IMPACT OF ROAD CONSTRUCTION ON STREAM ECOLOGY: A STREAM ASSESSMENT AND MONITORING PROJECT IN STEWART COUNTY, TENNESSEE

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IMPACT OF ROAD CONSTRUCTION ON STREAM ECOLOGY: A STREAM ASSESSMENT AND MONITORING PROJECT IN STEWART COUNTY, TENNESSEE

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Laura Inglis
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Abstract

Increases in the Tennessee population and escalation of vehicle miles traveled require additional construction of roads and bridges. Road construction required two new bridges to cross Dyers Creek in conjunction with the road expansion of State Route 76 from Clarksville to Dover. This study was initiated to analyze various biotic and abiotic factors throughout the construction with the null hypothesis that there would be no significant difference in water chemistry data between any of the sites. Two sites at each bridge construction location, one upstream from construction and one downstream were assessed monthly for various water quality parameters. Water quality variables were used to develop a model of bridge and road construction effects on these variables. All water quality variables analyzed for this study showed no significant difference between upstream or downstream sites or between locations. A model using least-squares method was accurate in long term prediction of water quality variables during road and bridge construction. This study concluded there was no significant impact due to the road and bridge construction on water quality variables.

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CHAPTER 1

Introduction

The United States integrates 3,936,229 miles of highway into the landscape; Tennessee maintains 87,419 of these miles (United States Bureau of Transportation Statistics, 2000). The estimated United States population in 2006 was 299,398,484 and Tennessee supports 6,038,803 of these citizens. This is a 6.1 % increase in the Tennessee population from 2000 to 2006 (United States Census Bureau, 2007). Increases in the population and escalation of vehicle miles traveled (up to 70,708 million miles annually in Tennessee; Tennessee Department of Transportation, 2006) necessitates additions to the already expansive road network. Newly built roads have only moderately increased and expansion of existing U.S. roads constitutes about 80% of all road construction (Bissonette, Clevenger, Cutshall, Dale, Foreman & Sterling, 2002). An estimated 946 Tennessee waterway miles intersect these expanding highways. This often requires building new bridges or repairing some of the 19,362 current bridges in Tennessee (USBTS, 2002).

State Route 76 or U.S. 79 from Clarksville to Dover crosses several streams in Stewart County, Tennessee (Figure 1, 2). Current construction to widen State Route 76 from two lanes to a four-lane divided highway required an additional bridge at two stream-crossings of Dyers Creek. According to the United States Environmental Protection Agency (2000), Tennessee Department of Environment and Conservation (2001, 2004, 2006), United States Geological Survey (2007), and Tennessee Department of Transportation (1998) these small streams had not previously been assessed for water quality.

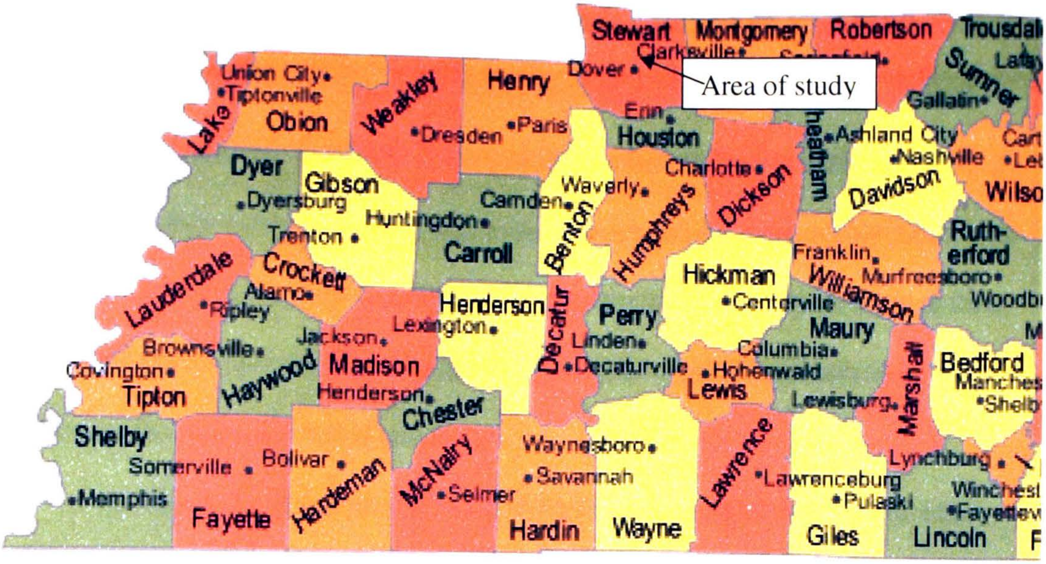


Figure 1 Dyers Creek Study Area in Stewart County, Tennessee.

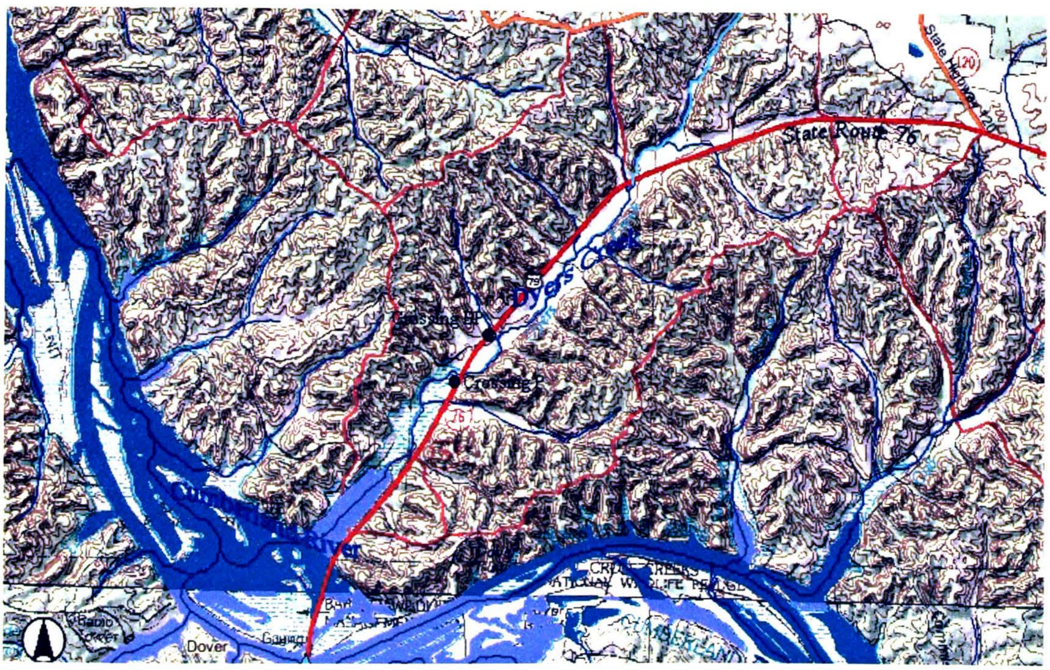


Figure 2 Dyers Creek Study Area on State Route 76, depicting stream crossings studied in Stewart County, Tennessee (United States Geological Survey, 2007).

An Environmental Impact Assessment on the effects of the State Route 76 road and bridge construction by the United States Department of Transportation, Federal Highway Administration, and the Tennessee Department of Transportation (1998) determined there would be no long term significant impact on water quality. Short term impacts, such as erosion, increased siltation from vegetation removal, or damage from heavy equipment used in bridge or culvert construction would be minimized by strict adherence to erosion control methods.

Incorporating numerous biotic and abiotic variables into this study provided information to determine stream health for Dyers Creek. Biotic and abiotic variables have been used extensively for stream quality assessment. Common techniques have included use of sensitive macroinvertebrates (Blettler & Marchese, 2005), vegetation (Batiuk, Bergstrom, Carter, Collier, Dennison, Moore, Orth, & Stevenson 1993), periphyton (Cooper, Davis-Colley, Quinn, Rutherford, & Williamson, 1997), fish (Crawford & Lenat, 1992), habitat assessment (Allen, Erickson, & Roth, 1996), and land use (Bolstad & Swank, 1997). These studies offered valid results, such as using taxa richness to indicate lower water quality at urban sites (Crawford & Lenat, 1992) or determining reduced benthic invertebrate biomass under bridges (Blettler & Marchese, 2005).

This study determined species richness and relative dominance in vegetation, macroinvertebrate community pollution sensitivity, and habitat assessment scores. However, the primary focus was on water chemistry data to develop a mathematical model as a predictor of water quality. Water quality influences stream integrity, with acceptable physical and chemical parameters necessary in supporting a healthy and diverse community of macroinvertebrates, vegetation, and fish (USEPA, 2000). Models can freely ask questions and answer these questions through simulations (Ashkensas, D'Angelo, Gregory & Meyers, 1997) minimizing the need for field studies. Therefore, being able to predict changes in water quality attributed to bridge construction by using mathematical models would provide a rapid and cost effective stream assessment. Continued monitoring and improvement of processes in which we directly impact or degrade the environment remains important and mathematical modeling can be a significant component in assessing human impacts to the stream environment.

Mathematical models have proven useful in studying effects on stream health. Dague & Wallace (1973) modeled pollution run-off effects on dissolved oxygen. Cushman & Morgan (2005) modeled urbanization effects on fish. Ashkansas, Baker, Bayley, Haggerty, Herlihy, Li, & Van Sickle (2004) devised a regression model to estimate fish and aquatic invertebrate status in streams relative to land cover and land use. Thus, models have proven useful in determining how area land use affects water quality and understanding how the consequential hydrologic effects can benefit in developing ecologically sound management practices (Chen & Tong, 2002). Models can examine the implications of a theory and be used to answer questions at minimal cost (Ashkensas et. al., 1997).

Objective

The first objective of this study was to determine habitat assessment scores, tree species richness and relative dominance, macroinvertebrate community pollution tolerance, and collect water chemistry data at two stream segments above and below Tennessee State Route 76 crossings (Figure 2). These parameters allow monitoring of changes to the stream environment during the road construction process and provided baseline ecological data. Monitoring these parameters allowed detection of changes to the environment during road construction. Secondly, this study was to develop a mathematical model that could be used to predict changes in water quality due to road and bridge construction.

Hypothesis

The null hypothesis of this research was that there would be no difference between samples taken upstream of the road and bridge construction and those taken downstream of the road and bridge construction or between any of the study sites.

Study Area

Two main bridges connect the nearly 13,000 residents of Stewart County to neighboring counties (USCB, 2007). Stewart County lies in the northwestern corner of Middle Tennessee within the north – western portion of Tennessee (Figure 1). Its western boundary is the Tennessee River (Kentucky Lake reservoir). The Cumberland River (Barkley Lake reservoir) flows from the southeastern corner of the county north and westerly to enter Kentucky at the midpoint of the Stewart County boundary with that state. The county is dissected by numerous smaller streams. Streams in the extreme western portion of the county enter Kentucky Lake (Tennessee River). These streams are part of the Western Tennessee Valley watershed. Streams to the east of the Tennessee River Valley enter Barkley Lake (Cumberland River) from either the east or west and are part of the Cumberland River watershed (Figure 2). These streams are in the Western

Highland Rim Interior Plateau Ecoregion (USEPA, 2007). The area surrounding the study sites includes mixed land use, with segregated parcels remaining undeveloped and forested, some areas planted as agriculture fields (primarily tobacco and corn), or developed for business and residential use.

Site Description

Two Dyers Creek stream-crossings were monitored. Stream area BP (Figure 3) located 8.69 kilometers east of Dover, where State Route 79 intersects Dyers Creek and stream area P (Figure 4) located 4.83 kilometers east of Dover, where State Route 79 intersects Dyers Creek. At each crossing two stream reaches, one upstream from the construction area and one directly downstream were sampled. Each site incorporated a mixture of riffle, run, and pool habitats as perennial streams that drain into the Cumberland River. The stream reaches cross perpendicular to State Route 76, flowing north to south at crossing BP with collection site BPN located north of State Route 76, approximately 100 meters upstream of the original bridge. Site BPS was located south of State Route 76, approximately 25 meters from the original bridge and downstream from the construction. A reference site well upstream of construction, site BPN3 was located 277 meters upstream from the original bridge site.

Dyers Creek meanders between upstream area BP and downstream area P flowing mainly east to west, crossing State Route 76 from south to north at crossing P. Site PS was located east of State Route 76, approximately 100 meters upstream from the original bridge and projected construction. Site PN was located west of State Route 76, approximately 35 meters downstream from the original bridge (Table 1). Reference site

PS3 was located 323 meters upstream from the original bridge site. Collection sites varied slightly when necessary due to extreme drought or exceptionally high waters.

Figure 3 "BP" sample sites on Dyers Creek, along State Route 76 near proposed bridge and road construction, Stewart County, Tennessee.

Figure 4 "P" sample sites on Dyers Creek, along State Route 76 near proposed bridge and road construction, Stewart County, Tennessee.

Table 1 Study site descriptions and GPS coordinates; Dyers Creek bridge crossing study sites, State Route 76, Stewart County, Tennessee.

Site location	Direction from construction	Direction from roadway	Distance from construction	GPS coordinates
BPS	Immediate downstream	South	25 meters	36.55365 N - 87.78584 W
BPN	Immediate upstream	North	100 meters	36.55449 N - 87.78593 W
BPN3	Distant upstream - Reference site	North	277 meters	36.55672 N - 87.78544 W
PN	Immediate downstream	West	35 meters	36.52846 N - 87.81441 W
PS	Immediate upstream	East	100 meters	36.52846 N - 87.81374 W
PS3	Distant upstream – Reference site	East	323 meters	36.52846 N - 87.81298 W

Stream Statistics

Stream flow statistics were estimated using Streamstats (USGS, 2007) by including all six sample sites in a basin drainage area of 13.7 square miles (35.5 km). This estimated a stream slope of 35.1 percent and soil permeability of 2.35 inches or 5.97 cm per hour for the basin. Streamstats basin characteristics used the 10 and 85 method, taking the change in elevation between points 10% and 85% of the length along the main channel to the basin divide, divided by the length between points. Streamflow statistics for all sites approximated two-year peak-flow of 1420 ft^2/sec (131.9 m^2/sec) to 500-year peak-flow of 6860 ft^2/sec (637.3 m^2/sec). Low-flow statistics approximated two-year 3-day lows from 2.05 ft^2/sec (0.19 m^2/sec) to twenty-year 3-day lows of 1.02 ft^2/sec (0.09 m^2/sec). Average prediction error rate was 33% for all acquired statistics (USGS, 2007)

CHAPTER 2

Methods and Materials

Habitat Assessment

The two stream sites to be bridged during the road widening process were digitally photographed using a Sony DSC H2, with shots taken from designated photo points. Photographs coincided with collection dates to visually ascertain noticeable differences in riparian vegetation, slope, possible erosion, and tree species observed. A Habitat Assessment and Physiochemical Characterization form (Barbour, Gerritsen, & Stribling, 1999) was completed at each site during the study (October 2007) to ascertain variation between study sites at different stages of construction. Habitat Assessment scores are a valuable component in assessing the quantity and quality of habitat and thus possible limitations on macroinvertebrates and the aquatic community (Barbour et al., 1999). Habitat assessment field data scores were compared by collection site, including upstream, downstream, and reference sites for both stream areas. An erosion stake was placed at site BPS with 10.16 cm out of ground and 24.4 cm in the ground. Global Position System (GPS) coordinates were determined using a Garmin 60 unit, providing x, y, z coordinates of water collection sites, biological collection areas, and habitat assessment locations. Collection site coordinates and habitat assessment scores were displayed visually on ArcGIS 9.1.

Vegetation

Riparian tree species greater than 10 centimeters in diameter were measured at breast height (dbh) along both streambanks approximately 100 meters from the original bridge and leaves collected for identification in June 2007.

The biological integrity of stream ecosystems depends critically on human activities that affect land use/cover along stream margins (Allen, Erickson, & Roth, 2006). Riparian vegetation is closely connected to stream food webs through input of leaf detritus as a primary energy supply, and therefore, any alteration of plant diversity may influence aquatic ecosystem functioning (Chauvet, Dang, Dobson, & Lecerf, 2005). Relative species dominance was determined by comparing individual species diameter to total species diameter at each study reach. Species richness was determined as the total number of tree species at each study reach. Plant species richness may indirectly govern ecosystem functioning through complex trophic interactions (Chauvet et al., 2005). Tree species were identified using various tree identification resources (Arbor Day Foundation; Chester, personal communication 2007; Williams, 2005) and species richness for each study site recorded. Tree species were identified September 2007.

Macroinvertebrates

Benthic macroinvertebrates were collected in July 2007 using triangular dip nets with 500 micrometer mesh-opening, according to Tennessee's protocols for macroinvertebrate stream surveys (TDEC, 2006). Six riffle samples were collected from each stream reach. The macroinvertebrate collection sites began at the first riffle closest to the original bridge with successive collection sites followed the stream away from the bridge and continuing to the sixth riffle. Samples were collected for the four stream reaches, PN, PS, BPN, and BPS.

Macroinvertebrate samples were placed in jars and preserved in 8% formalin. The six samples from each of the four stream reach sites were combined to form a composite sample from each of the four stream reaches. In the lab, samples were rinsed and randomly sub-sorted to 200 specimens for each of the four stream reach samples using a raised grid tray (TDEC, 2006). Macroinvertebrates were identified to order, then family when possible (Berg, Cummins, & Merrritt, 2008) using a dissecting microscope. Macroinvertebrates were then determined to be "pollution tolerant," "somewhat pollution tolerant," or "pollution intolerant" (USEPA, 2008). Voucher specimens were preserved in 80% ethanol with a label indicating date and site and stored in the macroinvertebrate lab at Austin Peay State University.

Water Quality

Water chemistry data, were collected monthly beginning June 2007 and ending March 2008 for a total of ten samples. The Hach test kit (model FF – 1A) was used to measure dissolved oxygen, conductivity, nitrite, alkalinity, hardness, carbon dioxide, chloride, and ammonia.. Temperature, pH, and conductivity were measured monthly with instruments from Fisher Scientific (model S40), Hanna Instruments (model pH ep3), and Corning (model CD 55), respectively. Water chemistry levels were used to evaluate water quality by comparison to standards using the 2004 General Water Quality Criteria for fish and aquatic life (TDEC).

Water samples were collected upstream and downstream of the construction area at both of the sites for a total of four collection sites. The upstream site was located approximately thirty meters from the original bridge location. The downstream site was located as the nearest point to the construction containing a run with adequate depth for sample collection. An additional reference sample was collected once during the study, approximately three hundred meters upstream from the construction, in an area containing a riparian zone which extended beyond the stream bank a minimum of 30 meters. These sites PS3 and BPN3 were used as a control and to verify the validity of upstream data for purposes of the math model.

Photographs and field notes were used to compare construction progress with sample data. Additional measurements (dissolved oxygen, temperature, turbidity, specific conductance, and total dissolved solids) were collected simultaneously with biological samples using a YSI 600QS multi-parameter meter (Yellow Springs Instruments). Water quality parameters were analyzed using ANOVA to determine whether any statistical difference exists between upstream or downstream sites or between sites P and sites BP.

Water Quality Model

Water quality data were used to develop an accurate model useful in predicting effects of road and bridge construction on the selected water quality variables including alkalinity, hardness, pH, and temperature for downstream sites PN and BPS. This model intended to predict stream health by analyzing water chemistry data using three mathematical techniques: graphical analysis, higher-order polynomials, and least squares method. Computer software programs used were Microsoft Excel and Mathmatica (Jator & Sahi, personal communication 2008).

CHAPTER 3

Results

Habitat Assessment

Sites PN and PS showed little change due to construction progress from the beginning of the study, June 2007 until the end, March 2008. Variations in stream flow and consequent erosion and gravel deposits were noted within areas of the stream at sites PN and PS. Portions of the stream at sites PN and PS were completely dry during August and September. Streamside vegetation remained on both banks although construction progress approached the study site. Water levels remained low yet flowing during the same time period for sites BPN and BPS. This time period coincided with rapid construction progress at site BPS with all streamside vegetation removed, rip-rap placed along the steepened bank, and the bridge put in place (Figure 5, 6). An erosion stake placed near site BPS in the bridge construction area showed no noticeable erosion with 10.16 cm remaining out of ground and 24.4 cm in the ground.

Figure 5 Collection site area BPS (June 2007); photo shows the location where the new bridge will be located.

Habitat assessment scores taken during the study (October 2007) reflected no difference in any of the sites at location P, including site PS, PN, and reference site PN3, all with assessment scores of 138. However, the sites were not identical. Site PS3 had a wide riparian zone but bank instability on the east bank. Site PN and PS had lower riparian zone and channel alteration scores but were higher in velocity/depth regime and frequency of riffles.

Figure 6 Collection site area BPS (March 2008); photo depicts the new bridge with the old bridge located behind it.

Sites BP showed differences in habitat assessment scores with reference site BPN3 rated 138, site BPN located upstream from construction rated 107, and site BPS located immediately downstream from construction rated lowest with 81 (Figure 7). Site BPN3 had higher scores in frequency of riffles and vegetative zone, while site BPN had low scores in riparian zone width and channelization. Site BPS had very little riparian zone, almost no vegetation, and evident channel alteration. All scores fell below the median habitat score of 164 for the Western Highland Rim subregion but most were above123 considered necessary to have potential in supporting an acceptable level of biota (TDEC, 2001, Table 3).

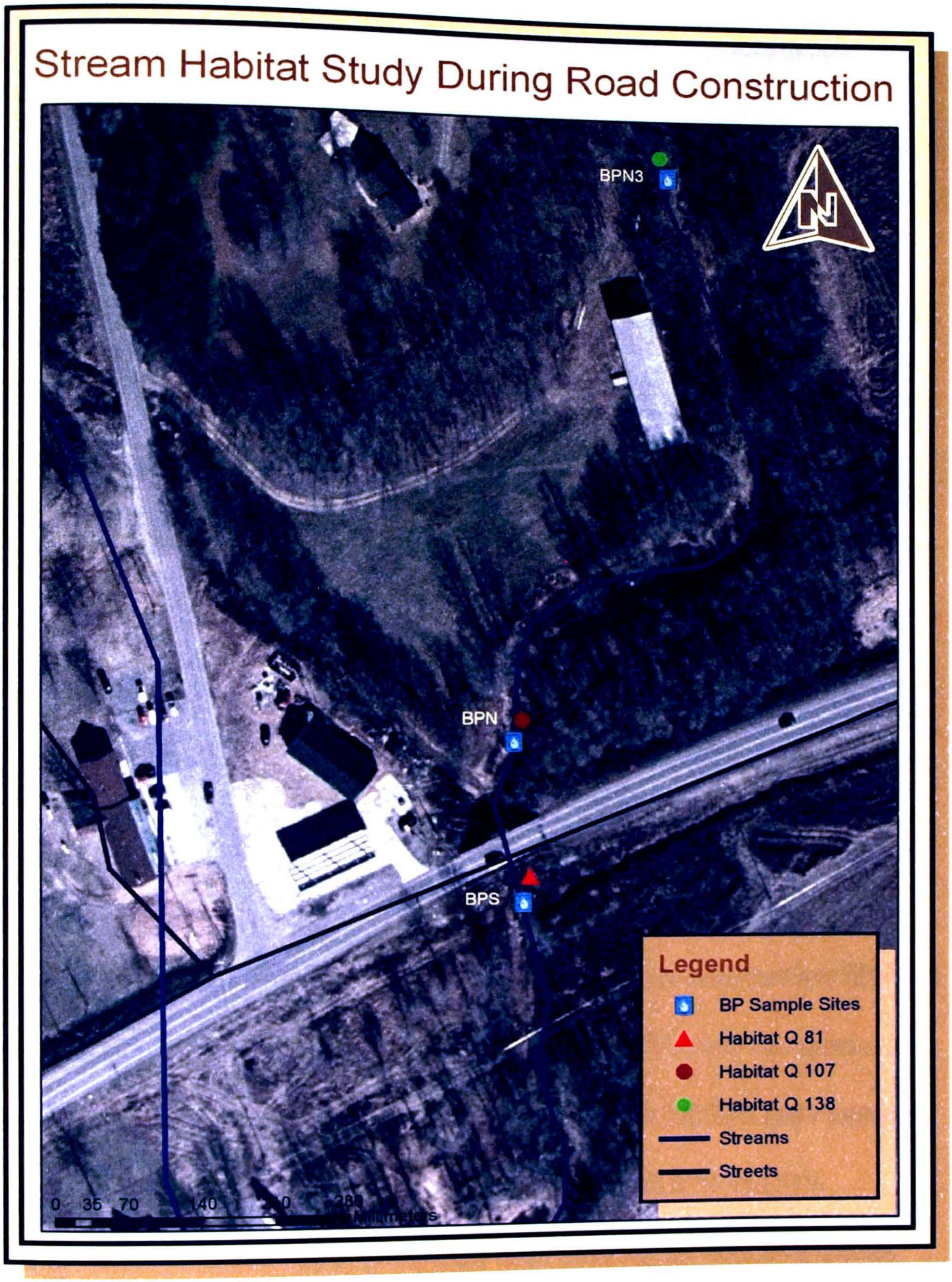


Figure 7 Map of Dyers Creek BP sites on State Route 76; map depicts area, sample sites, and habitat quality in accordance with EPA protocols.

Table 2 Comparison of Dyers Creek Study Site, Stewart County, Tennessee; Habitat Quality Assessment Scores compared to Western Highland Rim Expected Scores.
* Below level considered acceptable to support biota

Site location	Score
Western Highland Rim Streams Assessed, median habitat	**164**
Western Highland Rim Streams, acceptable to support biota	**123**
Site PN, downstream from construction	138
Site PS, upstream from construction	138
Site PS3, distant upstream from construction	138
Site BPN3, distant upstream from construction	138
Site BPN, upstream from construction	107*
Site BPS, downstream from construction	81*

Vegetation

Species richness was greater at sites upstream from bridge construction, BPN and PS. Downstream site PN containing only one species and site BPS only two species of trees over 10 cm dbh. Both upstream site BPN and downstream site BPS had *Plantanus occidentalis* (American Sycamore) as the dominant species with 67% and 54% respectively. Sites PN and PS had *Acer negundo* (Box Elder) as the dominant species with 100% and 44% (Table 3). Species richness and dominant species for reference sites were not determined however observation of tree species and leaf litter indicated the presence of *Acer saecharum (Sugar Maple), Liriodendron tulipifera (Tulip Poplar), Fagus grandifolia (American Beech), Quercus rubra (Red Oak)* near or upstream of the reference site BPN3 and *Acer seacharum*, *Quercus alba (White Oak)*, *Quercus muehlenbergii (Chinkapin Oak)*, and *Plantanus occidentalis* present near or upstream of the reference site PS3. Tree species were identified September 2007.

Table 3 Analysis of riparian tree species, 10 cm at breast height located at study sites, Stewart County, Tennessee.

	Relative Dominance of Tree Species over 10 cm						
Site	***Acer negundo***	***Acer saccharum***	***Plantaris ocidentalis***	***Quercus pagoda***	***Maclura pomifera***	***Albizia julibrissin***	**Number of trees**
PN	100%						5
PS	44%	32%	20%	4%			12
BPS	33%		67%				9
BPN	13%		54%		10%	23%	16

Macroinvertebrates

All four sites had pollution tolerant macroinvertebrates. Site PN also had high numbers of gilled snails and water pennies, both sensitive to pollution. Site PS exhibited the least amount of pollution sensitive species with damselflies (order Odonta, suborder Zygoptera) and lung snails (order Gastropoda) being the predominant organisms, damselflies being moderately tolerant to pollution and lung snails pollution tolerant (Table 4). Site BPS was highest in water pennies, (order Coleoptera, family Psephenidae) and flatworms (order Tricladida, family Planariidae) while site BPN contained high amounts of gilled snails and caddisflies, (order Trichoptera), all determined sensitive to pollution (EPA 1997). Macroinvertebrate samples were collected July 2007.

Table 4 Predominant macroinvertebrate species; Dyers Creek study reaches, Stewart County, Tennessee.

Site	Macroinvertebrate	Count	Pollution Tolerance
PN	Water penny - Coleoptera, Psephenidae	60	sensitive
	Right-handed snails – Gastrapoda	35	sensitive
	Caddisfly – Trichoptera	14	sensitive
	Mayfly – Ephemeroptera	12	sensitive
PS	Lung snail – Lymnaeidae	24	tolerant
	Damselfly – Odonta zygoptera	19	moderate
	Caddisfly – Trichoptera	13	sensitive
	Mayfly – Ephemeroptera	11	sensitive
BPS	Water penny – Coleoptera, Psephenidae	52	sensitive
	Flatworm - Tricladida, Planariidae	39	sensitive
	Mayfly – Ephemeroptera	33	sensitive
	Right-handed snail – Gastrapoda	19	sensitive
	Caddisfly – Trichoptera	15	sensitive
BPN	Caddisfly – Trichoptera	73	sensitive
	Right-handed snail – Gastrapoda	46	sensitive
	Mayfly – Ephemeroptera	37	sensitive
	Water Penny - Coleoptera, Psephenidae	32	sensitive
	Flatworm - Tricladida, Planariidae	23	sensitive

Water Quality

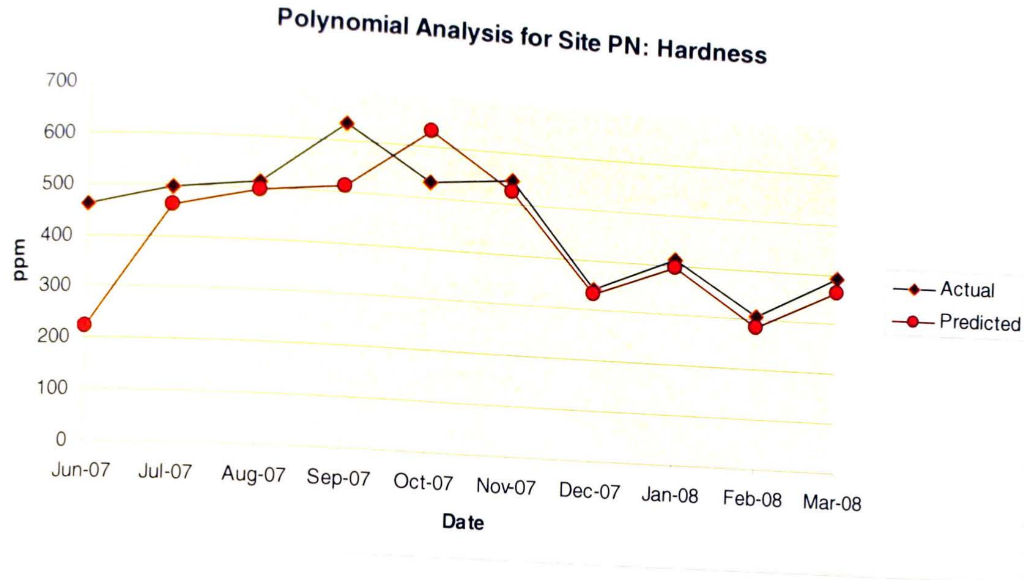
Water quality showed no significant difference between any of the four sample sites for any of the water quality variables (ANOVA, F statistic < F critical, F critical = 2.866). Nitrite remained absent throughout the study. Chloride and ammonia remained stable (60 – 90 mg/l, .01 - 0.4 mg/l) and there was no significant difference between any of the study sites. September was the only month with dissolved oxygen readings below acceptable levels for fish and aquatic life (TDEC, 2004). However, there was no significant difference between upstream and downstream sites or between site locations for dissolved oxygen (Table A.5, F = 0.411, F critical = 2.866). All other water quality parameters analyzed (alkalinity, carbon dioxide, hardness, conductivity, pH, and temperature) also showed no significant difference (Table 5, Tables A.1 – A.8) between upstream and downstream sites for all locations (ANOVA, F statistic < F critical, F critical = 2.866)

Table 5 Mean water chemistry levels for study sites; PN, PS, BPN, & BPS.

Site	**Alkalinity**	**Carbon Dioxide**	**Chloride**	**Conductivity**	**Dissolved Oxygen**	**Hardness**	**pH**	**Temperature**
PN	176.1	83.0	78.0	304.5	19.0	463.4	7.6	16.8o C
PS	174.4	92.5	72.0	296.1	21.1	444.6	7.6	17.8o C
BPS	186.4	107.0	69.0	301.4	21.7	492.4	7.7	16.8o C
BPN	208.6	73.5	78.0	327.0	24.8	497.6	7.9	16.6o C

Water Quality Model, Polynomial Analysis

Higher-order polynomial analysis and least squares method were used to predict changes in the water chemistry variables alkalinity, hardness, pH, and temperature due to road and bridge construction for the two sites downstream from construction, PN and BPS. A graphical analysis assisted in visualizing patterns in the data, formulating the model, and comparing the two techniques. Higher order polynomials of degree nine were applied to capture the trend of the collected data. Sample values and predicted values remained accurate during the months of June through October for alkalinity, pH, hardness, and temperature at both sites. Values also were well within established parameters for fish and aquatic life (TDEC, 2004). Site PN remained accurate on predicted values for hardness and pH, (Figure 8a, 8b), however values for alkalinity and temperature at site PN (Figure 8c, 8d) and all predicted values for site BPS reduced in accuracy past November (Figure 9a, 9b, 9c, 9d). Although some of the values remained accurate, the polynomial analysis was not a reliable predictor of water quality during construction (Jator & Sahi, personal communication 2008).



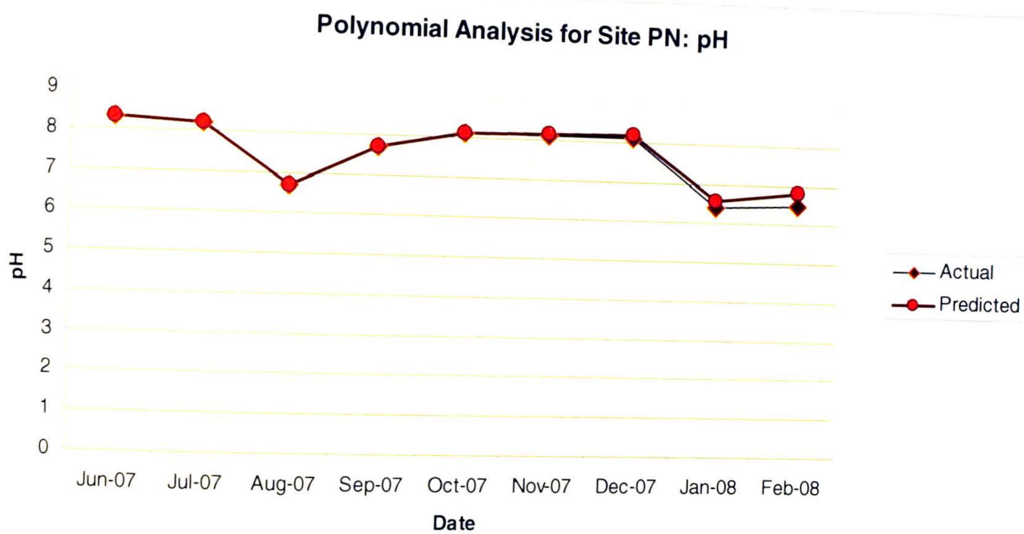
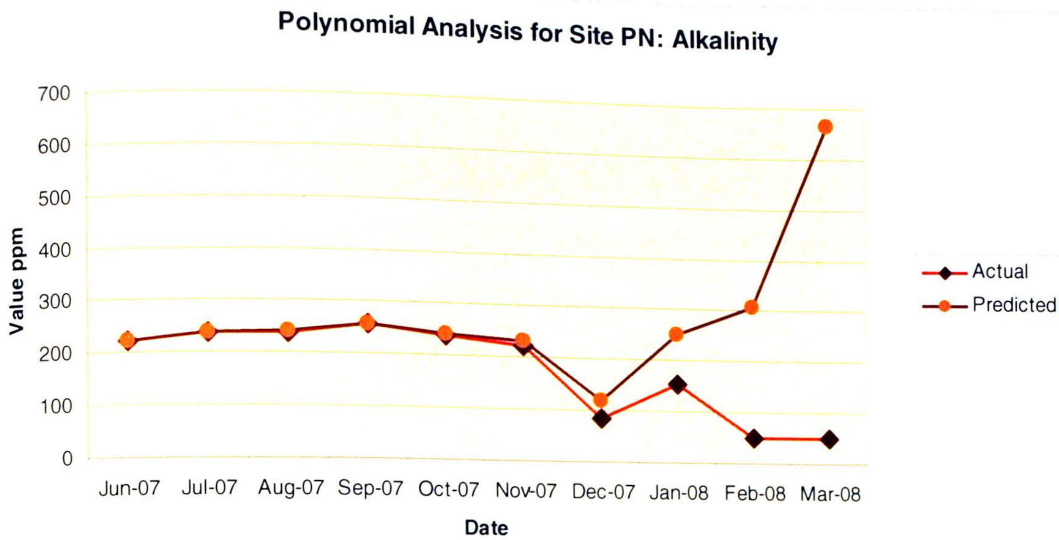


Figure 8a & 8b Site PN hardness and pH levels, using polynomial analysis depicting accurate predicted water chemistry values.



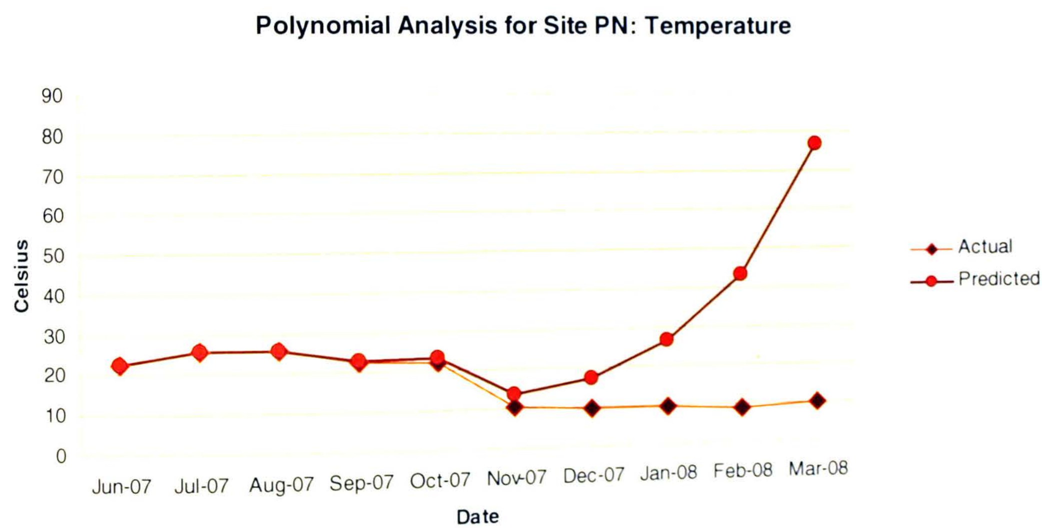
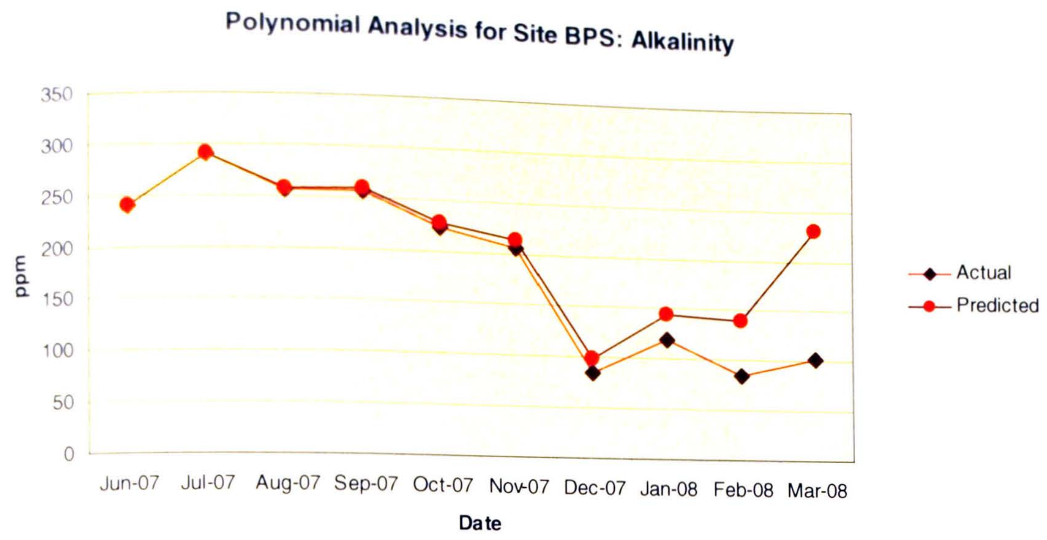


Figure 8c & 8d Site PN alkalinity and temperature levels, using polynomial analysis depicting decreased accuracy of model as time progresses.



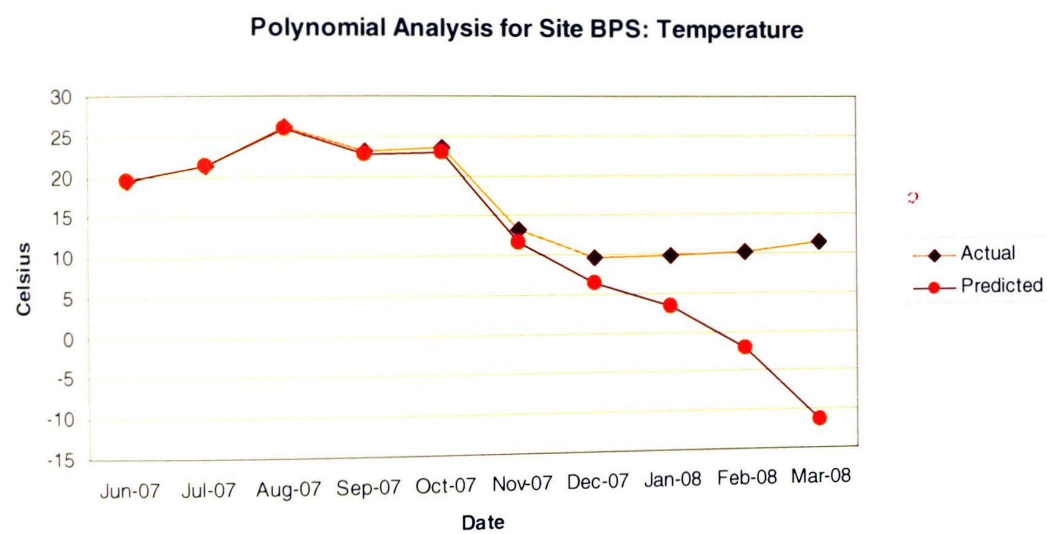
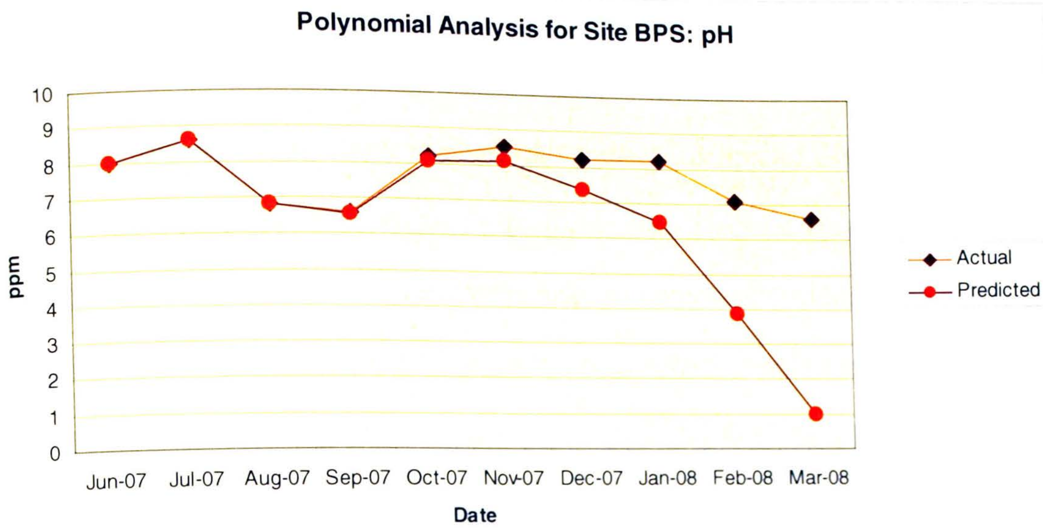


Figure 9a & 9b Site BPS alkalinity and temperature levels, using polynomial analysis depicting decreased accuracy of model as time progresses.



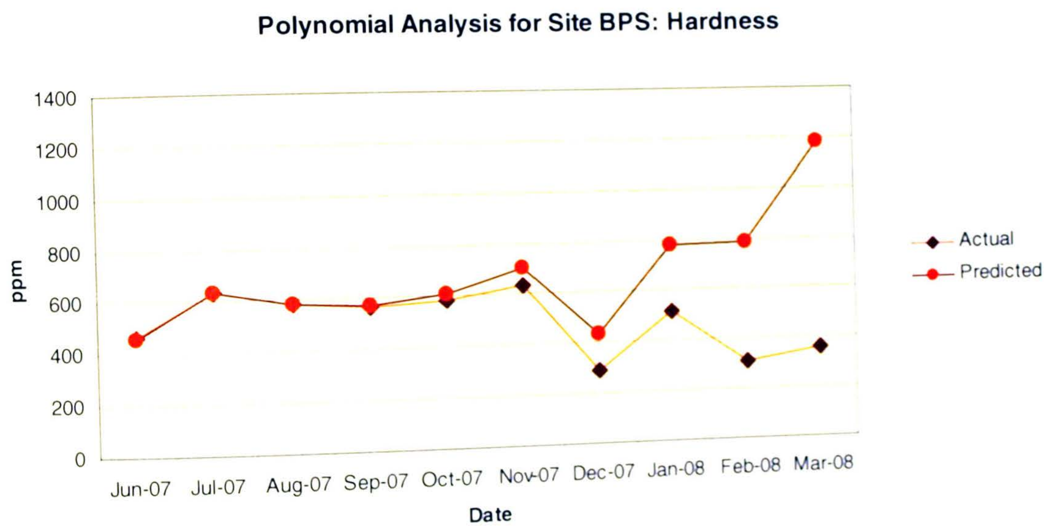
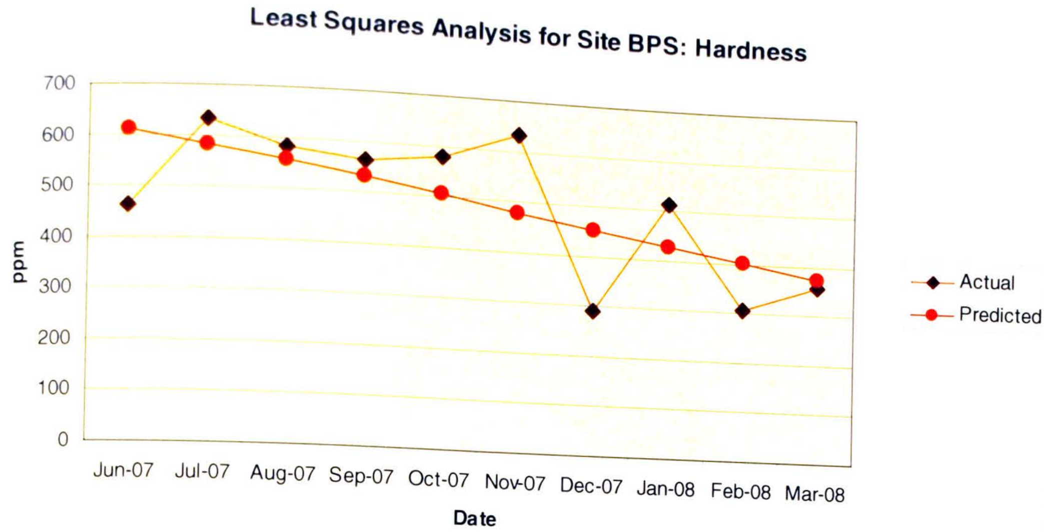


Figure 9c & 9d Site BPS pH and hardness levels, using polynomial analysis depicting decreased accuracy of model as time progresses.

Least Squares Method

Assuming no extreme circumstance and hypothesizing that water chemistry parameters will behave in a linear manner, least squares was applied using actual data and the ten sample points to formulate the predicted data. The least squares method showed variation between some predicted and actual water quality values. The values for hardness and temperature showed the greatest discrepancy for both sites BPS and PN (Figure 10a, 10b, 11a, 11b). Alkalinity and pH (Figure 12a, 12b, 13a, 13b,) were more accurate throughout the ten samples. However, predicted values became accurate for all variables showing the least squares method effective in analyzing water quality in the long term.

Overall, these mathematical models determined that the construction had no long term effect on the water quality variables alkalinity, pH, hardness, and temperature (Jator & Sahi, personal communication, 2008) with values remaining within the parameters determined for fish and aquatic life (TDEC, 2004).



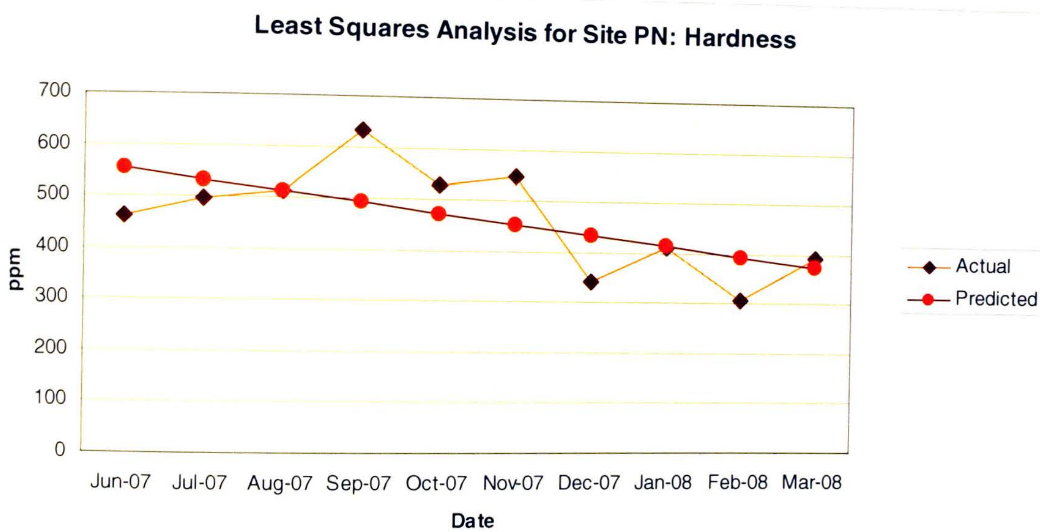
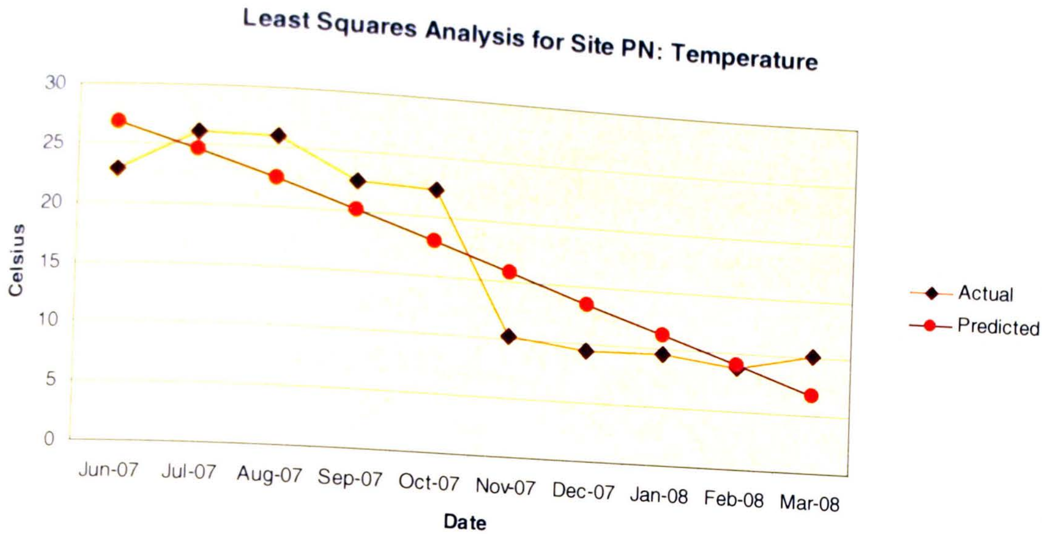


Figure 10a, 10b Site BPS and PN hardness levels; using least squares analysis depicting initial discrepancies in water quality values with increased accuracy as time progresses.



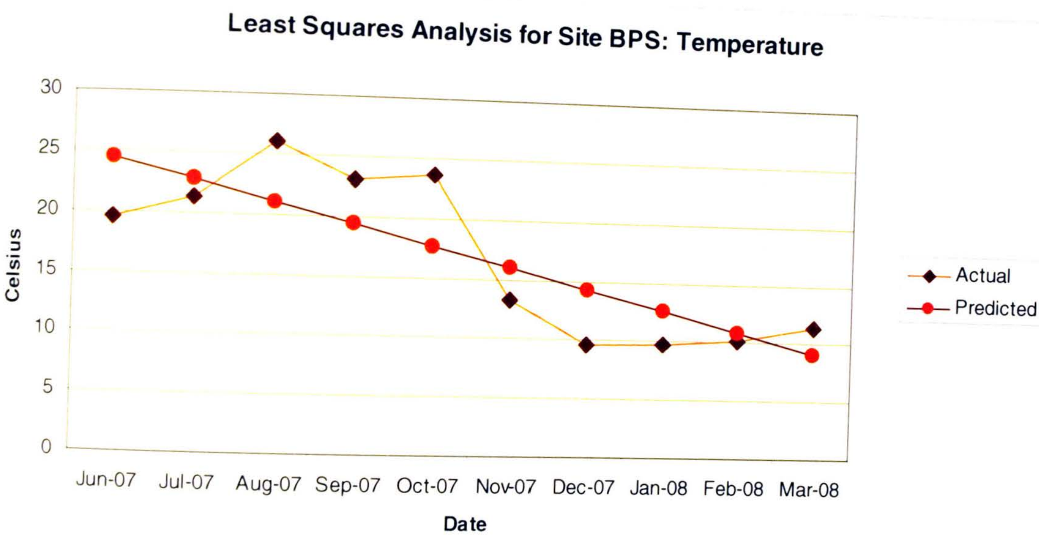
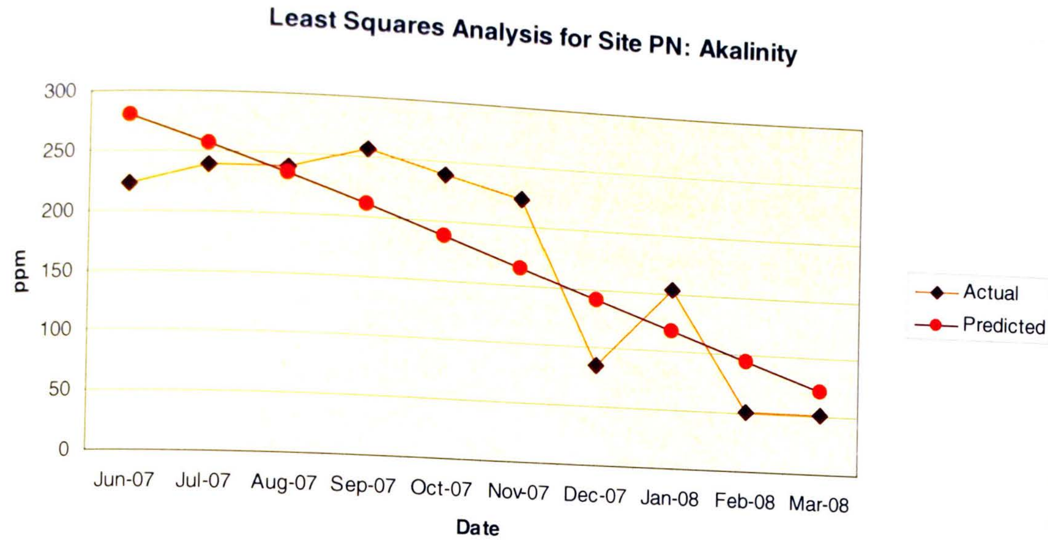


Figure 11a, & 11b Site BPS & PN temperature levels; using least squares analysis depicting initial discrepancies in water quality values with increased accuracy as time progresses.



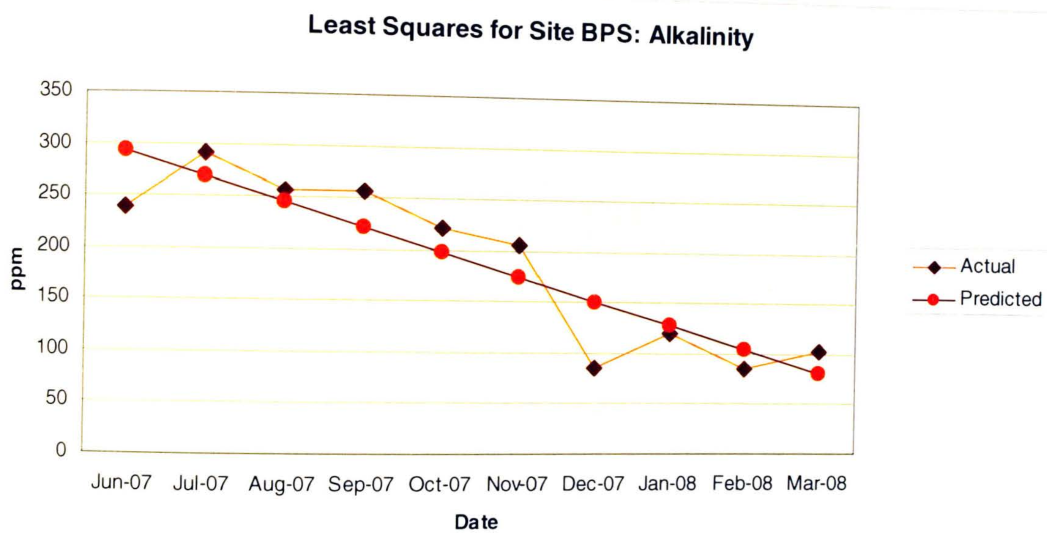
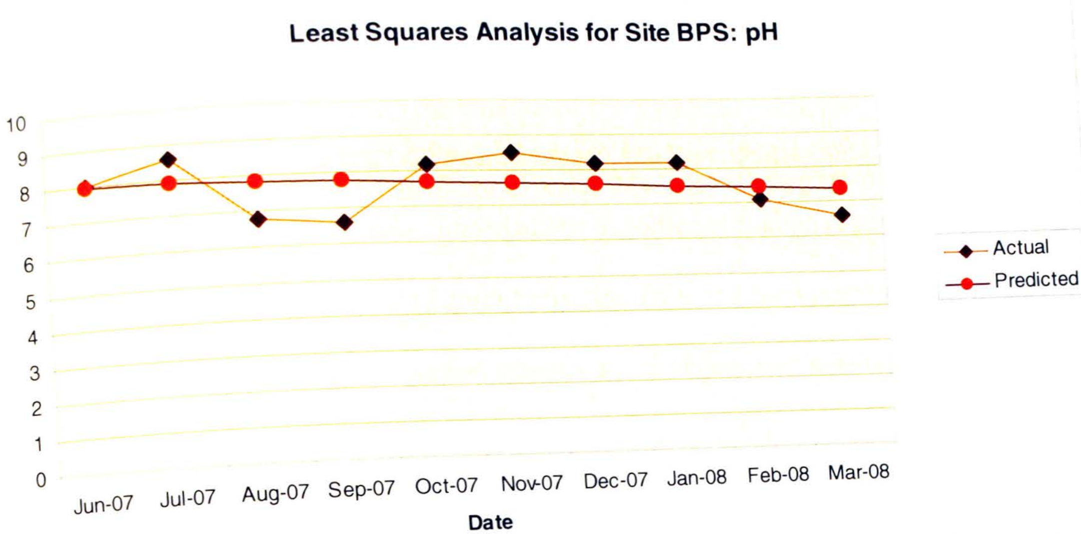


Figure 12a & 12b Site BPS & PN alkalinity levels; using least squares analysis depicting initial discrepancies in water quality values with increased accuracy as time progresses.



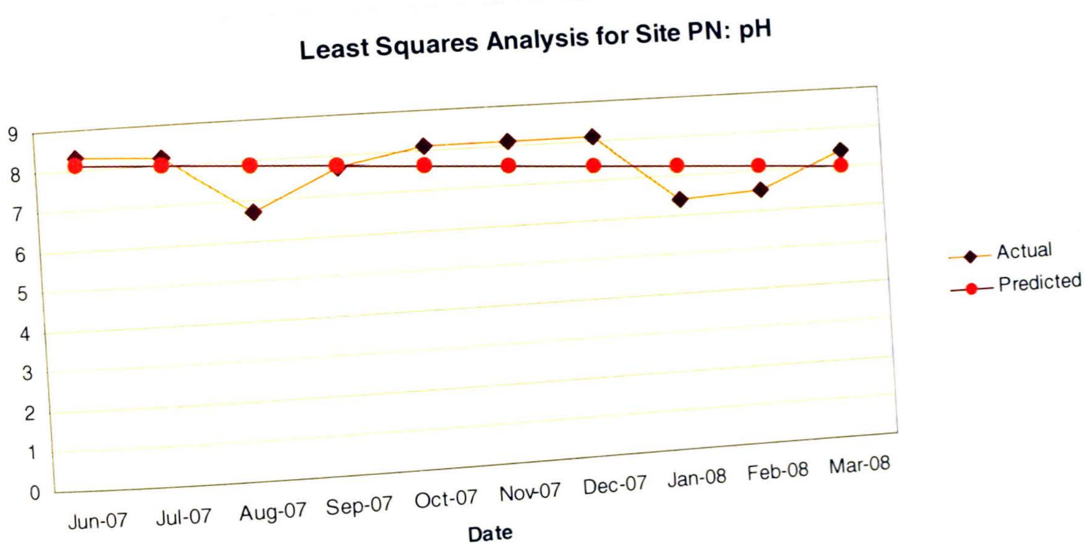


Figure 13a & 13b Site PN & BPS pH levels; using least squares analysis depicting predicted values comparable to actual values

CHAPTER 4

Discussion

Although road construction neared area P, bridge construction did not begin at this site during the course of this investigation. Significant change resulting from bridge construction occurred at site BP (Figure 5, 6). Site BPS had the lowest habitat quality scores, primarily attributed to channel alteration and vegetation removal in the construction area.

Site PN had no diversity in tree species and contained mainly grasses. Site PN also showed reduced numbers of pollution sensitive macroinvertebrates. Though this site was upstream from projected bridge construction, it was downstream from construction site BPS. Additionally, site PN appeared most affected by drought conditions, such as occurred after plant and macroinvertebrate samples were collected (September 2007). All sites contained existing area disturbance through previous construction, area farming, or nearby development. These factors could account for lower habitat quality, low tree species diversity, and comparable macroinvertebrate pollution tolerance levels.

All water quality data analyzed (except September 2007 dissolved oxygen) were within acceptable parameters (TDEC, 2004) and sites downstream from construction did not have significantly lower water quality. Other water quality parameters, as well as increased sample size could provide a more complete assessment of construction influence. Additionally, long-term studies of construction effects on water quality and stream organisms, as well as resultant changes in biodiversity could prove valuable. Studies on wetlands have shown short-term assessments of construction impacts on susceptible species and biodiversity to underestimate effects (Bourdages & Findlay, 2000).

Ecologically beneficial practices, such as fencing, rip-rap, sod, and drainage were implemented conscientiously throughout the construction. Without minimizing impact, stream waters could have shown decreased quality. Although direct short-term impacts from vegetation removal, erosion, and sedimentation can occur; impacts from heavy construction equipment and stream crossing alterations attributed to bridge construction were minimized by strict adherence to erosion control methods (USDOT, 1998). This study of road and bridge construction on State Highway 76 and its influence on Dyers Creek concluded there was no significant impact to the stream s ability to support aquatic life.

Mathematical modeling has proven beneficial in predicting land use changes on the stream environment. Chen & Tong (2002) modeled the effect of land use on local watersheds, finding a significant relationship between land use and stream water quality. Modeling factors influencing stream temperature proved useful in estimating timber harvest effects (Bartholow, 2000). A model was useful in simulating stream flow velocity from projected bridge placement. The new bridge was moved to an area estimated to minimize increases in water velocity (Barks & Funkhouser, 2002). Thus, development of models that fully represent ecosystem hierarchies becomes the next step in stream modeling (Ashkensas et al., 1997).

Modeling construction impacts on water quality using least squares analysis was effective in predicting road and bridge construction impacts on stream water quality.

Additional studies providing more water quality data with a longer study period would be beneficial in expanding the model accuracy.

Conclusion

Roads have far reaching and complicated implications for numerous ecological factors and frequently alter stream ecology through channelization, invasive plant increase, and species limitations resulting from habitat changes (Deblinger & Forman, 2000). Bridge construction influences macroinvertebrate communities by reducing or altering species density, thereby affecting a decline in biodiversity and reduction of available food source (Blettler & Marchese, 2005). The Dyers Creek study sites reflected differences in habitat quality assessment scores and variation in vegetation composition and macroinvertebrate distribution, with water chemistry showing no significant difference. Incorporating numerous ecological factors into a road and bridge study can offer a more complete picture of construction repercussions.

Modeling projected land use changes and their influence on ecological factors can provide a cost – effective means to practice sound development while protecting the stream environment. Stream systems greatly benefit from physical representation made possible through effective modeling (Ashkensas et al., 1997). The least squares method of modeling water chemistry variables was effective in determining that water quality would remain with in acceptable levels for fish and aquatic life (TDEC, 2004). Road and bridge construction effects have been accurately simulated with results used to reduce negative influence on the stream environment (Barks & Funkhouser, 2002). A model that effectively predicts road and bridge construction effects on water quality provides a valuable asset in preserving stream ecosystems.

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APPENDICES

Table A.1 ANOVA results for alkalinity.

Anova: Single Factor   Alkalinity

SUMMARY

Groups	Count	Sum	Average	Variance
Column 1	10	1761.09	176.109	6957.151
Column 2	10	1744.2	174.42	7069.824
Column 3	10	1863.9	186.39	6332.301
Column 4	10	2086.2	208.62	8564.364

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	7431.527	3	2477.176	0.342581	0.794664	2.866266
Within Groups	260312.8	36	7230.91			
Total	267744.3	39				

Table A.2 ANOVA results for carbon dioxide.

Anova: Single Factor   Carbon Dioxide

SUMMARY

Groups	Count	Sum	Average	Variance
Column 1	10	830	83	773.3333
Column 2	10	925	92.5	1118.056
Column 3	10	1070	107	3434.444
Column 4	10	735	73.5	750.2778

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	6125	3	2041.667	1.344061	0.275402	2.866266
Within Groups	54685	36	1519.028			
Total	60810	39				

Table A.3 ANOVA results for chloride.

Anova: Single Factor Chloride

SUMMARY

Groups	Count	Sum	Average	Variance
Column 1	10	780	78	240
Column 2	10	720	72	240
Column 3	10	690	69	210
Column 4	10	780	78	240

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	607.5	3	202.5	0.870968	0.465102	2.866266
Within Groups	8370	36	232.5			
Total	8977.5	39				

Table A 4 ANOVA results for conductivity.

Anova: Single Factor Conductivity

SUMMARY

Groups	Count	Sum	Average	Variance
Column 1	10	304.5	304.5	5698.944
Column 2	10	2961	296.1	4024.544
Column 3	10	3014	301.4	6844.933
Column 4	10	3270	327	5828.667

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	5561.7	3	1853.9	0.331097	0.802884	2.866266
Within Groups	201573.8	36	5599.272			
Total	207135.5	39				