Reservoir must also be carefully weighed.

Kendall Tau (KT) Analysis was used to measure the strength of the relationship between total phosphorus concentrations and flow at each site and during each season. Kendall Tau correlations are rank-based, appropriate for skewed (non-normal) relationships and were determined using STATISTICA (StatSoft, Version 6). Strong linear correlations ($r \geq 0.9$) correspond to tau values ≥ 0.7 (Helsel & Hirsch, 1992). Relationships that are not significant ($p > 0.05$) suggest factors other than flow are affecting the concentration. Significant tau values that do not indicate "strong" linear correlations, may suggest a nonlinear relationship or indicate other factors or processes are influencing concentration in addition to flow. Diversions and return flows likely confound the relationships during the irrigation season (approximately April - September). Results for the entire period of record are summarized in Tables 5 and 6. Correlations may change if the analysis excluded the data collected prior to termination of the effluent discharges.

TABLE 5 Kendall's Tau Correlation Analysis for TP and Flow α = 0.05

Monitoring Site	Period of Record	Relationship	Tau(τ) - correlation coefficient	p value
WF Paynesville	7/68 - 5/04	NS	-0.05	0.175
EF Riverview	6/68 - 5/04	S+	0.30	0.000
Mexican Gage	9/75 - 5/04	S-	-0.39	0.000
New Empire	5/79 - 5/04	S-	-0.15	0.004
Weeks Bridge	6/68 -5/04	S+	0.37	0.000

S+ = Significant positive relationship S- = significant negative relationship NS = not significant

The results imply a number of processes are occurring that control phosphorus concentration. Significant positive correlations between TP and flow (concentration increases with increasing flow) indicate particulate mobilization and erosion. Significant negative correlations suggest dilution. At the West Fork site, there is no significant relationship between TP and flow. At the remaining sites, total phosphorus concentration is significantly correlated to flow.

After stratifying the data by season, the analysis shows a number of significant associations exist. The relatively low tau values indicate weak linear correlations or other monotonic relationships (e.g.-logarithmic or exponential). At the West Fork site, TP and flow are significantly related only during the summer months. The inverse correlation implies that a decrease in flow may contribute to an increase in total phosphorus concentration. The correlation is not significant at other times of year, suggesting that the consistently low TP concentrations measured at Paynesville are not sensitive to changes in flow.

TABLE 6 Kendall's Tau Correlation Analysis by Season for TP and Flow $\alpha = 0.05$

Monitoring Site	Jan - Mar		Apr - Jun		Jul - Sep		Oct - Dec	
	τ	p	τ	p	τ	p	τ	p
West Fork Paynesville	-0.0698	0.3192 **NS**	0.04480	0.5488 **NS**	-0.1808	0.0116 **S-**	0.0721	0.3286 **NS**
East Fork Riverview	0.3786	0.0000 **S+**	0.2874	0.0001 **S+**	0.1856	0.0096 **S+**	0.2061	0.0051 **S+**
Mexican Gage	-0.2141	0.0087 **S-**	-0.3796	0.0000 **S-**	-0.2285	0.0051 **S-**	-0.3247	0.0002 **S-**
New Empire	0.0648	0.5066 **NS**	-0.2489	0.0187 **S-**	-0.1177	0.2433 **NS**	0.0812	0.4607 **NS**
Weeks Bridge	0.2680	0.0014 **S+**	0.1209	0.1722 **NS**	0.5431	0.0000 **S+**	0.2095	0.0239 **S+**

S+ = Significant positive relationship S- = significant negative relationship NS = not significant
Tau (τ) = correlation coefficient

At the East Fork Riverview site, the significant positive correlations between TP and flow indicate that erosion and particulate transport are affecting the total phosphorus concentration. At Mexican Gage on the Main Stem, correlations are significant and *negative*; indicating dilution at high flows may be the dominant process influencing the TP concentration. Flow appears to have less influence at the New Empire Bridge site. A significant, negative correlation exists between TP and Flow at New Empire only during spring runoff conditions. The *change* in the mechanism or process affecting TP between the East and West Forks and the Main Stem at New Empire may be the result of numerous diversions, push-up dams and return flows along the river. It also infers that a mean increase in orthophosphate has occurred and has become the dominant P species instead of particulate (sediment + organic) phosphorus.

KT analysis was also used to determine the strength of the relationship between TP and TSS (Appendix E). Significant positive correlations were determined at WF Paynesville, EF Riverview and at Weeks Bridge, suggesting that an increase in TSS contributes to an increase in TP concentration. A significant negative correlation exists between TP and TSS at Mexican Gage, implying that increasing TSS (increasing erosion and particulate transport with increasing flow) does *not* contribute to an increase in TP. Some other process (e.g. - upstream source, dilution) may be exerting control over the relatively high OP and TP concentrations observed at Mexican Gage. At the New Empire site, there is no significant correlation between TP and TSS. The lack of association between TP and TSS may be because greater than 80% of the average phosphorus measured at this location is orthophosphate (Figure 9).

In summary, phosphorus is being contributed by a variety of sources that cannot be further characterized without more intensive sampling to identify storm event contributions and loads discharged from specific drains or return flows tributary to the river. Limited resources and access to private property are obstacles to increasing the level of monitoring. The primary conclusion from the data analysis indicates an increase in TP (as OP) occurs between the upstream TMDL sites on the East and West Forks and the downstream sites at Mexican Gage and New Empire on the main stem of the Carson River. Mitigation efforts should be focused within these reaches.

3.3 Target Analysis

The Carson River total phosphorus standard is the same value from the California stateline to Weeks Bridge to support the most restrictive beneficial uses, propagation of aquatic life and recreation involving contact with water. A concentration of 0.1 mg/L is set by NAC Section 445A.147 through 445A.157 and reflects the "desired goal" recommended by EPA in the 1986 Gold Book to protect against cultural eutrophication "in streams or flowing waters *not* discharging directly to lakes or other impoundments". For the purposes of this TMDL, the total phosphorus target has been set at the single value standard of

0.1 mg/L. As previously discussed, the TMDL is based upon the total number of standard exceedances instead of annual averages in order to assess the seasonal differences in concentration and loading.

3.4 Pollutant Load Capacity and Allocation

The total phosphorus Load Capacities or TMDLs for the Carson River is represented by the following equation:

TMDL (lbs/day) = Water Quality Target x Flow x 5.39 *(Eq. 2)*

Where:

Water quality target = 0.1 mg/L
Flow = streamflow at the appropriate USGS Gage, cfs
5.39 = conversion factor

Equation 2 can be illustrated by a load duration curve as described in "Load Duration Curve Methodology for Assessment and TMDL Development" (NDEP, 2003). Under the load duration curve method, water quality data (as a load) are compared to the allowable target loads. *Compliance with the TMDLs occurs when 90% of the observed loads fall below the load duration curve*. As described in Section 2.2, the Duration Curves are calculated at individual sites, but are applied to the reach upstream of the designated "TMDL" site. Percent contributions from each pollution source have not been determined. A gross load allocation that accounts for all sources of total phosphorus is represented by:

Load Allocation (lbs/day) = TMDL (lbs/day) *(Eq. 3)*

The East Fork Riverview and West Fork Paynesville sites meet the water quality target. The East Fork at Riverview and West Fork at Paynesville sites do not require a TMDL because they are not impaired for TP. The Load Duration curves were developed for these sites to illustrate the decline in water quality between Carson Valley and Carson City. Greater than 70% of the sample loads at Mexican Gage, New Empire Bridge and Weeks Bridge exceed the duration curves. The Watershed Plan being developed by the Carson Water Subconservancy District will discuss implementation strategies to reduce the observed pollutant loads in order to meet the TMDLs.

As previously discussed, TMDLs should include a margin of safety to account for uncertainties in meeting the water quality standards when the target and TMDL are met. An implicit margin of safety is incorporated in the total phosphorus TMDLs through the conservative assumption that all flow conditions are represented by the load duration curves.

Table 7 lists a breakdown of duration curve exceedances for three different time periods. Seasonal exceedances for the complete Period of Record at each site are given in Table 8. Target exceedances clearly indicate that an increase in TP is occurring in Carson Valley between the EF and WF sampling sites and the downstream sites at Mexican Gage and New Empire Bridge. Concentrations tend to decrease between New Empire and Weeks Bridge. This may be due to the low gradient and subsequent settling of particulates. In addition, it appears that eliminating the effluent discharge from the sewage treatment plants in 1987 did not dramatically affect the *percentage* of total phosphorus exceeding the duration curves. The ratio of OP to TP decreased (Table 9) but a relatively high percentage of orthophosphate is still found throughout the system. This suggests dissolved or bio-available P is being discharged into the river from a number of diffuse sources such as irrigation return, livestock or other animals/wildlife, urban runoff, streambank erosion or organic matter decay. The duration curve for the Carson River at Mexican Gage is provided in Figure 12. The curves for the remaining sites are included in Appendix F.

It should be noted that this TMDL is not applicable on Tribal property. As a sovereign nation, the Washoe Tribe of Nevada and California is responsible for developing water quality standards and TMDLs within the boundaries of their land.

TABLE 7 SUMMARY OF % DURATION CURVE EXCEEDANCES for TOTAL PHOSPHORUS

Site	Overall Period of Record		Jan 1988 - May 2004 Effluent discharges eliminated	May 1999 - May 2004 5 year time period
West Fork Paynesville	7/68 - 5/04	1	0	0
East Fork Riverview	6/68 - 5/04	6	11	1
Mexican Gage	9/75 - 5/04	91	93 *	84
New Empire	5/79 - 5/04	92	89	80
Weeks Bridge	6/68 -5/04	73	63	42

*** (7/90 - 5/04; no flow data 1988-89)**

TABLE 8 SUMMARY OF % DURATION CURVE EXCEEDANCE BY SEASON

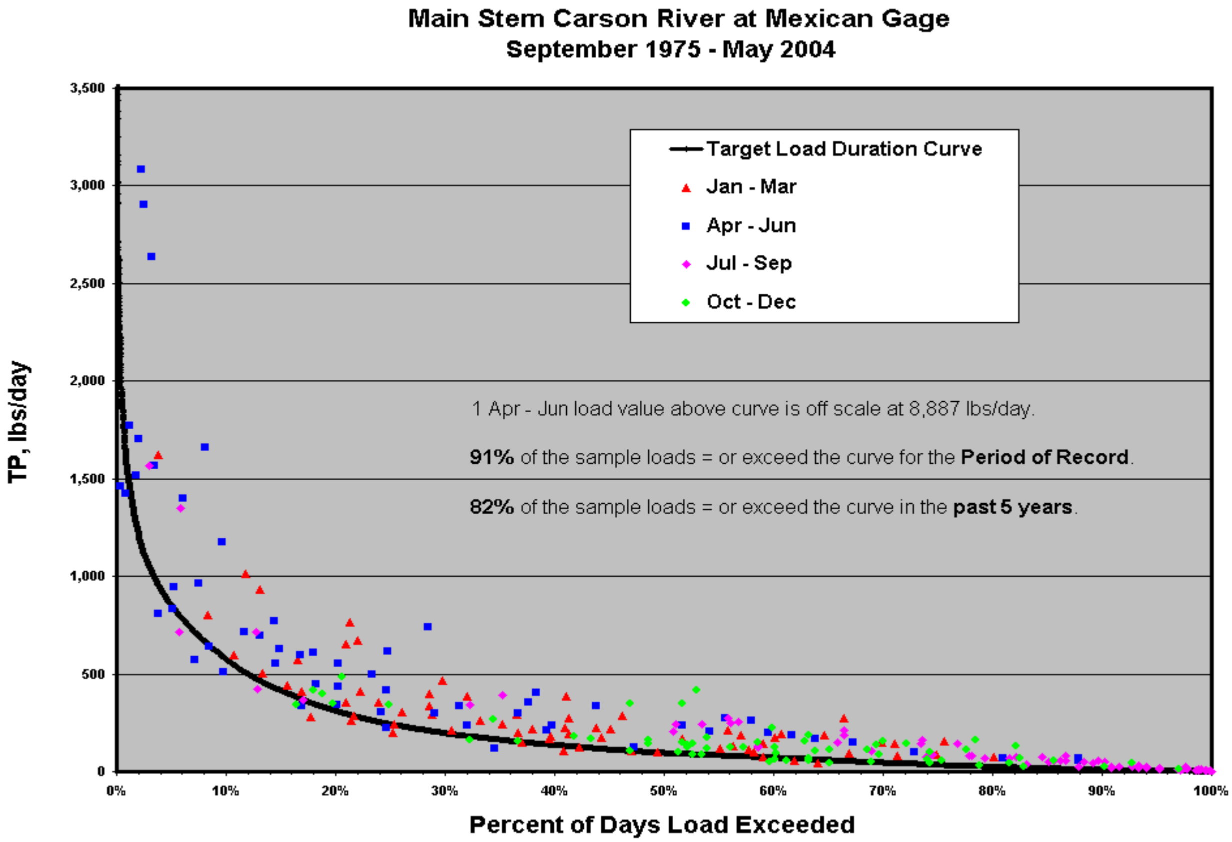
Site	Period of Record	Jan - Mar	Apr - Jun	Jul - Sep	Oct - Dec
West Fork Paynesville	7/68 - 5/04	1	0	1	2
East Fork Riverview	6/68 - 5/04	5	13	4	1
Mexican Gage	9/75 - 5/04	91	87	97	89
New Empire	5/79 - 5/04	90	95	98	83
Weeks Bridge	6/68 -5/04	78	92	43	78

TABLE 9 SUMMARY OF AVERAGE % OP (OP/TP)

Site	Overall Period of Record		Jan 1988 - May 2004 Effluent discharge eliminated	May 1999 - May 2004 5 year time period
West Fork Paynesville	7/68 - 5/04	50	38	21
East Fork Riverview	6/68 - 5/04	50	29	28
Mexican Gage	9/75 - 5/04	76	66	53
New Empire	6/68 - 5/04	81	63	49
Weeks Bridge	6/68 - 5/04	73	48	39

Load reductions based on reference conditions are not presented in this TMDL. There is insufficient data to calculate historical loads prior to the degradation that began in the Carson River during the mid 1800's. Reference reaches have not been established to date because hydrologic alteration and subsequent loss of river function has taken place throughout the Great Basin and it is difficult to identify even the "least disturbed" site on any of the river systems that could be used to determine natural background in the Carson River. Load reduction estimates are determined from the duration curves and will be discussed in the next section.

FIGURE 12



3.5 Estimated Load Allocations and Reductions

Full compliance with each TMDL occurs when 90% of the observed loads fall below the allowable loads as defined by the Target Duration Curve. *Reductions necessary to achieve the TMDL are determined by computing the difference between the total observed sample loads and the corresponding total target loads from the curve for selected duration intervals.* The intervals represent the percent of days the load is exceeded under different hydrologic conditions. This method is described for median observed and allowable loads in a white paper written by Tetra Tech (2004). Cleland (2003) also discusses using the duration curve to identify load exceedances under specific conditions. Table 10 provides the calculation at the Mexican Gage control point in Carson City and the data is illustrated in Figure 13. The reduction tables for the remaining sites are provided in Appendix G. East Fork at Riverview and West Fork at Paynesville are also included in the analysis for comparison to the three impaired sites.

Summarizing the load exceedances by the duration intervals again demonstrates that the load increases between the upstream sites and the downstream sites in Carson City (Figure 14). Table 11 shows the influence of spring runoff on loadings within each interval at four of the "TMDL" sites. For example, 75% of the Mexican Gage samples (15 out of 20 samples) that fall on or above the duration curve within 0-10% exceedance were collected in April, May or June. Flows occurring during this time period are dominated by snowmelt. Thirty-seven percent of the Mexican Gage samples falling on or above the duration curve within the 10-40% interval were collected in April, May or June. Spring snowmelt is not a factor influencing exceedance of the duration curve at the West Fork Paynesville site.

Approximately 50% of the TP loads at Riverview, Mexican Gage and New Empire are concentrated within the 0 to 10% duration interval, which is typically associated with streambank erosion processes. Sixty percent of the observed TP load is generated under high flow conditions at Weeks Bridge. Management of nonpoint source loads produced by extreme flows or flood events, represented by points located on the steepest part of the curve, may not be feasible.

TABLE 10 Estimated Load Reductions for Mexican Gage

Duration Interval	Hydrologic Condition	# Samples = to or exceeding curve within Interval	Total Observed Sample Load, lbs/day	Total Allowable Load Allocation, lbs/day	Estimated Reduction to meet Target, lbs/day	Estimated Reduction *, %
0 - 10%	Extreme high flows or flood	20	49,169	22,013	27,156	55
10 - 40%	Wet conditions	65	27,832	17,800	10,032	36
40 - 60%	Mid range flows	56	10,516	5304	5211	50
60 - 90%	Dry conditions	70	7201	2666	4536	63
90 - 100%	Low flows	31	511	163	348	68

* (Estimated Reduction in lbs/day / Total Observed Sample Load in lbs/day) x 100

TABLE 11 Percent of April - June Sample Loads Equal to or Exceeding curve within each duration interval

"TMDL" Site	Extreme high flows 0 - 10%	Wet Conditions 10 - 40%	Mid-range flows 40 - 60%	Dry conditions 60 - 90%	Low Flows 90 - 100%
West Fork at Paynesville	0	0	0	0	0
East Fork at Riverview	90	14	0	33	0
Mexican Gage	75	37	13	11	0
New Empire Bridge	67	40	13	12	0
Weeks Bridge	82	34	10	17	0

FIGURE 13 Carson River at Mexican Gage
Estimated Observed and Allowable Loads for Specific Duration Intervals

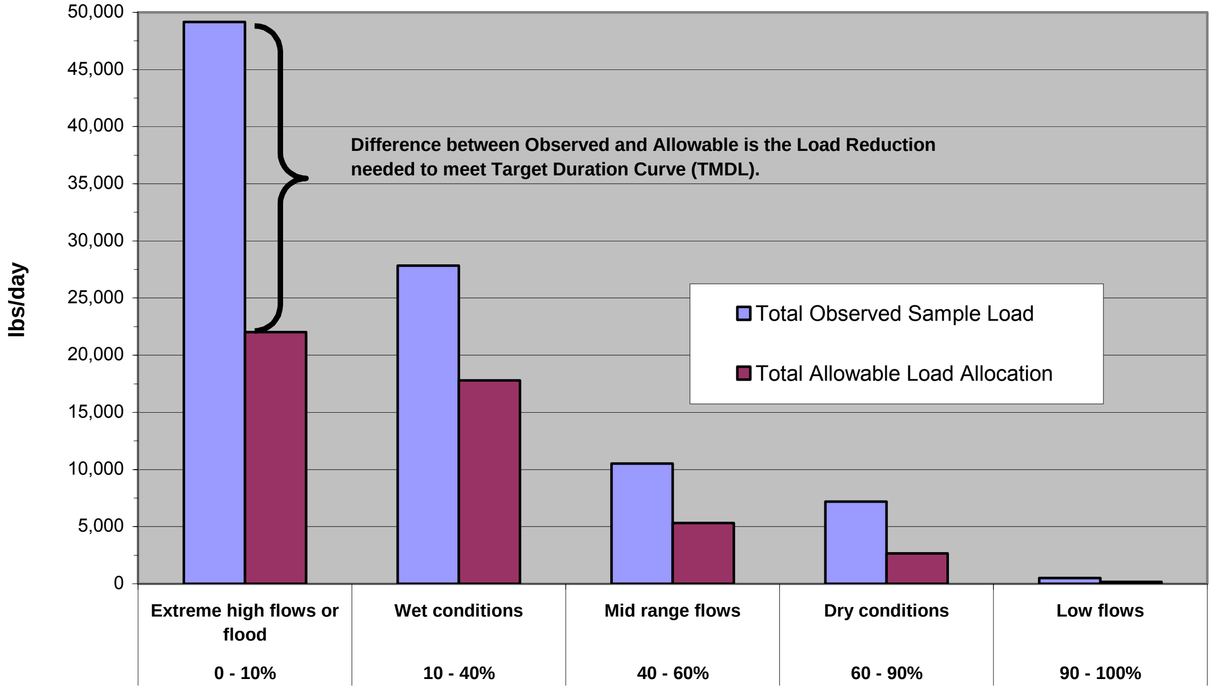
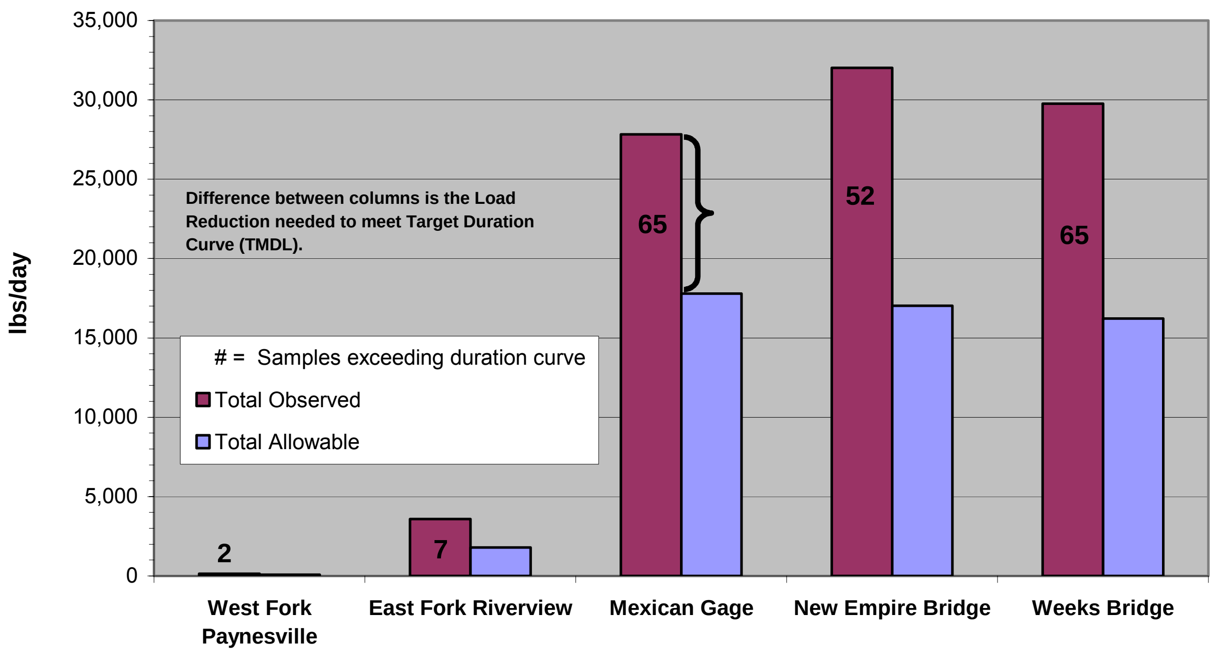


FIGURE 14 Carson River Example of Estimated Observed & Allowable Loads
Under Wet Conditions: 10 - 40% Days Exceeded
(East & West Forks added to compare to impaired sites)



3.6 Future Needs/Next Steps

The following activities have been identified as critical to further refinement of the phosphorus TMDL:

- Evaluate how nitrogen may be contributing to water quality impairment
- Analyze the water quality data collected by the Conservation Districts
- Complete evaluation of the USGS Sources of Phosphorus Study (2004) and related data
- Assess physical condition and relate characteristics within a reach to the degree of water quality impairment or biological integrity
- Determine if updates to the nitrogen or phosphorus standards are warranted

3.6.1 Possible Contribution of Nitrogen to Water Quality Impairment

For the Carson River in Nevada, Beneficial Use Standards (BUS) have been established for nitrate, nitrite and Total Ammonia. An RMHQ (Requirement to Maintain Higher Quality) has been established for Total Nitrogen. The Nevada nitrate BUS is the drinking water standard of 10 mg/L, however, ecological impacts can occur at much lower concentrations. Nitrate concentration in rivers undisturbed by human activities is estimated to be 0.1 mg/L (Allan, 1995). The USGS (1999) reports the *nationwide* nitrate background level in streams at 0.6 mg/L. According to NDEP's approved 2002 303(d) list and draft 2004 list, the Carson River is not impaired for any of the nitrogen species. Nitrite and Total Ammonia infrequently exceed laboratory-reporting limits and a preliminary analysis of the data between May 1999 and May 2004 indicates Nitrate values at the 5 "TMDL" sites are typically below 0.2 mg/L. Since May 1999, one sample at West Fork Paynesville was detected at 0.4 mg/L and one sample at Mexican gage was measured at 0.46 mg/L. A complicating factor was introduced in March 2004 - the State Health Lab changed the reporting limit for Nitrate + Nitrite from 0.1 mg/L to 0.5 mg/L. Therefore, the nitrate values for the past year at all five "TMDL" sites are reported as < 0.5 mg/L. This higher reporting limit may be masking anthropogenic inputs of nitrogen (N).

Data collected by NDEP indicates that the Carson River may be a Nitrogen-limited system. Molar dissolved inorganic nitrogen:orthophosphate (DIN/OP) ratios are generally less than 10:1. The nitrogen limitation and low N:P ratios may be in part due to lower atmospheric deposition in the arid West compared to the eastern United States. As cited in Allan (1995), Omernik (1977) reported that DIN is two to three times higher in eastern watersheds than in the central or western regions of the country. Grimm and Fisher (1986) investigated 92 streams in the Southwest and found that under low flow conditions, 80% of the sites studied had ratios lower than 10. Generally, N-limited systems indicate phosphorus is in excess of demand and nuisance algae growth is controlled by inputs of nitrogen. Research cited by Dodds et al. (2002) suggest that it is necessary to consider both N and P as limiting nutrients for periphyton growth in streams and rivers.

Field observations indicate periphyton is abundant throughout the Carson system where adequate substrate (e.g. gravel or cobble) exists. Metabolizing algae cells produce oxygen during the day from photosynthesis but consume oxygen at night. However, it is unknown to what extent the dissolved oxygen levels drop below the beneficial use standard of 5 mg/L during the evening or early morning hours when algal respiration is at a maximum. NDEP's routine monitoring program only collects grab samples during the day. A project funded by NDEP was conducted by the Desert Research Institute to measure diel oxygen and nutrients in selected reaches and results should be available later this year. In addition, as dead algae and other organic matter decompose, oxygen depletion can occur, creating conditions detrimental to aquatic life. Low oxygen levels can also alter the availability of phosphorus retained by oxides in sediment. Orthophosphate is released into solution under anoxic conditions (Correll, 1998; Mitsch & Gosselink, 1993), potentially adding to the nutrient load in the river.

Based on the relatively high Total Kjeldahl Nitrogen (TKN) values (mean values at the "TMDL" sites range from approximately 0.2 to 0.4 mg/L and generally increase downstream) and low inorganic nitrogen measurements, organic nitrogen is the dominant species. If both nitrogen and phosphorus are available in sufficient quantity other factors such as light, temperature, grazing macroinvertebrates or substrate may be limiting algae biomass (ENSR, 2001; Welch et al. 1992). Light availability and temperature can be related to certain physical characteristics of a disturbed stream system, such as the lack of vegetation shading the stream and shallow, over-widened channels. In addition, diversions can further exacerbate temperature increases under low flow conditions. Changes in phosphorus load or concentration must be evaluated in concert with the level of nitrogen, the physical channel condition and the biological integrity of the river system. A short-term decrease in phosphorus loads will not necessarily indicate if the overall health of the system has improved.

3.6.2 Supplemental Monitoring

Carson Valley and Dayton Valley Conservation Districts conduct additional monitoring to supplement the routine data collected by the state in the Carson River. The programs began in 2002 and will end in December 2005. Samples from the "TMDL" sites will be compared to the developed Duration Curves and NDEP's ambient data. The additional data may increase the number of duration curve exceedances, because the district monitoring programs target times or flows NDEP does not sample. Monitoring schedules are given in Table 12. Frequency differences between districts reflect different irrigation priorities and staff availability. Only the sites for which duration curves were developed are listed; a complete list of monitoring sites will be provided in future revisions of this document.

3.6.3 USGS - Sources of Phosphorus to the Carson River

The USGS Scientific Investigations Report 2004-5186 was released late January 2005. Because the Duration Curves and related analyses had already been completed, the USGS data set (Water Years 2001 - 02) was not fully evaluated. This more recent information will be included in future updates to this TMDL.

One of the primary conclusions of the USGS report suggests "about 58 percent of the total phosphorus load leaving Carson valley on an annual basis could be attributed to headwater reaches upstream of Carson Valley." This percentage is considered a maximum but the USGS does not actually quantify how much load the diversions are removing, how much mass may be due to stream bank erosion or the amount of phosphorus urban runoff or return flow may be adding to the downstream load. The investigation does acknowledge, "particulate phosphorus could be settling out when water is applied to fields, for example and be replaced by orthophosphate from other sources." Particulates may also settle out in wider, shallower sections of the river or in the irrigation channels.

TABLE 12 Conservation District Sampling Schedules for "TMDL" Sites

Site	Carson Valley Conservation District	Dayton Valley Conservation District
East Fork at Riverview	Collect March - October; alternating months with NDEP	-
Mexican Gage	Collect March - October; alternating months with NDEP	-
New Empire Bridge	Collect March - October; alternating months with NDEP	-
Weeks Bridge	-	Weekly over a 6 to 8 week period during high & low flow

3.6.4 Assessment of Physical Condition

A Hyperspectral/LiDAR survey was conducted in June 2004 from the California-Nevada stateline to Lahontan Reservoir. The information collected may be analyzed to obtain the amount of vegetation or the percentage of incised banks within a specified reach to assess the degree of physical degradation. If resources allow, another survey will be flown in 5-7 years to determine changes in system attributes such as vegetation growth in the riparian zone, channel morphology and land use. A comparison between data sets would provide a way to measure river restoration implemented to mitigate nonpoint source pollution and attain the TMDL. Habitat information collected as part of the Bioassessment Program will also be utilized to assess the Carson River. Physical characteristics related to water quality impairment and macroinvertebrate populations will help NDEP establish a clearer picture of overall river health and provide criteria for tracking improvements. Existing conditions will be described in the Carson River watershed assessment or "Report Card". Projected completion date for this document is December 2007.

Linking physical condition to water quality and biology is essential to improving the health of the river system. All stakeholders must work together in a coordinated effort to mitigate the damage caused by hydrogeomorphic alteration and NPS pollution. However, the degree of form and function that can be recreated in a riparian corridor fragmented by urbanization and infrastructure may be minimal because of societal constraints, such as local water law or zoning ordinances. When these constraints restrict restoration activities, stretches of the river that have been rehabilitated are alternated with sections where efforts to revegetate, restore floodplain or mitigate erosion have not occurred. Fragmentation may hinder stakeholder ability to improve water quality and habitat for aquatic life. Localized reaches may be repaired, but because restoration projects are not contiguous, watershed wide improvements may be moderate at best. There must be an understanding that the constraints placed on a river system by the community will limit the extent of restoration and biological function that can be achieved.

3.6.5 Water Quality Standard Updates for Nitrogen and Phosphorus

Upon completion of the "Report Card", NDEP will determine if the water quality standards for nitrogen and phosphorus warrant modification to improve support of the beneficial uses. A potential revision may be the addition of a nitrogen standard to reflect the possible N limitation of the river. New criteria may be narrative or numerical. It is also possible that information collected for the watershed assessment (Report Card) may show that other parameters or measurements will be a better indicator of river health (e.g. diurnal DO).

3.7 Schedule of TMDL Updates or Revisions

Potential Activity	**Tentative Completion Date**
Analysis of nitrogen data	September 2006
Analysis of Conservation District and USGS Phosphorus Study data for inclusion in Duration Curve analysis	September 2006
Assessment of Existing Physical Condition - "Report Card"	December 2007
Determine if N or P standards warrant modification	June 2008
Conduct 2nd aerial survey of river corridor if resources allow	Summer 2012
Evaluate exceedances of Duration Curves - Have concentrations and loadings decreased after 7 years of nonpoint source mitigation projects and programs?	December 2012

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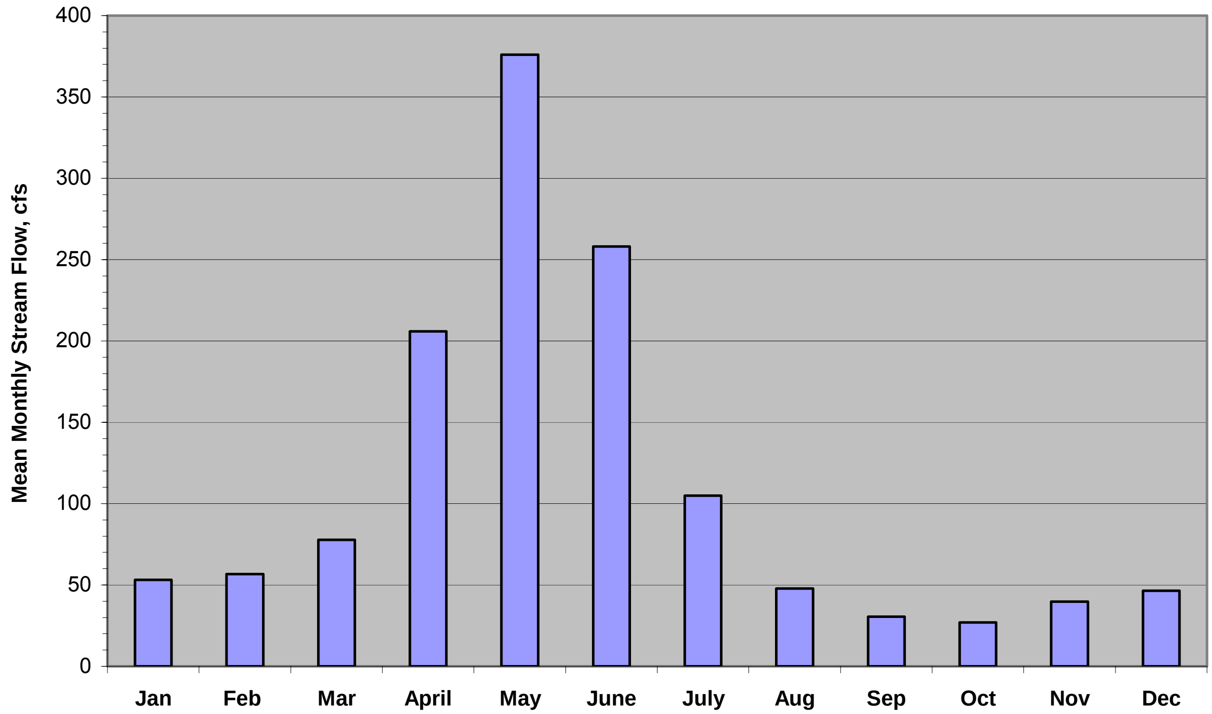
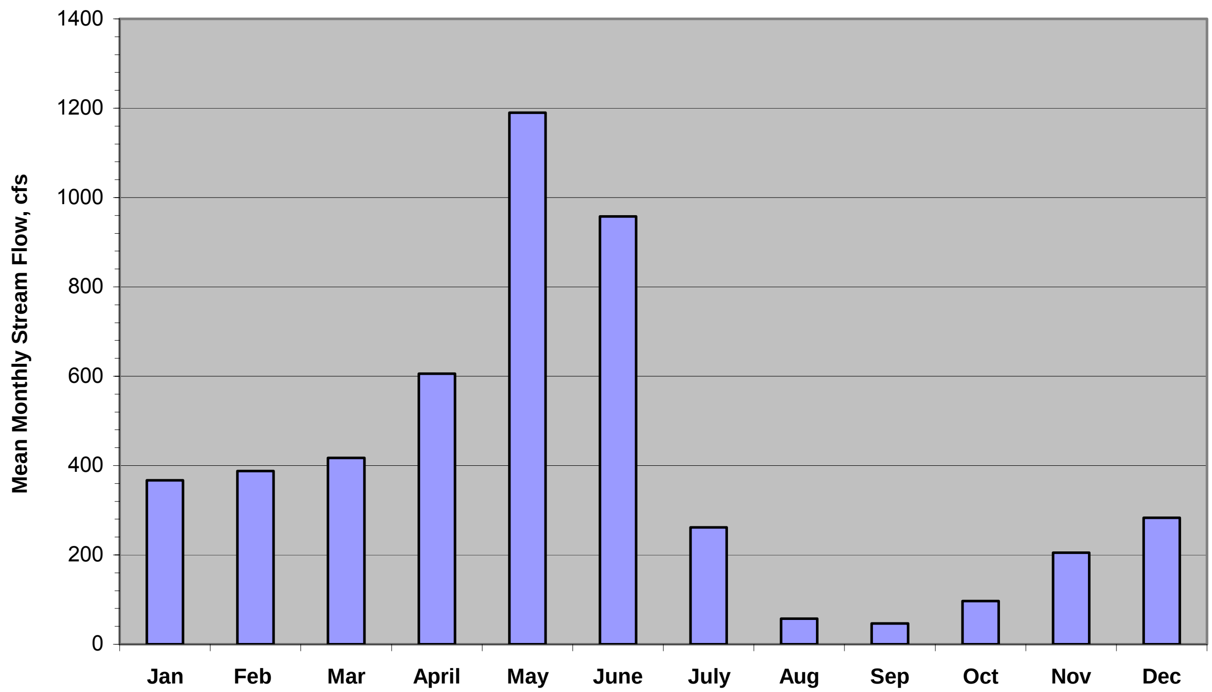
Appendix A

Mean Monthly Flows for Selected Gaging Stations

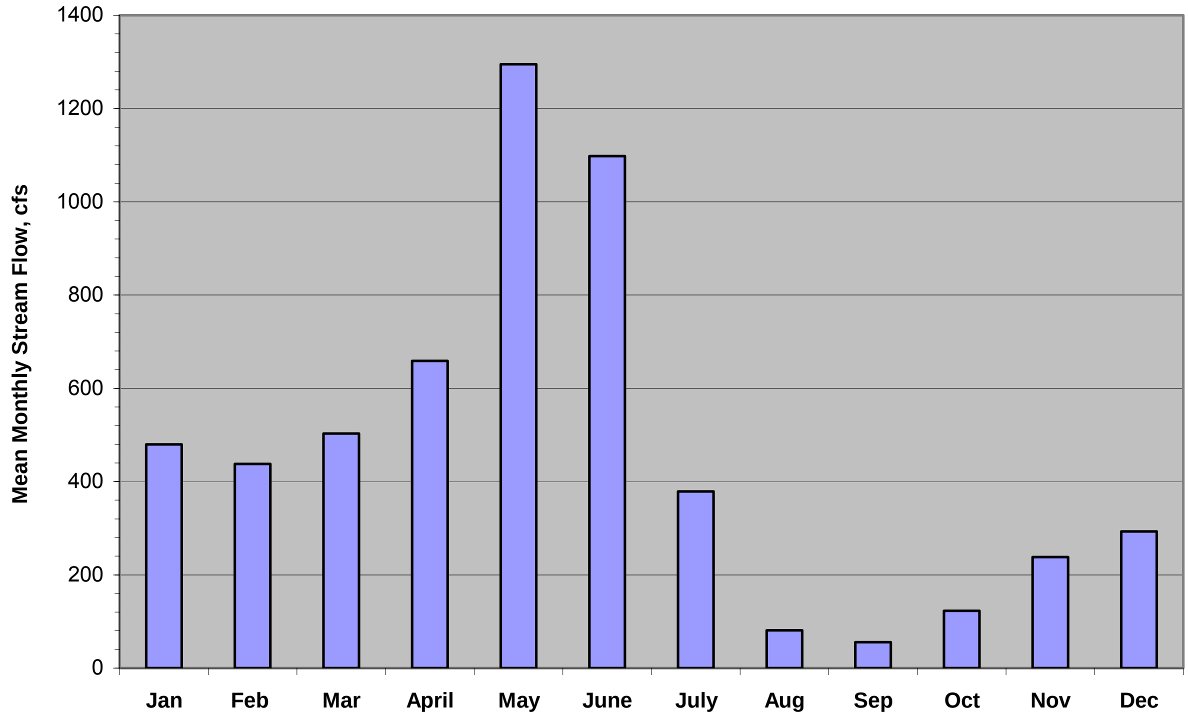
Mean Monthly Stream Flow (1900 - 2003) - West Fork Carson River at Woodfords,CA USGS #10310000



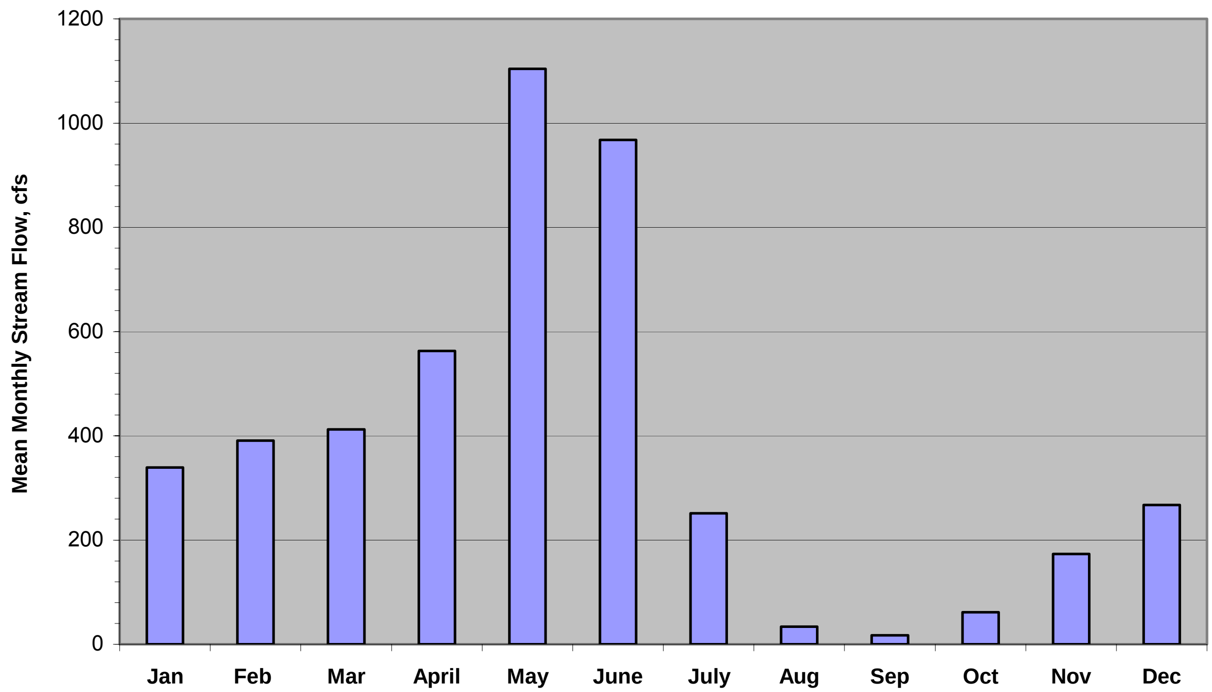
Mean Monthly Stream Flow (1939 - 2003) - Carson River near Carson City, NV USGS #10311000



Mean Monthly Stream Flow (1979 - 2003) - Carson River at Deer Run Road, NV
USGS #10311400

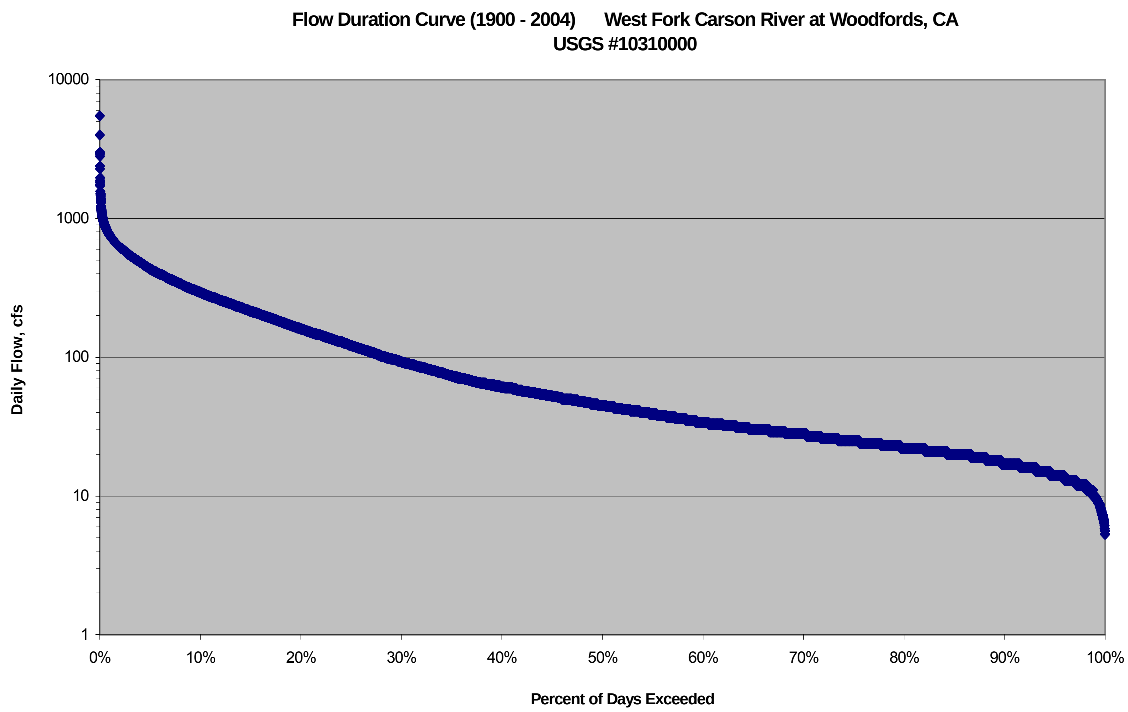


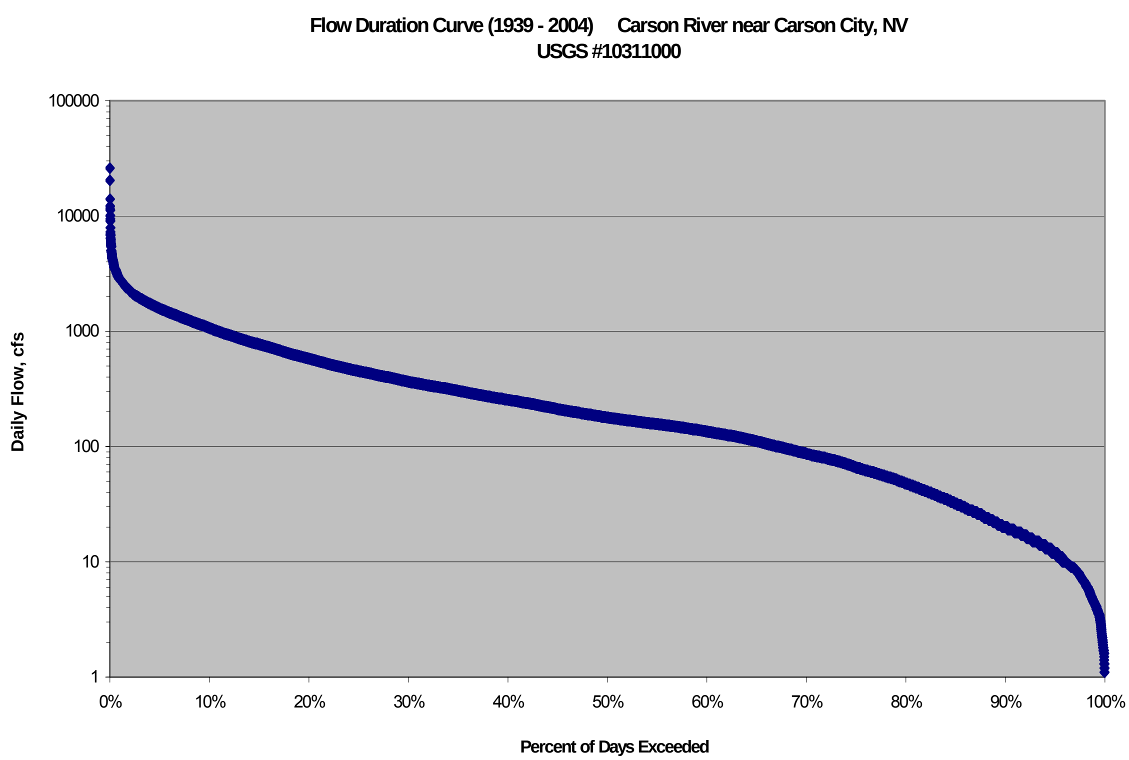
Mean Monthly Stream Flow (1911 - 2003) - Carson River near Fort Churchill, NV
USGS #10312000

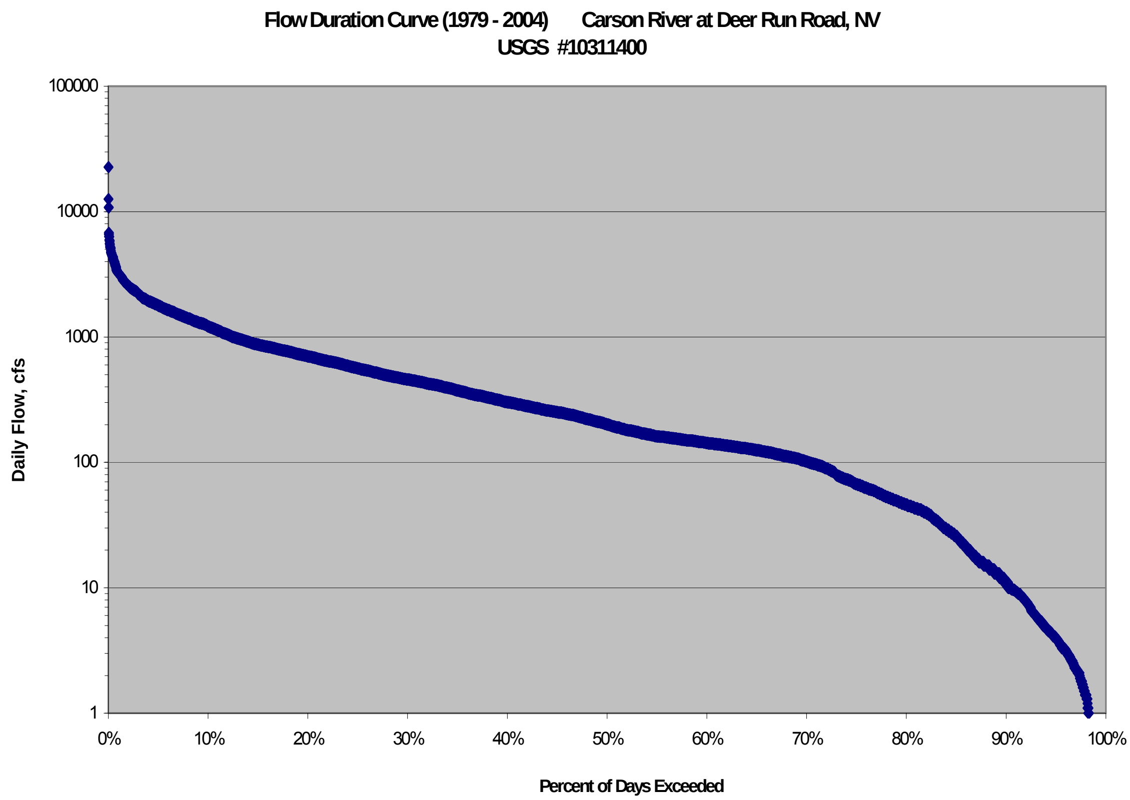


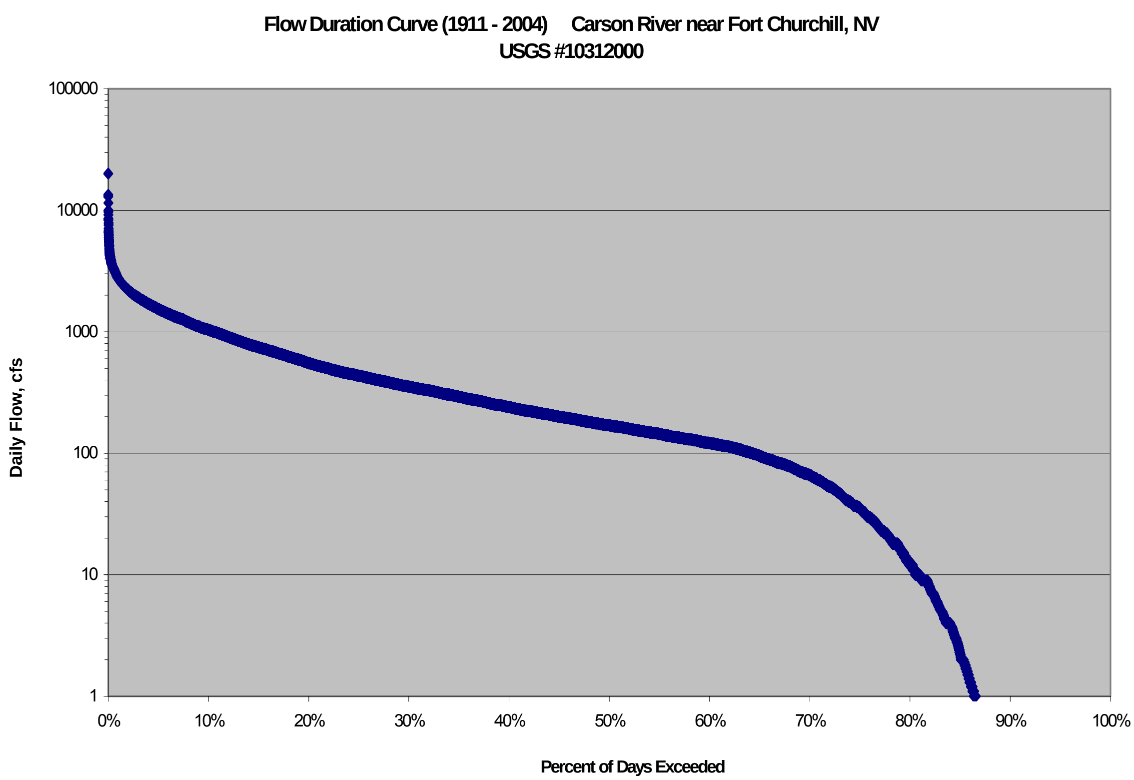
Appendix B

Flow Duration Curves for Selected Gaging Stations


Flow Duration Curve (1900 - 2004) West Fork Carson River at Woodfords, CA
USGS #10310000
Daily Flow, cfs
10000
1000
100
10
1
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percent of Days Exceeded


Flow Duration Curve (1939 - 2004) Carson River near Carson City, NV
USGS #10311000
Daily Flow, cfs
100000
10000
1000
100
10
1
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percent of Days Exceeded

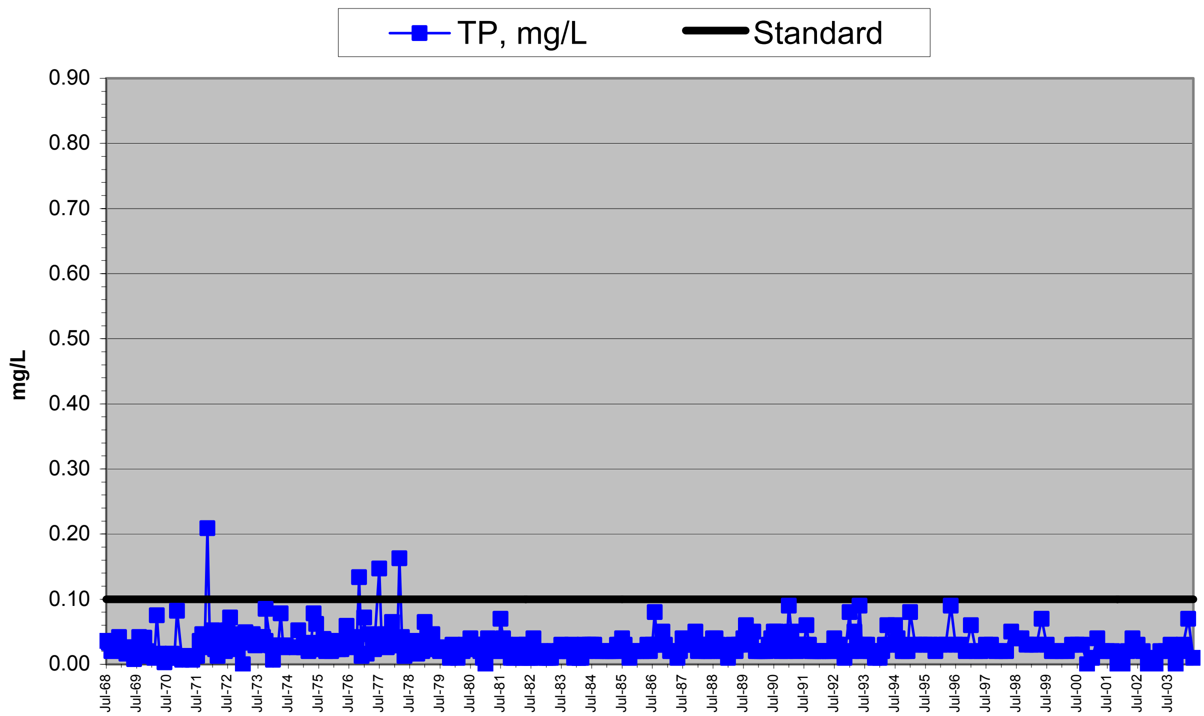

Flow Duration Curve (1979 - 2004) Carson River at Deer Run Road, NV
USGS #10311400
Daily Flow, cfs
100000
10000
1000
100
10
1
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percent of Days Exceeded


Flow Duration Curve (1911 - 2004) Carson River near Fort Churchill, NV
USGS #10312000
Daily Flow, cfs
100000
10000
1000
100
10
1
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percent of Days Exceeded

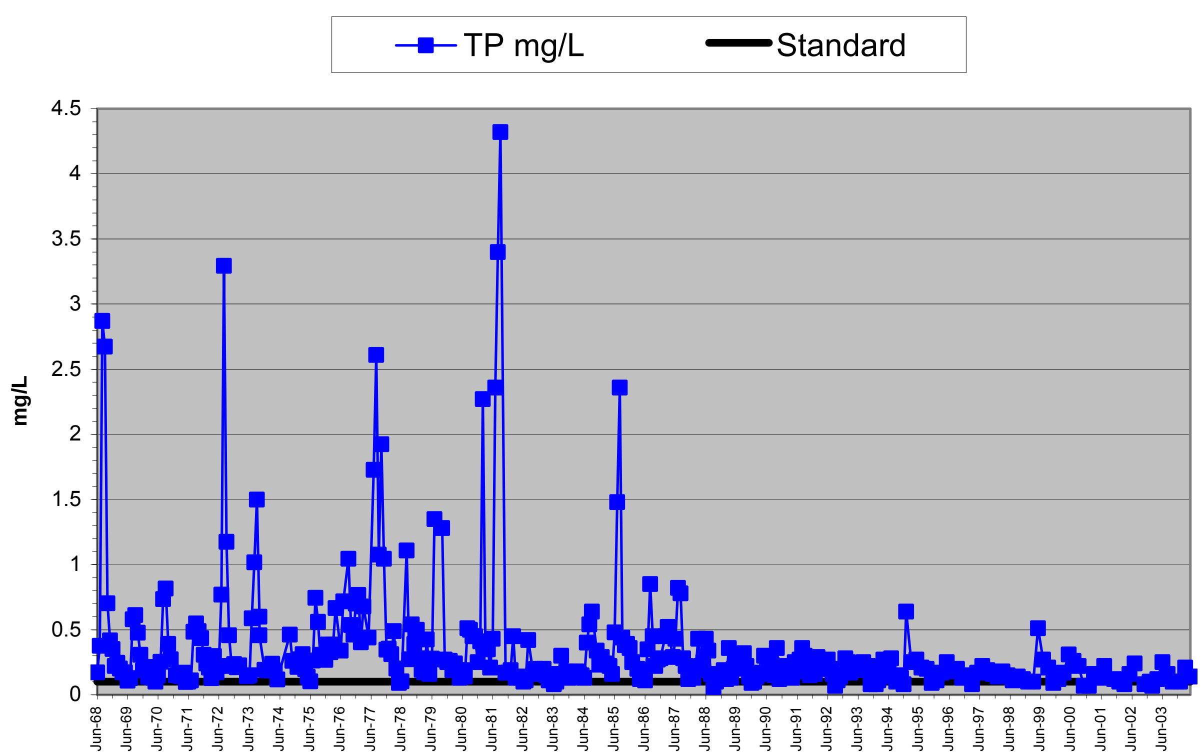
Appendix C

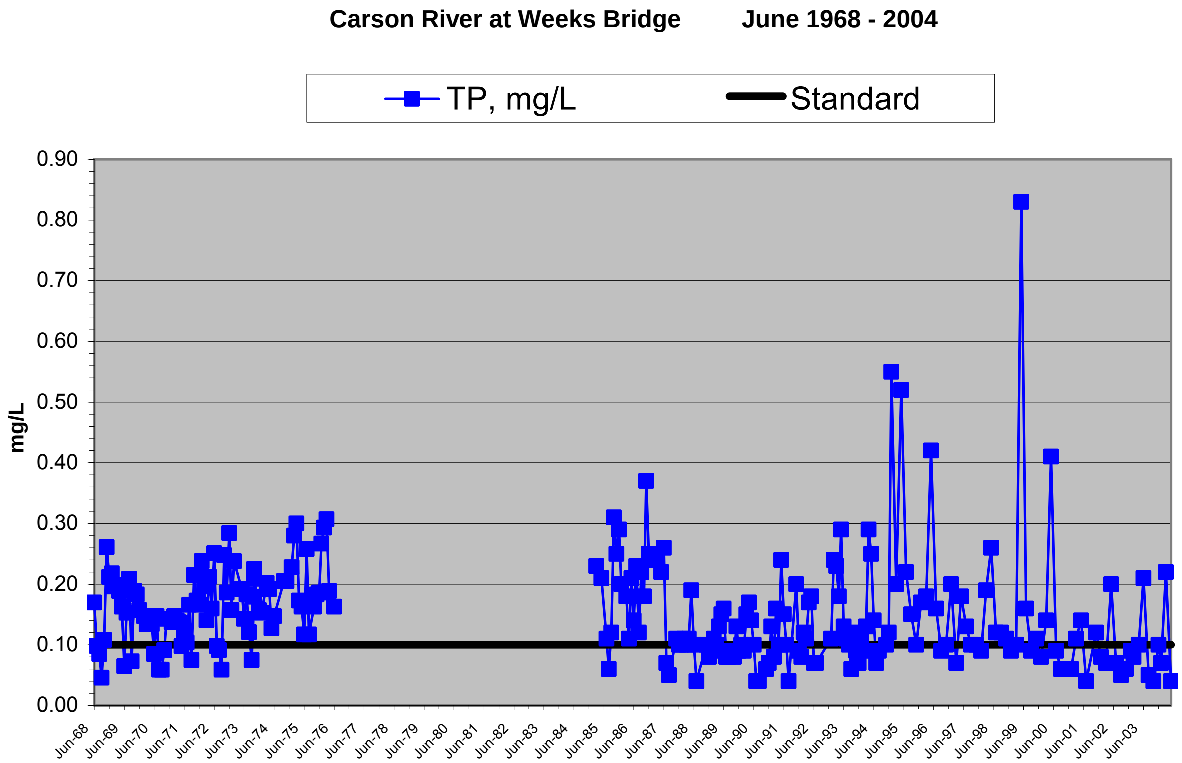
TP Time Series Plots for Selected NDEP Monitoring Stations

West Fork Carson River at Paynesville, CA July 1968 - May 2004



Carson River at New Empire Bridge (Deer Run Road) June 1968 - May 2004



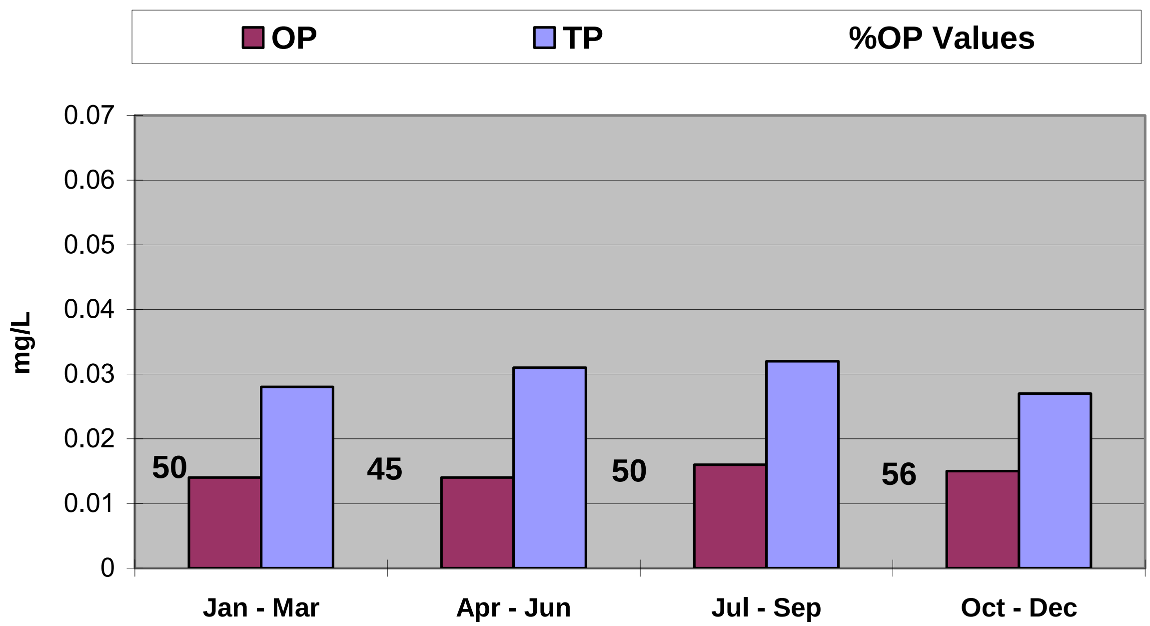

Carson River at Weeks Bridge June 1968 - 2004
TP, mg/L
Standard
mg/L
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
Jun-68
Jun-69
Jun-70
Jun-71
Jun-72
Jun-73
Jun-74
Jun-75
Jun-76
Jun-77
Jun-78
Jun-79
Jun-80
Jun-81
Jun-82
Jun-83
Jun-84
Jun-85
Jun-86
Jun-87
Jun-88
Jun-89
Jun-90
Jun-91
Jun-92
Jun-93
Jun-94
Jun-95
Jun-96
Jun-97
Jun-98
Jun-99
Jun-00
Jun-01
Jun-02
Jun-03

Appendix D

Seasonal Average Phosphorus for Selected NDEP Monitoring Stations

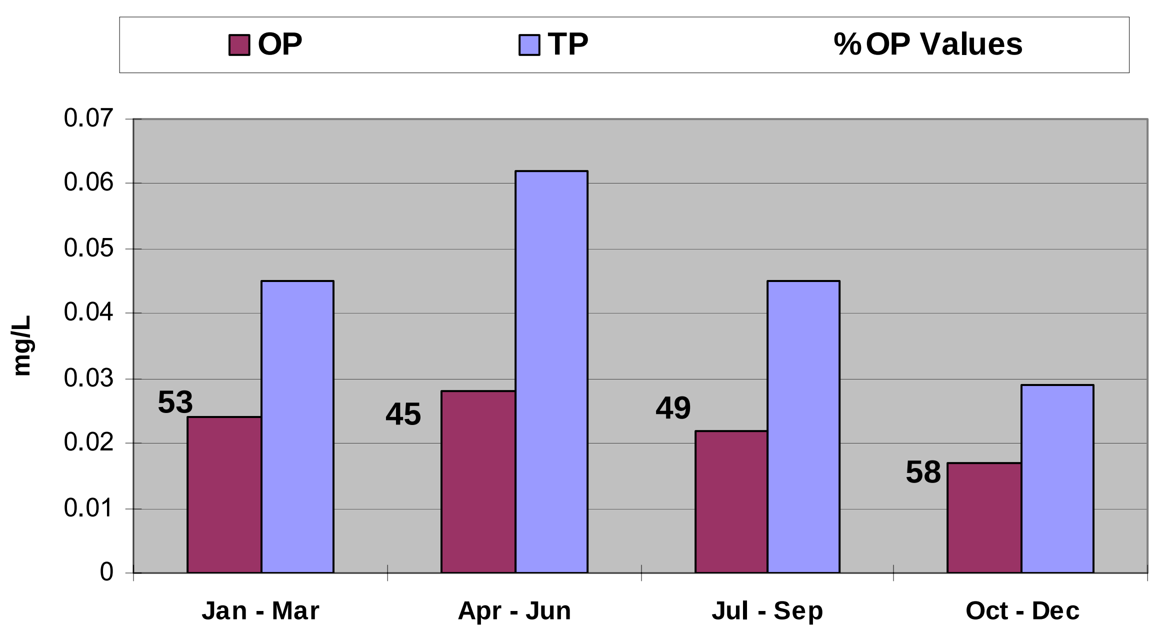
West Fork Carson River at Paynesville, CA

Seasonal Average Phosphorus July 1968 - May 2004



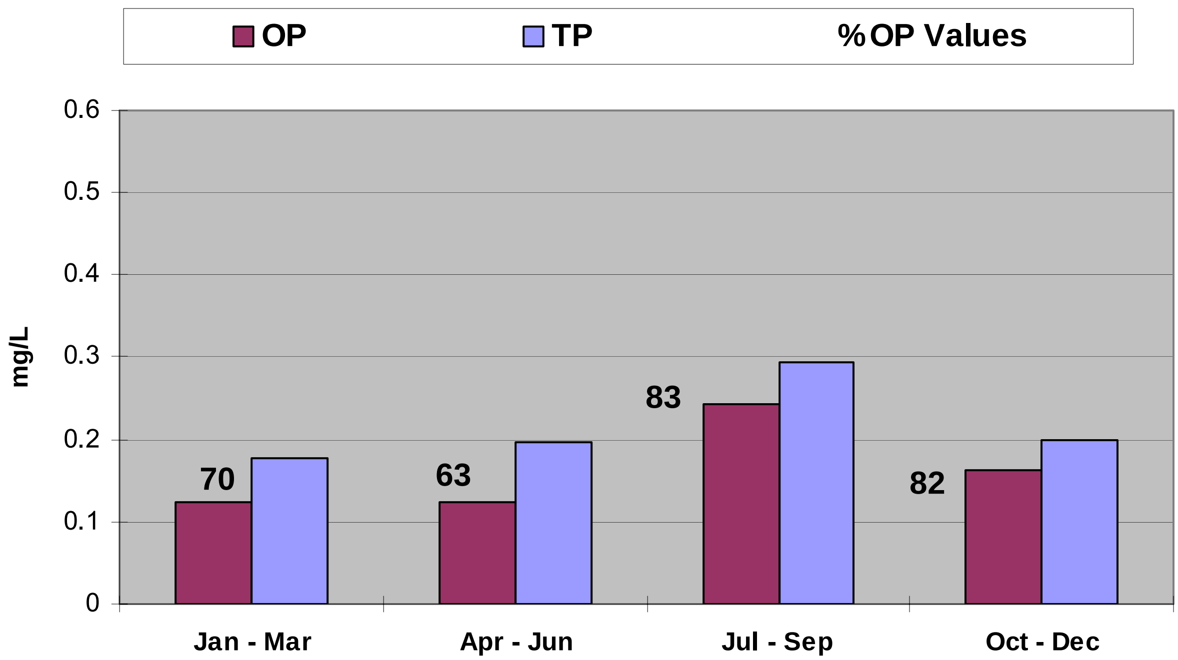
East Fork Carson River at Riverview

Seasonal Average Phosphorus June 1968 - May 2004



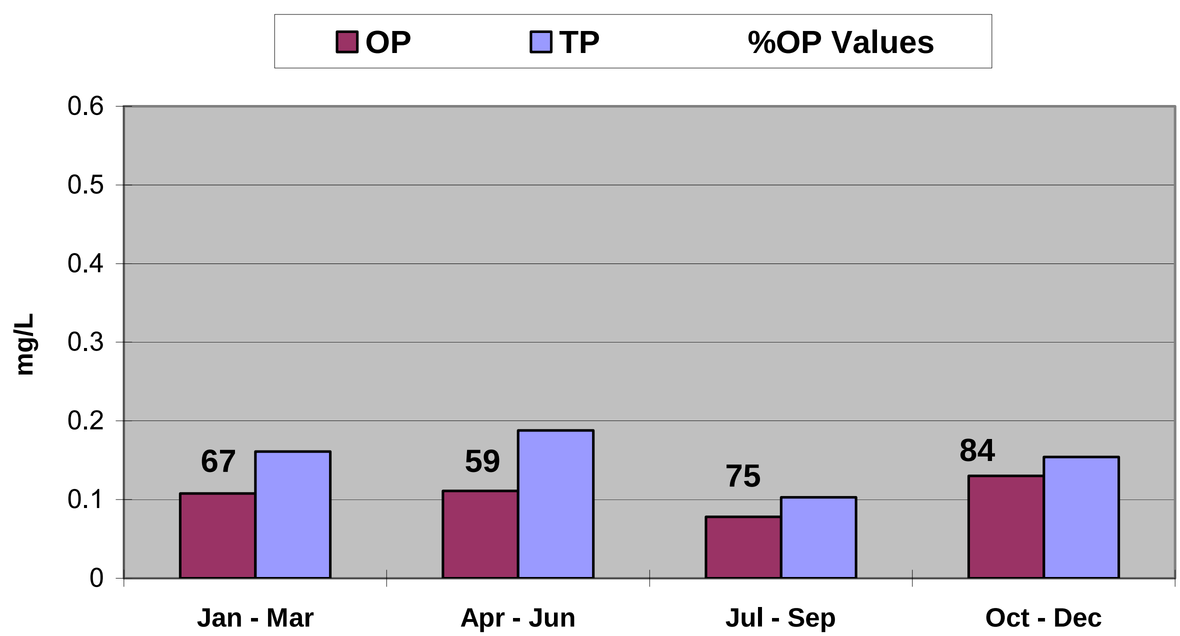
Carson River at Mexican Gage

Seasonal Average Phosphorus July 1975 - May 2004



Carson River at Weeks Bridge

Seasonal Average Phosphorus June 1968 - May 2004



Appendix E

Kendall Tau Correlation Analysis for TP:TSS

Kendall's Tau Correlation Analysis for TP:TSS **α = 0.05**

Monitoring Site	Period of Record	Relationship	Tau(τ) - correlation coefficient	p value
West Fork at Paynesville	2/80 - 5/04	S+	0.3187	0.0000
East Fork at Riverview	11/78 - 5/04	S+	0.5415	0.0000
Mexican Gage	2/80 - 5/04	S-	-0.1447	0.0012
New Empire Bridge	11/78 - 5/04	NS	-0.0068	0.8758
Weeks Bridge	3/85 - 5/04	S+	0.5354	0.0000

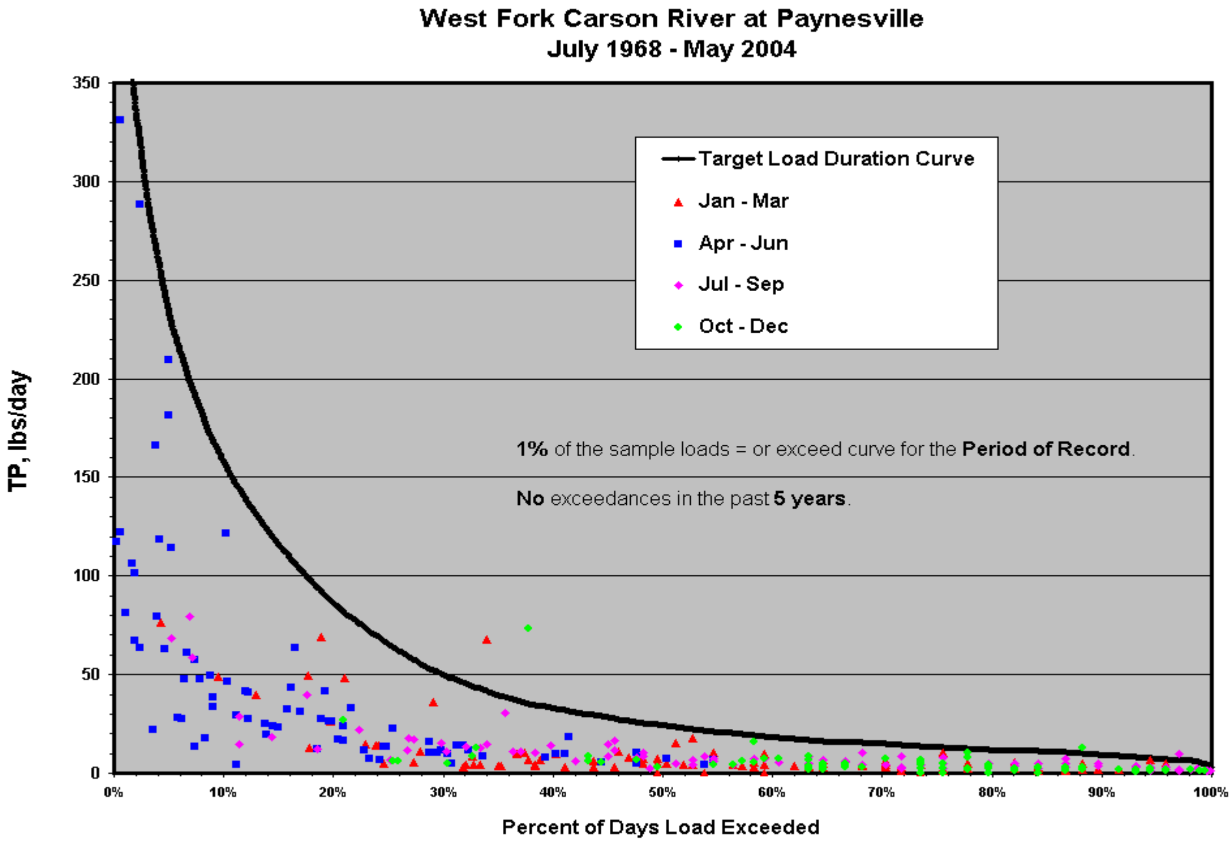
S+ = Significant positive relationship

S- = significant negative relationship

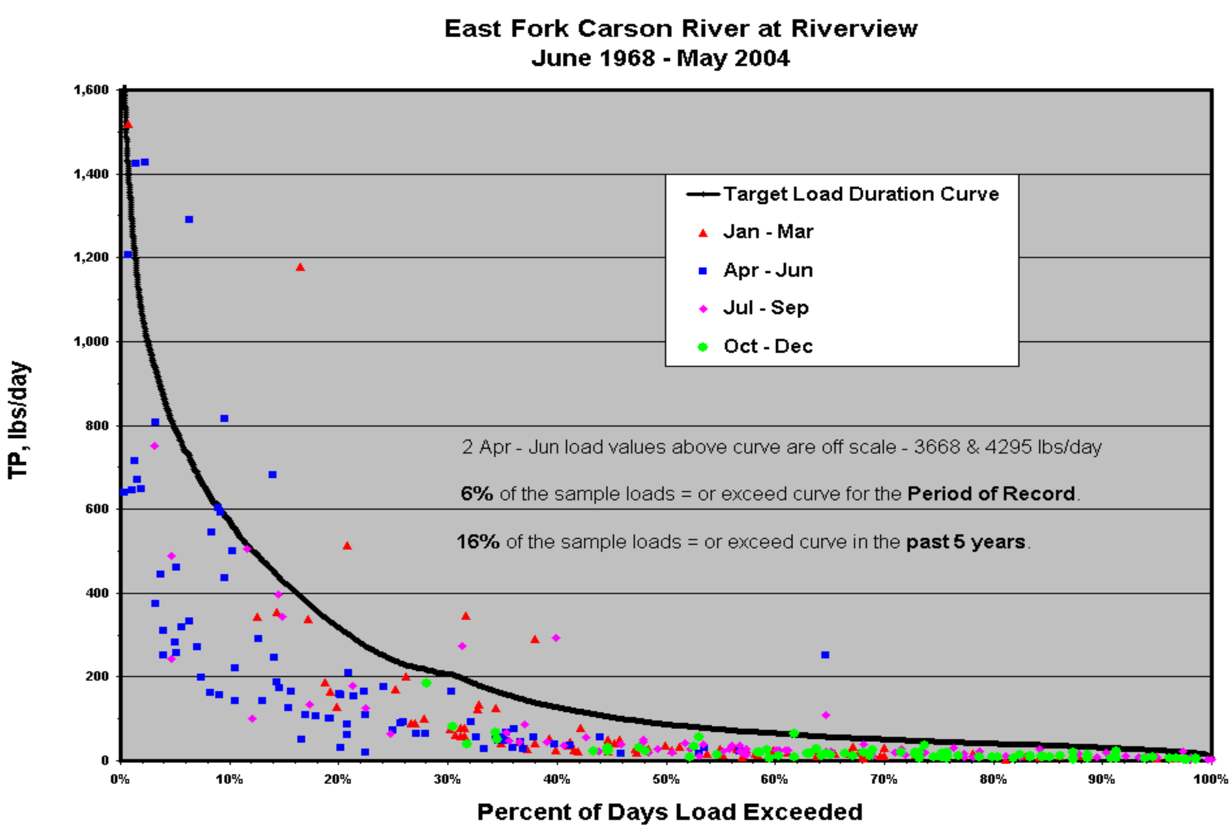
NS = not significant

Appendix F

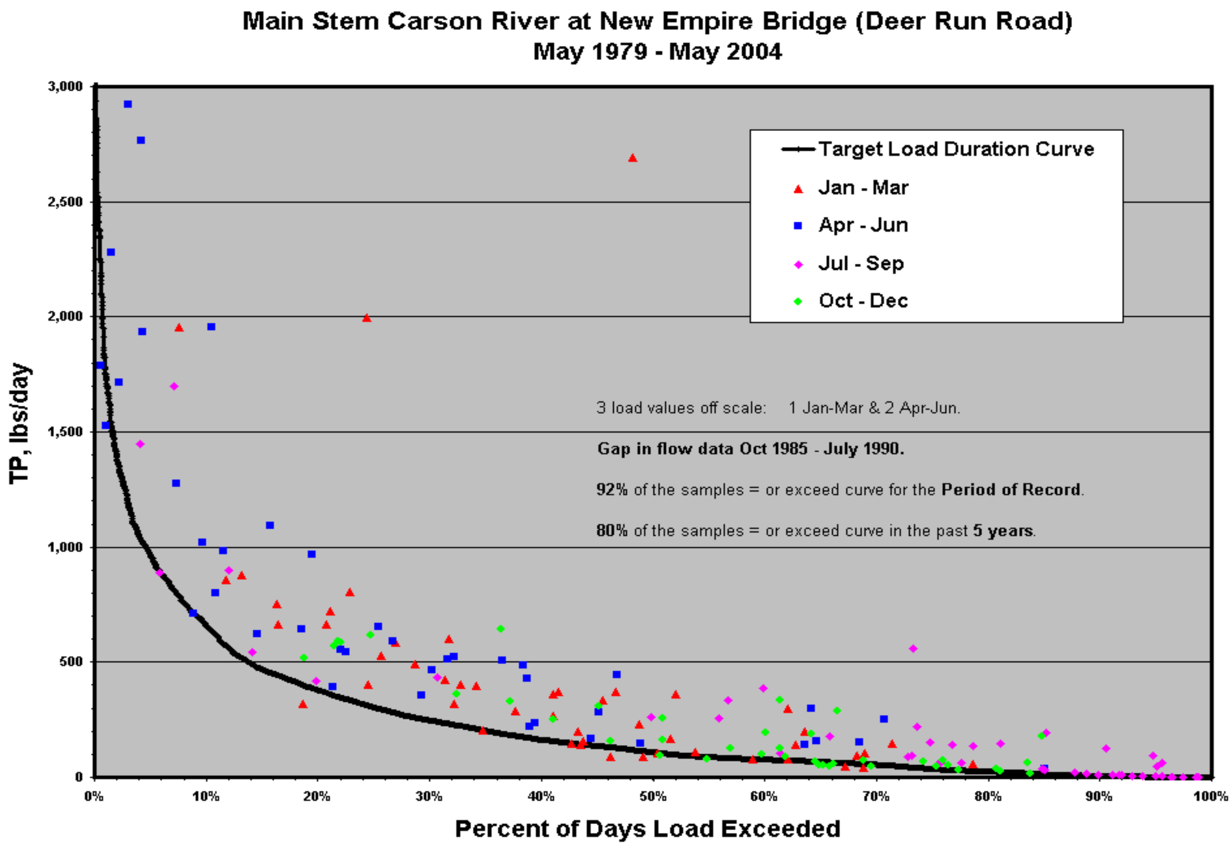
Load Duration Curves
For Selected Sites



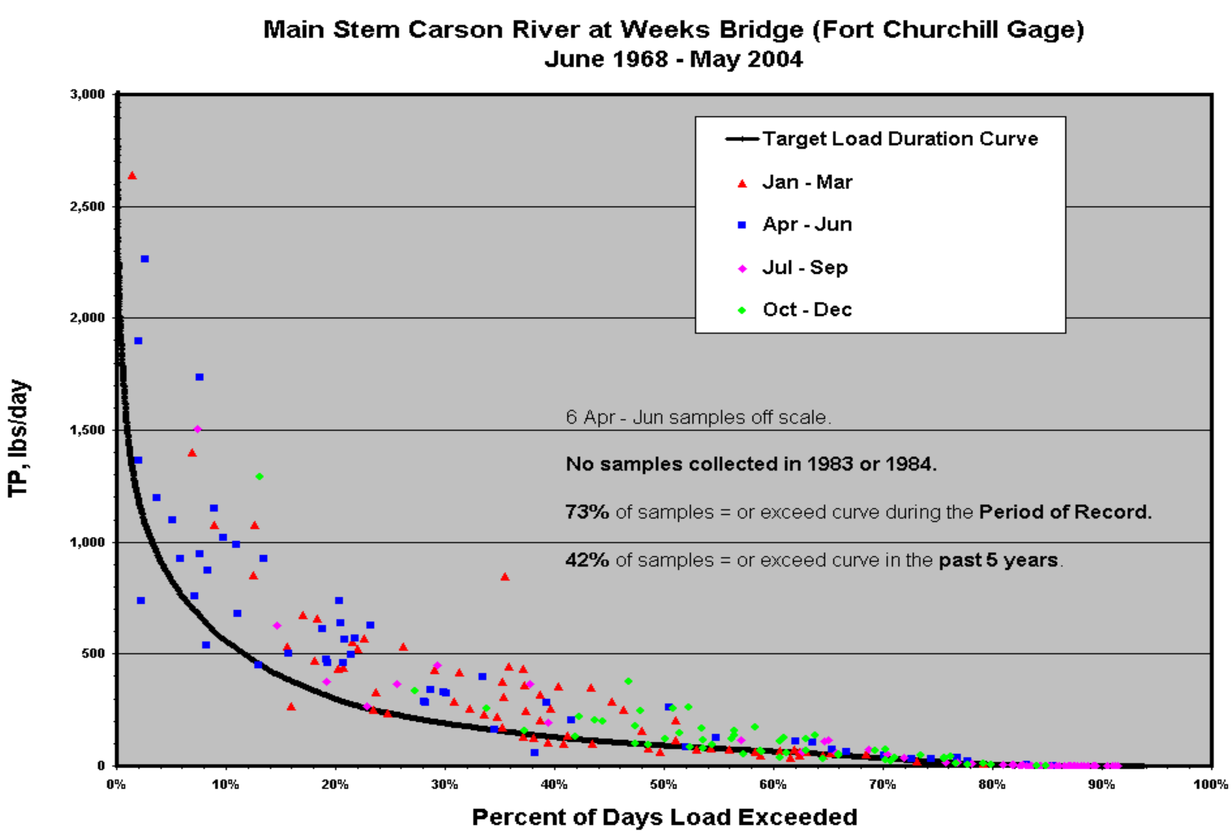
West Fork Carson River at Paynesville
July 1968 - May 2004
Target Load Duration Curve
Jan - Mar
Apr - Jun
Jul - Sep
Oct - Dec
1% of the sample loads = or exceed curve for the Period of Record.
No exceedances in the past 5 years.
TP, lbs/day
0
50
100
150
200
250
300
350
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percent of Days Load Exceeded



East Fork Carson River at Riverview
June 1968 - May 2004
Target Load Duration Curve
Jan - Mar
Apr - Jun
Jul - Sep
Oct - Dec
2 Apr - Jun load values above curve are off scale - 3668 & 4295 lbs/day
6% of the sample loads = or exceed curve for the Period of Record.
16% of the sample loads = or exceed curve in the past 5 years.
TP, lbs/day
0
200
400
600
800
1,000
1,200
1,400
1,600
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percent of Days Load Exceeded



Main Stem Carson River at New Empire Bridge (Deer Run Road)
May 1979 - May 2004
TP, lbs/day
Percent of Days Load Exceeded
Target Load Duration Curve
Jan - Mar
Apr - Jun
Jul - Sep
Oct - Dec
3 load values off scale: 1 Jan-Mar & 2 Apr-Jun.
Gap in flow data Oct 1985 - July 1990.
92% of the samples = or exceed curve for the Period of Record.
80% of the samples = or exceed curve in the past 5 years.



Main Stem Carson River at Weeks Bridge (Fort Churchill Gage)
June 1968 - May 2004
TP, lbs/day
Percent of Days Load Exceeded
Target Load Duration Curve
Jan - Mar
Apr - Jun
Jul - Sep
Oct - Dec
6 Apr - Jun samples off scale.
No samples collected in 1983 or 1984.
73% of samples = or exceed curve during the Period of Record.
42% of samples = or exceed curve in the past 5 years.

Appendix G

Load Reduction Estimates for Selected Sites

West Fork at Paynesville ***Only for comparison to impaired sites***

Duration Interval	Hydrologic Condition	#Samples = to or exceeding curve within Interval	Total Observed Sample Load, lbs/day	Total Allowable Load Allocation, lbs/day	Estimated Reduction to meet Target, lbs/day	Estimated Reduction, %
0 - 10%	Extreme high flows or flood	0	0	0	0	0
10 - 40%	Wet conditions	2	141	77	64	45
40 - 60%	Mid range flows	0	0	0	0	0
60 - 90%	Dry conditions	1	13	10	3	23
90 - 100%	Low flows	1	10	6	3	30

East Fork at Riverview ***Only for comparison to impaired sites***

Duration Interval	Hydrologic Condition	#Samples = to or exceeding curve within Interval	Total Observed Sample Load, lbs/day	Total Allowable Load Allocation, lbs/day	Estimated Reduction to meet Target, lbs/day	Estimated Reduction, %
0 - 10%	Extreme high flows or flood	10	16,225	8910	7315	45
10 - 40%	Wet conditions	7	3577	1803	1774	50
40 - 60%	Mid range flows	0	0	0	0	0
60 - 90%	Dry conditions	3	424	176	248	58
90 - 100%	Low flows	1	23	21	2	9

New Empire Bridge

Duration Interval	Hydrologic Condition	#Samples = to or exceeding curve within Interval	Total Observed Sample Load, lbs/day	Total Allowable Load Allocation, lbs/day	Estimated Reduction to meet Target, lbs/day	Estimated Reduction, %
0 - 10%	Extreme high flows or flood	15	46,216	17,868	28,348	61
10 - 40%	Wet conditions	52	32,019	17,029	14,990	47
40 - 60%	Mid range flows	31	9723	3660	6063	62
60 - 90%	Dry conditions	51	6426	2219	4207	65
90 - 100%	Low flows	18	402	43	359	89

Weeks Bridge

Duration Interval	Hydrologic Condition	#Samples = to or exceeding curve within Interval	Total Observed Sample Load, lbs/day	Total Allowable Load Allocation, lbs/day	Estimated Reduction to meet Target, lbs/day	Estimated Reduction, %
0 - 10%	Extreme high flows or flood	22	56,897	21,096	35,800	63
10 - 40%	Wet conditions	65	29,753	16,224	13,529	45
40 - 60%	Mid range flows	38	6517	3515	3002	46
60 - 90%	Dry conditions	70	2647	1593	874	33
90 - 100%	Low flows	5	0	0	0	0