



Water Quality in Waikolu Stream, Kalaupapa National Historical Park

Summary Report 2007-2011

Natural Resource Data Series NPS/PACN/NRDS—2014/670



ON THE COVER

Near the mouth of Waikolu Stream, Kalaupapa National Historical Park, Moloka'i, Hawaii.

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Summary Report 2007-2011

Natural Resource Data Series NPS/PACN/NRDS—2014/670

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Abstract

This Natural Resource Data Series Report (NRDS) presents data collected from Waikolu Stream in Kalaupapa National Historical Park on the northern coast of the island of Moloka'i, Hawaii. This is a summary or "data report" as described in the Water Quality Vital Signs Monitoring Protocol for the Pacific Island Network Version 1.0, Natural Resource Report NPS/PACN/NRR-2011/418. This report is restricted to data presentation and limited description. The data presented in this report will be analyzed for the establishment of expected parameter value ranges and long-term trends in future reports published in the NPS Natural Resource Technical Report (NRTR) series. The purpose of collecting data on Vital Signs is to provide park managers information on current conditions and temporal trends in ecosystem health. Waikoloa Stream regularly exceeded state water quality criteria. Because dissolved nutrient concentrations do not include particulate nutrient concentrations, total nutrient concentrations, in which state criteria are written, will be higher in the stream. Thus while nutrient levels in the stream exceeded the state TP criteria in the dry seasons of each year based on dissolved nutrients alone, the stream may in fact exceed state criteria at all times due to additional phosphorus in particulate form. Likewise, while TDN did not exceed criteria, the stream may exceed criteria when particulate nitrogen is also considered. The stream exceeded nitrate + nitrite concentrations at all times.

Acknowledgments

We thank Eric Brown, Paul Hosten, and others on the staff of KALA for their cooperation and on-site logistical support.

List of Units and Acronyms

°C	Degrees Centigrade
$\mu\text{g} \cdot \text{L}^{-1}$	Micrograms per Liter
$\mu\text{gP} \cdot \text{L}^{-1}$	Micrograms of Phosphorus per Liter
$\text{mS} \cdot \text{cm}^{-1}$	Milli-Siemens per Centimeter
Chl	Chlorophyll
CO ₂	Carbon dioxide
HAVO	Hawai'i Volcanoes National Park
I&M	Inventory and Monitoring Program of the National Park Service
KALA	Kalaupapa National Historical Park
$\text{mg} \cdot \text{L}^{-1}$	Milligrams per Liter
$\text{mgN} \cdot \text{L}^{-1}$	Milligrams of Nitrogen per Liter
n	Number of measurements or samples
NO ₂	Nitrite
NO ₃	Nitrate
NPS	National Park Service
NRDS	Natural Resource Data Series Report
NRTR	Natural Resource Technical Report
NTU	Nephelometric Turbidity Units
ODO	Optical Dissolved Oxygen
ODOsat	Optical Dissolved Oxygen in terms of saturation
PACN	Pacific Island Inventory and Monitoring Network
ppt	Parts Per Thousand
SD	Standard Deviation
SE	Standard Error
SpC	Specific conductivity
TDN	Total Dissolved Nitrogen
TDP	Total Dissolved Phosphorus
Temp	Temperature
TN	Total Nitrogen
TP	Total Phosphorus
Turb	Turbidity
UHH	University of Hawai'i at Hilo

Introduction

Water quality is widely used as an indicator of aquatic ecosystem condition. The National Park Service (NPS) has designated water quality as a “Vital Sign”, or an indicator of physical, chemical, biological elements or ecosystem processes selected to represent the overall health or condition of natural resources within parks. Water quality is one Vital Sign monitored by the NPS Inventory and Monitoring (I&M) Pacific Island Network (PACN). This report presents data collected under the PACN water quality protocol (Jones et al. 2011) in Waikolu Stream, Kalaupapa National Historical Park (KALA) on the island of Moloka’i, Hawaii, USA, from 2007-2011.

Water quality criteria for streams are defined in §11-54-5.1b of the State of Hawaii Department of Health Water Quality Standards (State of Hawaii 2012, Table 1). Criteria in the water column are defined for the wet season (November 1 - April 30) and the dry season (May 1 - October 31). Criteria are defined for total phosphorus, total nitrogen, nitrate + nitrite, total suspended solids, and turbidity in terms of a geometric mean not to be exceeded, and values not to be exceeded 10% and 2% of the time. The arithmetic mean, or average, of a set of values is defined as the sum of those values divided by the count, and the geometric mean is the n th root of the product of n values.

Nutrients can be classified as particulate or dissolved. Total phosphorus (TP) is the sum of particulate phosphorus (PP) and total dissolved phosphorus (TDP), and total nitrogen is the sum of particulate nitrogen (PN) and total dissolved nitrogen (TDN). TDN or TDP values that exceed state criteria indicate impaired waters, but TDN or TDP values that do not exceed state criteria do not indicate non-impaired waters because of unknown PN and PP values.

This report is a Natural Resource Data Series Report (NRDS), defined by the NPS as an annual or periodic data summary report for long-term monitoring projects. NRDSs are intended only for the release of basic data sets and summaries, with minimal interpretation. This report is one part of the I&M reporting process. Data presented in this report will be incorporated into future I&M trend-analysis reports to be published as NPS Natural Resource Technical Reports (NRTR).

The mission of the I&M Program is to provide data to inform management decisions and support the NPS mission of preserving the natural resources of parks unimpaired for the enjoyment of future generations (16 U.S.C. §1). The purpose of collecting data on Vital Signs is to provide park managers information on current conditions and temporal trends in ecosystem health. The primary purposes of the water monitoring protocol are to characterize the ecosystem and identify existing problems, and identify temporal trends especially with regard to emerging problems. Park managers can use this information to respond to resource conditions and evaluate management actions.

Table 1. State of Hawaii specific inland water criteria for streams (State of Hawaii 2012).

Parameter	Unit	Season	Geometric mean not to exceed the given value	Not to exceed the given value more than 10% of the time	Not to exceed the given value more than 2% of the time
Total Phosphorus	$\mu\text{gP} \cdot \text{L}^{-1}$	Wet ¹ Dry ²	50.0 30.0	100.0 60.0	150.0 80.0
Total Nitrogen	$\text{mgN} \cdot \text{L}^{-1}$	Wet Dry	0.250 0.180	0.520 0.380	0.800 0.600
Nitrate + Nitrite	$\mu\text{gN} \cdot \text{L}^{-1}$	Wet Dry	70.0 30.0	180.0 90.0	300.0 170.0
Total Suspended Solids	$\text{mg} \cdot \text{L}^{-1}$	Wet Dry	20.0 10.0	50.0 30.0	80.0 55.0
Turbidity	NTU	Wet Dry	5.0 2.0	15.0 5.5	25.0 10.0

¹Wet season: November 1 - April 30.

²Dry season: May 1 - October 31.

Methods

Water from Waikolu stream in Kalaupapa National Historical Park on the island of Moloka'i was collected for nutrient analyses and limnological parameters were measured using a sonde to characterize the dry season water quality. In addition, weather conditions were recorded concurrently. A brief description of data collection methods follows with a more detailed narrative provided in version 1.0 of the PACN water quality protocol (Jones et al. 2011).

Sample Sites

Kalaupapa National Historical Park is located on the island of Moloka'i. Site names used by I&M were formatted to designate fixed or temporary sites ("F" or "T" respectively), park (KALA), a number (e.g. 01), and habitat type ("fw" for freshwater); e.g. "FKALA01_fw" (Table 2, (Figs. 1-5)). Names for temporary sites were based on the date of sampling. Sites were sampled during quarterly trips from November 2007 - November 2011 (Table 3). A new set of four temporary sites were chosen at random for quarterly trips, and site names for these sites include the date.

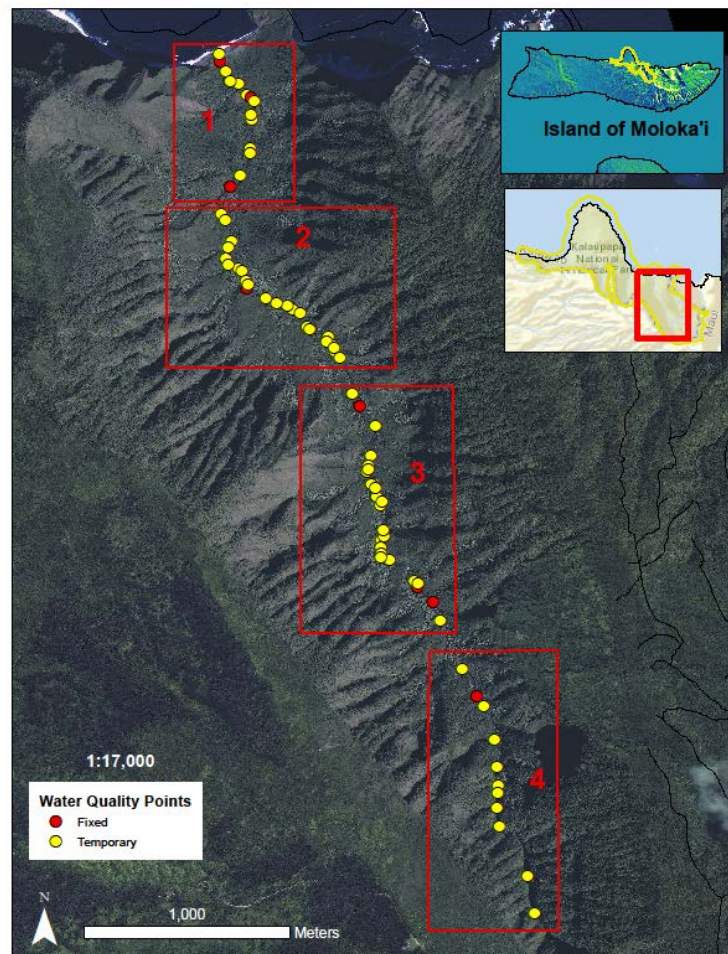


Figure 1. Sites in Waikolu Stream, Kalaupapa National Historical Park, overview.

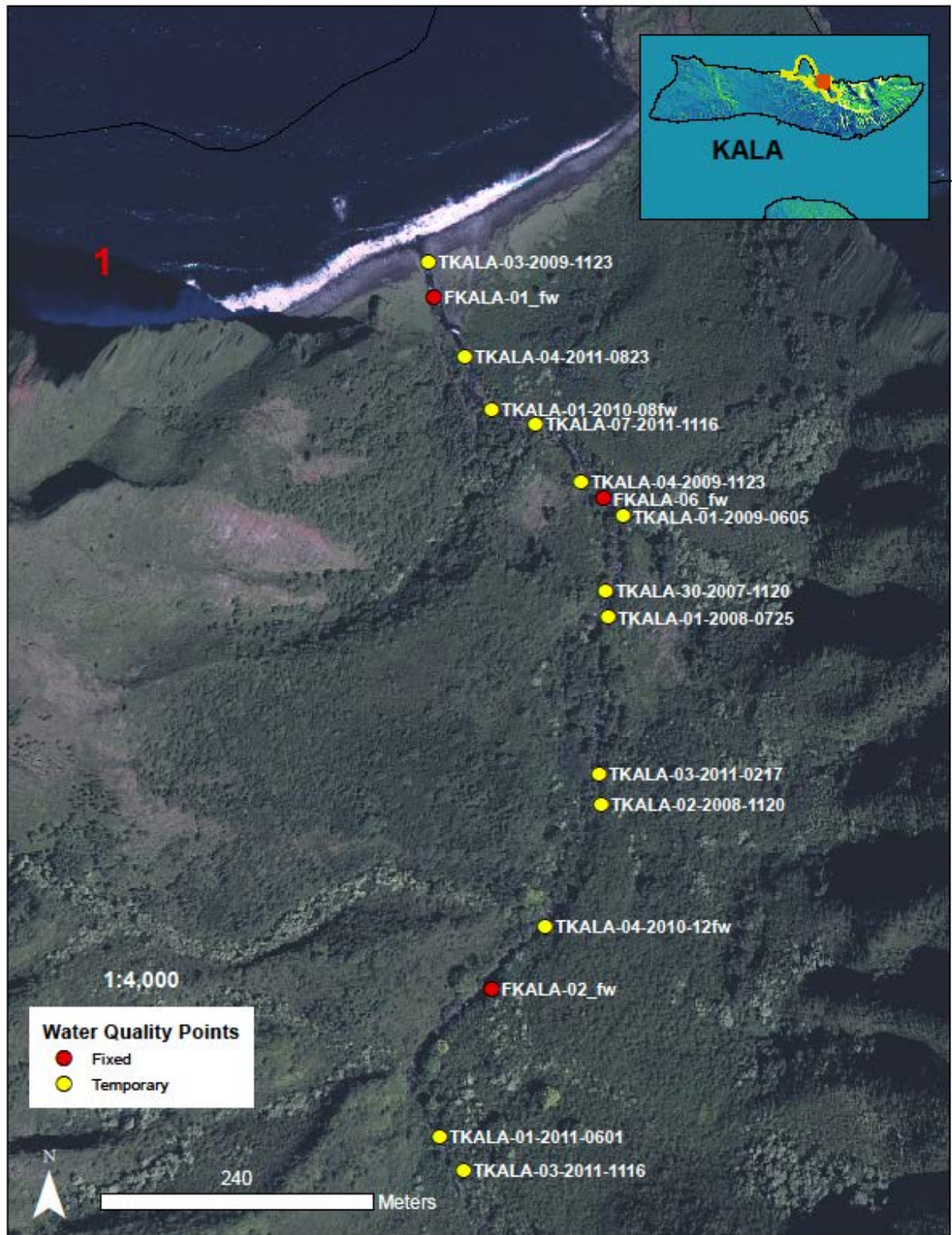


Figure 2. Sites in Waikolu Stream, Kalaupapa National Historical Park, detail 1.

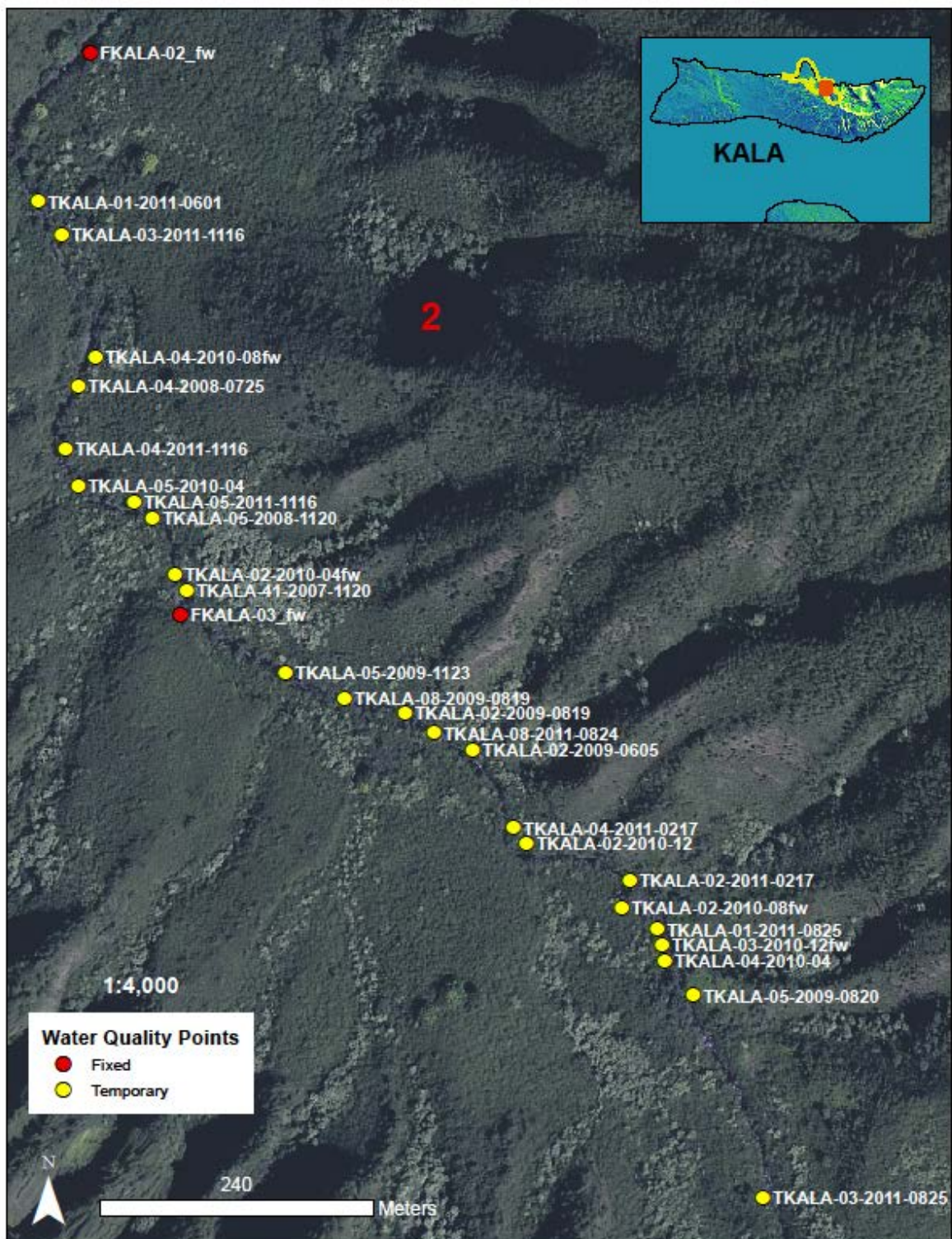


Figure 3. Sites in Waikolu Stream, Kalaupapa National Historical Park, detail 2.

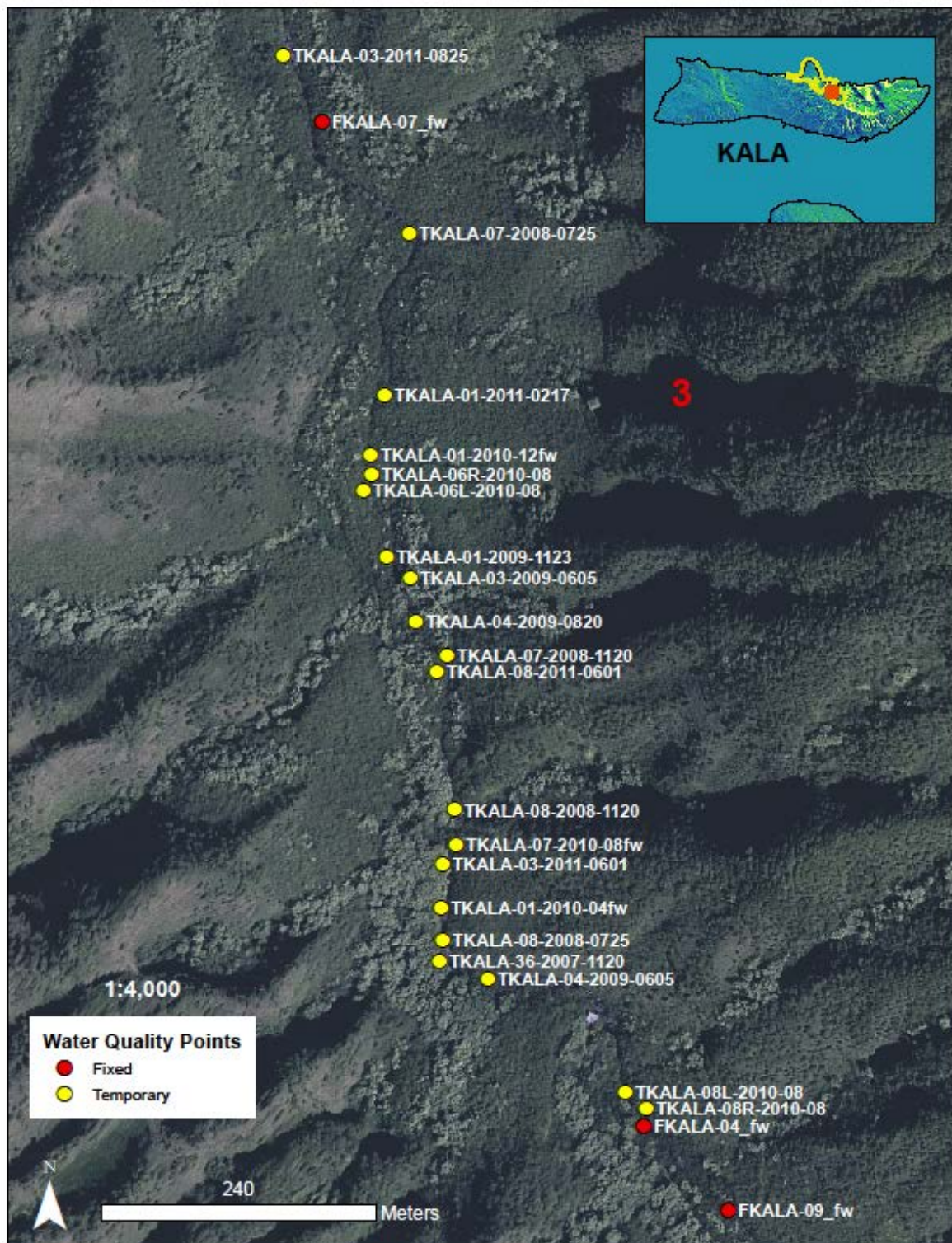


Figure 4. Sites in Waikolu Stream, Kalaupapa National Historical Park, detail 3.

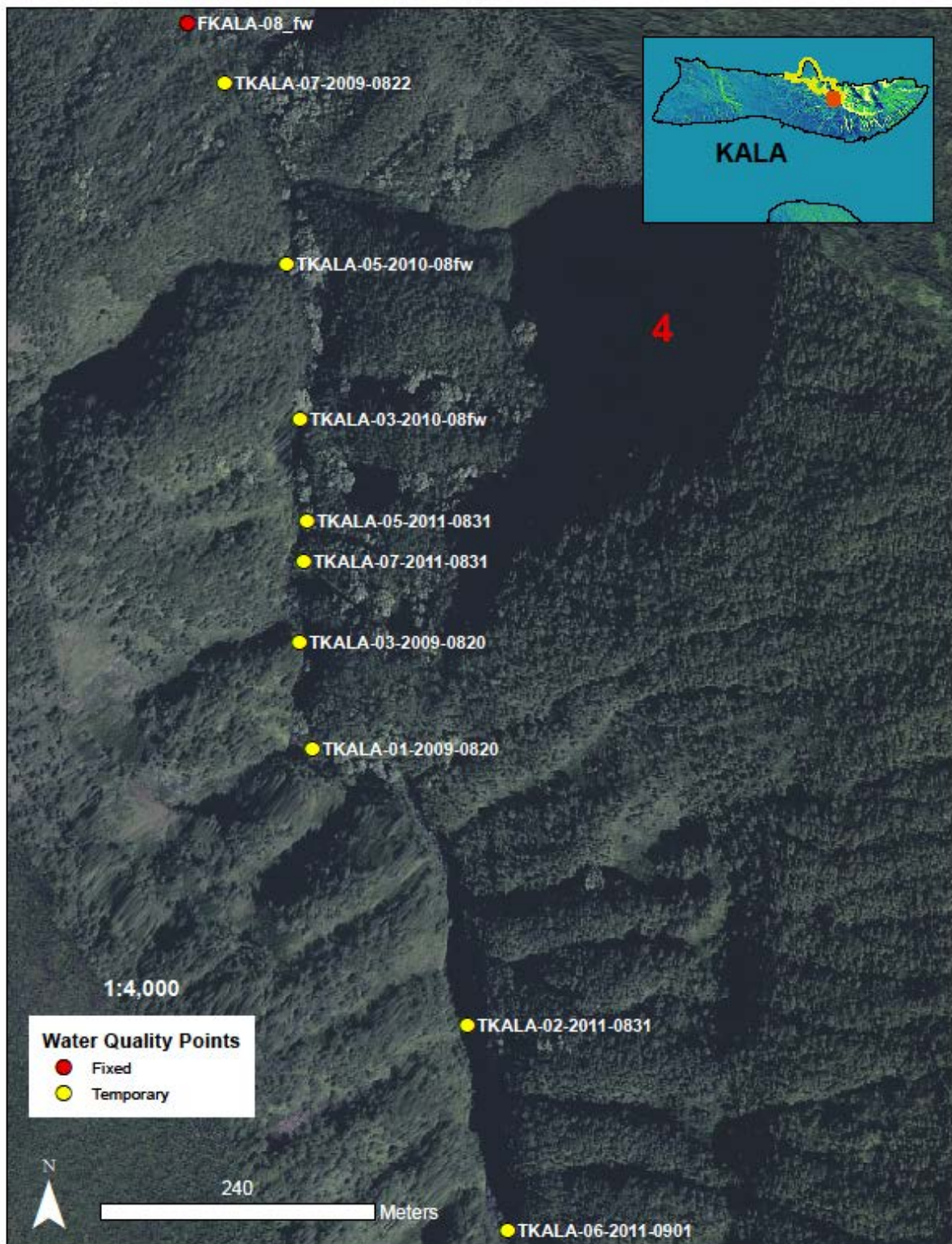


Figure 5. Sites in Waikolu Stream, Kalaupapa National Historical Park, detail 4.

Water Collection

Water was collected using a new or acid-washed 140 cc syringe just below the stream surface to avoid disturbance of sediment on the bottom or collection of floating material. This water was then discarded away from the collection location to rinse the syringe. Water was again collected using the rinsed syringe. An in-line filter holder and 0.7 μm filter were then placed on the syringe. Filtered water was used to rinse each sample bottle three times, for a total of 50ml per bottle, discarding water between each rinse. The filter assembly was removed, water again was drawn into the syringe, and a filter assembly was placed onto the syringe to input 140ml of filtered water into each sample bottle. Three 140ml samples were taken at each sample site. Sample bottles were placed on ice in the field inside an insulated backpack. Samples were transported to the headquarters of Kalaupapa National Historical Park on the day of collection and then frozen. Samples were later transported to Hawai'i Volcanoes National Park (HAVO) while frozen. Samples were delivered to the EPSCoR Analytical Laboratory at the University of Hawai'i at Hilo (UHH) Marine Science Department, 200 W. Kawili St., Hilo, Hawaii 96720 for chemical analysis. Samples were analyzed for total dissolved phosphorous (TDP), total dissolved nitrogen (TDN) and nitrate + nitrite ($\text{NO}_3 + \text{NO}_2$).

Limnological Parameters and General Conditions

A YSI 6600 Multiparameter Sonde was calibrated a few days before commencing field sampling. The sonde was used to measure temperature ($^{\circ}\text{C}$), specific conductivity (SpC) in milli-Siemens per centimeter (mS cm^{-1}), pH, optical dissolved oxygen in milligrams per liter ($\text{mg} \cdot \text{L}^{-1}$, ODO), chlorophyll in micrograms per liter ($\mu\text{g} \cdot \text{L}^{-1}$), and turbidity in nephelometric turbidity units (NTU). The sonde also reported salinity in parts per thousand (ppt) calculated from SpC, dissolved oxygen in percent saturation (% ODOsat) calculated from ODO, and temperature. The sonde was placed under the surface of the water at a sample site for ten minutes with readings taken every 30 seconds. The mean and variance of stable values, excluding initial readings prior to reaching stability, over this time period is reported. Minimum analytical detection limits were $15.0 \mu\text{gP} \cdot \text{L}^{-1}$ for total dissolved phosphorus (TDP), $0.070 \text{mgN} \cdot \text{L}^{-1}$ for total dissolved nitrogen (TDN), and $1.0 \mu\text{gN} \cdot \text{L}^{-1}$ for nitrate + nitrite ($\text{NO}_3 + \text{NO}_2$).

Environmental conditions, canopy cover, and water depth were estimated. Average wind speed over three minutes and wind direction were measured using a Kestrel wind speed device. Global positioning system coordinates and site elevation were recorded. Photographs of sample sites were also taken.

Table 2. KALA sample site locations.

I&M site designation	Decimal Degrees Latitude	Decimal Degrees Longitude
FKALA01_fw	21.169190	-156.930280
FKALA02_fw	21.163790	-156.930130
FKALA03_fw	21.159244	-156.929098
FKALA04_fw	21.146096	-156.921328
FKALA04a_fw	21.146800	-156.921590
FKALA06_fw	21.167573	-156.928800
FKALA07_fw	21.154042	-156.923925
FKALA08_fw	21.141321	-156.918644
FKALA09_fw	21.145427	-156.920627
TKALA0120080725	21.166628	-156.928776
TKALA0120090605	21.167436	-156.929033
TKALA0120090820	21.135578	-156.917670
TKALA0120091123	21.150610	-156.923429
TKALA0120100405	21.147841	-156.923010
TKALA0120100824	21.168257	-156.929806
TKALA0120101208	21.151252	-156.923728
TKALA0120110217	21.151880	-156.923560
TKALA0120110601	21.162470	-156.930424
TKALA0120110825	21.156699	-156.925109
TKALA0120120516	21.154020	-156.924260
TKALA0220081120	21.165147	-156.928854
TKALA0220090605	21.158097	-156.926850
TKALA0220090819	21.158530	-156.927107
TKALA0220100405	21.159557	-156.929143
TKALA0220100826	21.156875	-156.925405
TKALA0220101208	21.157399	-156.926202
TKALA0220110217	21.156998	-156.925051
TKALA0220110831	21.133401	-156.916237
TKALA0220120131	21.158619	-156.927827
TKALA0320090605	21.150463	-156.923554
TKALA0320090820	21.136487	-156.917904
TKALA0320091123	21.169455	-156.930323
TKALA0320100902	21.138207	-156.917933
TKALA0320101208	21.156657	-156.925295
TKALA0320110217	21.165366	-156.929151
TKALA0320110601	21.148187	-156.922990
TKALA0320110825	21.154572	-156.924245
TKALA0320111116	21.162195	-156.930384
TKALA0320120516	21.155670	-156.924620
TKALA0420080725	21.161060	-156.929936
TKALA0420090605	21.147318	-156.922668
TKALA0420090820	21.150092	-156.923190
TKALA0420091123	21.167709	-156.928988
TKALA0420100405	21.156446	-156.925046
TKALA0420100825	21.161274	-156.930134

Table 2. KALA sample site locations (continued).

I&M site designation	Decimal Degrees Latitude	Decimal Degrees Longitude
TKALA0420101208	21.164275	-156.929677
TKALA0420110217	21.157434	-156.926298
TKALA0420110823	21.168716	-156.929959
TKALA0420111116	21.160512	-156.930257
TKALA0420120822	21.157430	-156.926280
TKALA0520081120	21.160071	-156.929396
TKALA0520090820	21.156172	-156.924810
TKALA0520091123	21.158774	-156.928219
TKALA0520100405	21.160244	-156.929932
TKALA0520100901	21.139408	-156.917836
TKALA0520110831	21.137339	-156.917997
TKALA0520111116	21.160134	-156.929434
TKALA0520120131	21.160173	-156.929682
TKALA0520120516	21.154490	-156.924190
TKALA0620090822	21.142496	-156.919301
TKALA0620110901	21.131762	-156.915341
TKALA0620120201	21.150646	-156.923490
TKALA0620120516	21.162120	-156.930090
TKALA06L20100831	21.151264	-156.923734
TKALA06R20100831	21.151264	-156.923734
TKALA0720080725	21.153084	-156.923657
TKALA0720081120	21.149829	-156.922932
TKALA0720090822	21.140839	-156.918337
TKALA0720100831	21.148479	-156.923136
TKALA0720110601	21.144604	-156.920291
TKALA0720110831	21.137061	-156.917724
TKALA0720111116	21.168137	-156.929624
TKALA0720120825	21.168840	-156.930231
TKALA0820080725	21.147584	-156.923000
TKALA0820081120	21.148610	-156.922886
TKALA0820090819	21.158268	-156.927871
TKALA0820110601	21.149753	-156.923045
TKALA0820110824	21.158349	-156.927032
TKALA0820120201	21.147373	-156.922590
TKALA08L20100831	21.146218	-156.921554
TKALA08R20100831	21.146218	-156.921554
TKALA3020071120	21.166777	-156.929123
TKALA3620071120	21.147490	-156.923103
TKALA4120071120	21.159503	-156.929439
Waikolu Headwater	21.130911	-156.915594

Table 3. KALA sampling event personnel.

Year	Date	Personnel
2007	16-Nov-07	Anne Farahi, Danielle McKay, Eric Brown, Lindsey Kramer, Randall Watanuki, Tahzay Jones
2008	21-Jul-08	Anne Farahi, Eric Brown, Kazuki Kageyama, Lindsey Kramer, Randall Watanuki, Tahzay Jones
2008	18-Nov-08	Anne Farahi, Kazuki Kageyama, Lindsey Kramer, Randall Watanuki
2009	02-Feb-09	Anne Farahi, Eric Brown, Kazuki Kageyama, Lindsey Kramer
2009	05-Jun-09	Anne Farahi, Eric Brown, Jeannine Rossa, Lindsey Kramer, Randall Watanuki
2009	03-Aug-09	Alyra Halyn, Anne Farahi, Eric Brown, Lindsey Kramer, Randall Watanuki, Tahzay Jones
2009	22-Nov-09	Eric Brown, Lindsey Kramer, Randall Watanuki
2010	05-Apr-10	Anne Farahi, Eric Brown, Kimberley Tice, Marcus Marchesseault, Randall Watanuki
2010	02-Aug-10	Eric Brown, Kehau Tom, Kimberley Tice, M. Jerolaman, Randall Watanuki
2010	01-Sep-10	Anne Farahi, Kimberley Tice, M. Jerolaman, Randall Watanuki
2010	07-Dec-10	Kimberley Tice, Randall Watanuki
2011	16-Feb-11	Eric Brown, Kimberley Tice, Randall Watanuki
2011	01-Jun-11	Eric Brown, Guy Hughes, Kimberley Tice, Randall Watanuki
2011	17-Aug-11	Claire Lager, Dan Lager, Kimberley Tice, Randall Watanuki
2011	01-Nov-11	Eric Brown, Kimberley Tice, Randall Watanuki

Data Analysis, Management, and Quality Control

Environmental parameters, habitat descriptions, and general observations were recorded on datasheets in the field. Datasheets were stored at park offices, scanned, and uploaded to PACN servers. All data including results of laboratory analyses and photographs were entered into PACN databases. Data were downloaded from the YSI 6600 through the YSI 650 control unit and uploaded to databases. Accuracy of data entry into databases was verified by comparing database entries to the original datasheets by a person who did not enter the data into databases. Data were then certified by the PACN freshwater program lead at the time, either Tazhay Jones or David Raikow. Data determined to be unreliable were flagged in databases and removed from further consideration. Data were explored visually by plotting time-series and boxplots. Outlying data and data that deviated from regular temporal patterns were identified. Corroboration between related parameters and field notes was used to identify possible causes of deviation from regular temporal patterns. Statistical analysis of water quality data followed recommendations by the USGS (Helsel and Hirsch 2002) as described in the protocol (Jones et al. 2011).

Measurements from a series of water samples or sonde readings taken at an individual site within minutes of each other were expected to be normally distributed around the true value of the parameter, because the parameter should not change appreciably over the short time required to take multiple samples or readings. Variation in sample values should be most influenced by external factors. Non-normal distributions, however, are generally expected when summarizing limnological conditions over a time period such as a year due to censoring (i.e., values cannot drop below zero or have a minimum analytical detection limit) and positive skewness (i.e., having infrequent high values) (Helsel and Hirsch 2002). Therefore the median and standard deviation are reported for annual summaries, because the variance of the parameter over the

study period is of interest (Tables 4-8). The median equals the mean in normally-distributed parameters.

For the purposes of descriptive statistics, values below detection limits were assigned values equal to one-half of the detection limit. Mean values of chlorophyll that were less than zero were reported with a value of zero, i.e., as non-detects. Standard deviation was not calculated for sets of data with $n \leq 2$.

For comparison with state water quality standards, geometric means were calculated on data grouped by wet or dry season. Geometric mean calculations yield a value of zero when any datum in the set is zero. Turbidity probes can return negative values when conditions are at or near zero turbidity. Negative turbidity readings were set to 0.1, the lowest value above zero for the probe, to prevent a geometric mean of zero. Resetting extremely low turbidity to 0.1 NTU is based on the assumption that natural stream water, while often visually indistinguishable from transparent deionized (distilled) water, can never be completely particulate-free.

Within boxplots, the upper edge of the box indicates the third quartile (Q3, upper quartile, or 75th percentile), and the lower edge indicates the first quartile (Q1, lower quartile, or 25th percentile, Fig. 6). Within the box, the line indicates the median (Q2, or 50th percentile). The whiskers extend up or down until the maximum or minimum value within 1.5 IQRs (inter-quartile range, or $Q3-Q1$). Data outside 1.5 IQRs are displayed as dots or asterisks, and considered outliers. If there are no outliers the box or whiskers display the entire range of data.

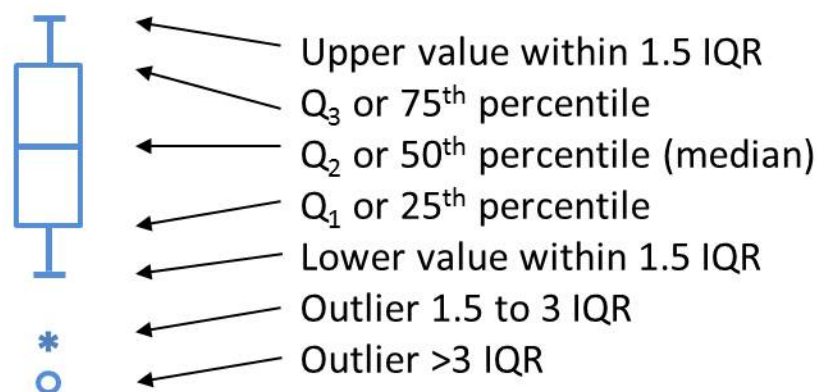


Figure 6. Box plot explanation.

Results

Sixteen sampling trips were conducted in Waikolu Stream from 2007 to 2011. Results are presented in summaries by year (Tables 4-8, Figs. 7-17). Annual summaries present the minimum, maximum, median, and variance as standard deviation of all individual measurements taken in the stream across an entire year. Geometric means are presented for comparison to state water quality criteria (Table 9). Box plots display data aggregated from all sites in the stream by year.

2007

One sampling trip was conducted in November (4th quarter, wet season). No notable conditions were measured. This was the start of the monitoring program.

Table 4. 2007 summary of water quality parameters in Waikolu Stream.

Parameter	Unit	n	Minimum	Maximum	Median	SD
Total Dissolved Phosphorus	$\mu\text{gP} \cdot \text{L}^{-1}$	19	13.6	35.2	24.3	6.3
Total Dissolved Nitrogen	$\text{mgN} \cdot \text{L}^{-1}$	21	0.126	0.209	0.159	0.020
Nitrite + Nitrate	$\mu\text{gN} \cdot \text{L}^{-1}$	21	72.7	154.3	83.9	23.4
Chlorophyll	$\mu\text{g} \cdot \text{L}^{-1}$	7	0.00	0.00	0.00	0.00
Dissolved Oxygen Concentration	$\text{mg} \cdot \text{L}^{-1}$	7	9.13	9.54	9.50	0.15
Dissolved Oxygen Saturation	%	7	99.6	104.6	104.2	1.9
pH	none	7	7.3	7.5	7.4	0.1
Salinity	ppt	7	0.04	0.04	0.04	0.00
Specific conductance	$\text{mS} \cdot \text{cm}^{-1}$	5	0.07	0.09	0.09	0.01
Temperature	$^{\circ}\text{C}$	7	18.8	19.9	19.8	0.4
Turbidity	NTU	1	1.3	1.3		

2008

Two sampling trips were conducted. No notable conditions were measured.

Table 5. 2008 summary of water quality parameters in Waikolu Stream.

Parameter	Unit	n	Minimum	Maximum	Median	SD
Total Dissolved Phosphorus	$\mu\text{gP} \cdot \text{L}^{-1}$	45	22.0	55.0	32.0	7.8
Total Dissolved Nitrogen	$\text{mgN} \cdot \text{L}^{-1}$	45	0.101	0.269	0.161	0.038
Nitrite + Nitrate	$\mu\text{gN} \cdot \text{L}^{-1}$	45	80.0	233.0	135.0	40.9
Chlorophyll	$\mu\text{g} \cdot \text{L}^{-1}$	13	0.31	3.88	1.06	0.90
Dissolved Oxygen Concentration	$\text{mg} \cdot \text{L}^{-1}$	16	8.50	9.42	9.01	0.23
Dissolved Oxygen Saturation	%	16	96.5	103.3	101.2	1.9
pH	none	15	7.3	8.4	7.8	0.29
Salinity	ppt	12	0.04	0.06	0.05	0.01
Specific conductance	$\text{mS} \cdot \text{cm}^{-1}$	13	0.09	0.12	0.11	0.01
Temperature	$^{\circ}\text{C}$	16	19.1	22.6	20.6	1.2
Turbidity	NTU	14	0.1	0.2	0.1	0.04

2009

Four sampling trips were conducted. No notable conditions were measured. A new fixed site was added to the sampling regime, upstream of the pumphouse. This site (FKALA04_fw) displayed slightly higher TDP concentrations, which are visible as outliers in years 2009-2011 (Fig. 7).

Table 6. 2009 summary of water quality parameters in Waikolu Stream.

Parameter	Unit	n	Minimum	Maximum	Median	SD
Total Dissolved Phosphorus	$\mu\text{gP} \cdot \text{L}^{-1}$	68	18.7	62.0	39.5	6.7
Total Dissolved Nitrogen	$\text{mgN} \cdot \text{L}^{-1}$	70	0.068	0.188	0.117	0.032
Nitrite + Nitrate	$\mu\text{gN} \cdot \text{L}^{-1}$	70	68.2	182.8	108.9	28.2
Chlorophyll	$\mu\text{g} \cdot \text{L}^{-1}$	24	0.00	2.07	0.39	0.59
Dissolved Oxygen Concentration	$\text{mg} \cdot \text{L}^{-1}$	29	8.55	9.46	9.04	0.24
Dissolved Oxygen Saturation	%	29	93.4	105.2	100.8	2.9
pH	none	32	6.2	8.0	7.8	0.41
Salinity	ppt	29	0.03	0.06	0.05	0.01
Specific conductance	$\text{mS} \cdot \text{cm}^{-1}$	30	0.06	0.12	0.11	0.02
Temperature	$^{\circ}\text{C}$	32	18.9	22.3	20.6	0.92
Turbidity	NTU	31	0.1	1.8	0.1	0.31

2010

Four sampling trips were conducted. No notable conditions were measured.

Table 7. 2010 summary of water quality parameters in Waikolu Stream.

Parameter	Unit	n	Minimum	Maximum	Median	SD
Total Dissolved Phosphorus	$\mu\text{gP} \cdot \text{L}^{-1}$	44	23.0	61.0	40.0	8.1
Total Dissolved Nitrogen	$\text{mgN} \cdot \text{L}^{-1}$	70	0.070	0.394	0.130	0.060
Nitrite + Nitrate	$\mu\text{gN} \cdot \text{L}^{-1}$	48	65.0	275.0	146.5	52.8
Chlorophyll	$\mu\text{g} \cdot \text{L}^{-1}$	26	0.00	4.10	0.02	1.50
Dissolved Oxygen Concentration	$\text{mg} \cdot \text{L}^{-1}$	33	8.48	9.59	9.16	0.25
Dissolved Oxygen Saturation	%	33	93.2	102.5	100.4	2.4
pH	none	32	6.6	8.0	7.3	0.3
Salinity	ppt	34	0.02	0.06	0.05	0.01
Specific conductance	$\text{mS} \cdot \text{cm}^{-1}$	34	0.05	0.12	0.11	0.02
Temperature	$^{\circ}\text{C}$	34	16.8	21.1	19.3	0.9
Turbidity	NTU	33	0.1	2.3	0.1	0.44

2011

Four sampling trips were conducted. No notable conditions were measured.

Table 8. 2011 summary of water quality parameters in Waikolu Stream.

Parameter	Unit	n	Minimum	Maximum	Median	SD
Total Dissolved Phosphorus	$\mu\text{gP} \cdot \text{L}^{-1}$	73	29.0	64.1	39.6	8.7
Total Dissolved Nitrogen	$\text{mgN} \cdot \text{L}^{-1}$	72	0.073	0.304	0.152	0.043
Nitrite + Nitrate	$\mu\text{gN} \cdot \text{L}^{-1}$	73	61.5	247.2	129.1	41.0
Chlorophyll	$\mu\text{g} \cdot \text{L}^{-1}$	34	0.13	4.35	0.70	0.83
Dissolved Oxygen Concentration	$\text{mg} \cdot \text{L}^{-1}$	39	8.49	9.36	9.18	0.23
Dissolved Oxygen Saturation	%	39	90.5	104.8	101.1	3.1
pH	none	40	7.2	8.6	7.9	0.29
Salinity	ppt	40	0.03	0.06	0.05	0.01
Specific conductance	$\text{mS} \cdot \text{cm}^{-1}$	40	0.07	0.12	0.11	0.02
Temperature	$^{\circ}\text{C}$	40	17.1	22.2	20.1	1.0
Turbidity	NTU	36	0.0	1.7	0.0	0.39

Comparison to State Water Quality Criteria

Geometric means are summarized in Table 9. TDP concentrations exceeded the state criterion for TP during the dry season of each year. Nitrate + nitrite concentrations exceeded state criteria for both wet and dry seasons in every year. TDN did not exceed state criteria for TN, and turbidity did not exceed state criteria.

Table 9. Geometric means of water quality parameters by season in Waikolu Stream. Bolded numbers indicate values that exceeded state criteria.

Parameter	Unit	Season	Year	Geometric mean
Total Dissolved Phosphorus	$\mu\text{gP} \cdot \text{L}^{-1}$	Dry	2008	39.1
			2009	40.0
			2010	37.8
			2011	40.5
		Wet	2007	23.9
			2008	29.4
			2009	40.5
			2010	42.4
			2011	40.6
Total Dissolved Nitrogen	$\text{mgN} \cdot \text{L}^{-1}$	Dry	2008	0.137
			2009	0.108
			2010	0.142
			2011	0.137
		Wet	2007	0.161
			2008	0.180
			2009	0.131
			2010	0.137
			2011	0.164
Nitrite +Nitrate	$\mu\text{gN} \cdot \text{L}^{-1}$	Dry	2008	115.2
			2009	100.8
			2010	110.6
			2011	109.2
		Wet	2007	92.6
			2008	159.5
			2009	125.5
			2010	170.2
			2011	138.1
Turbidity	NTU	Dry	2008	0.1
			2009	0.1
			2010	0.2
			2011	0.1
		Wet	2007	1.3
			2008	0.1
			2009	0.2
			2010	0.1
			2011	0.1

Summaries by parameter

Total Dissolved Phosphorus

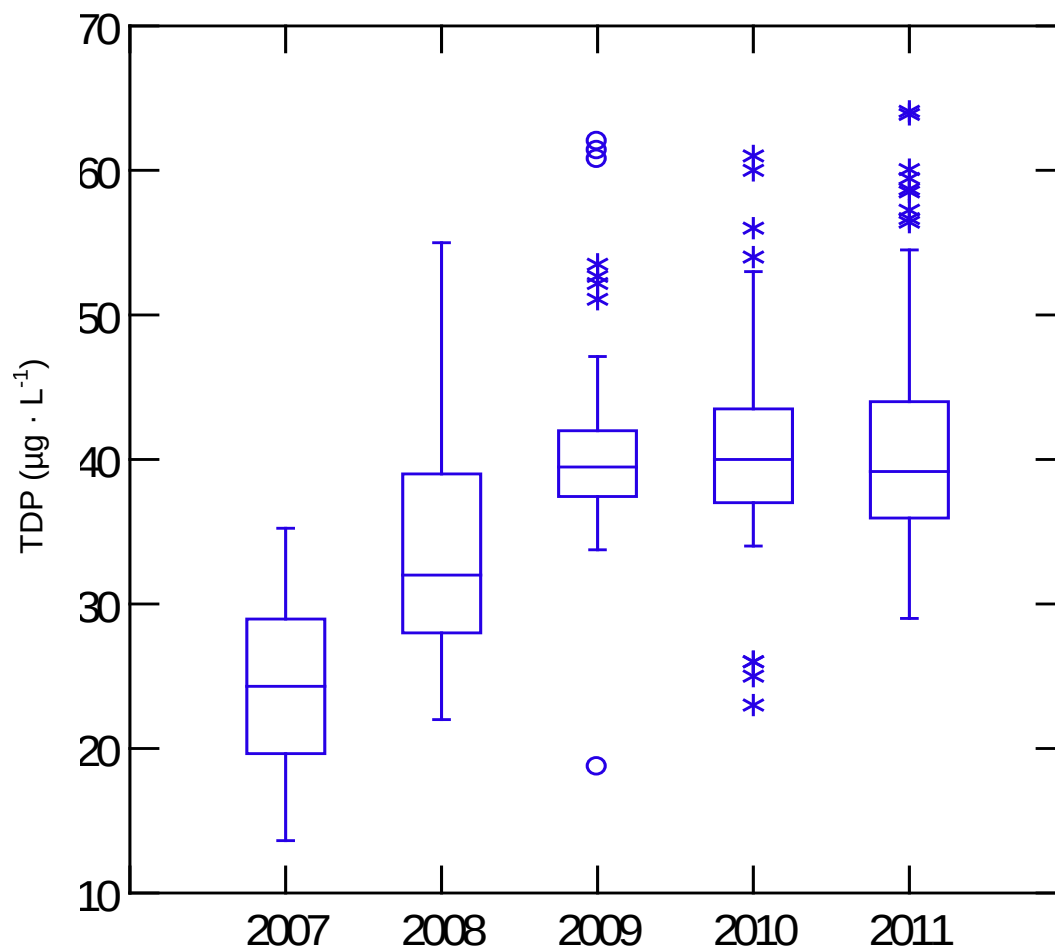


Figure 7. Box plots of Total Dissolved Phosphorus in Waikolu Stream.

Total Dissolved Nitrogen

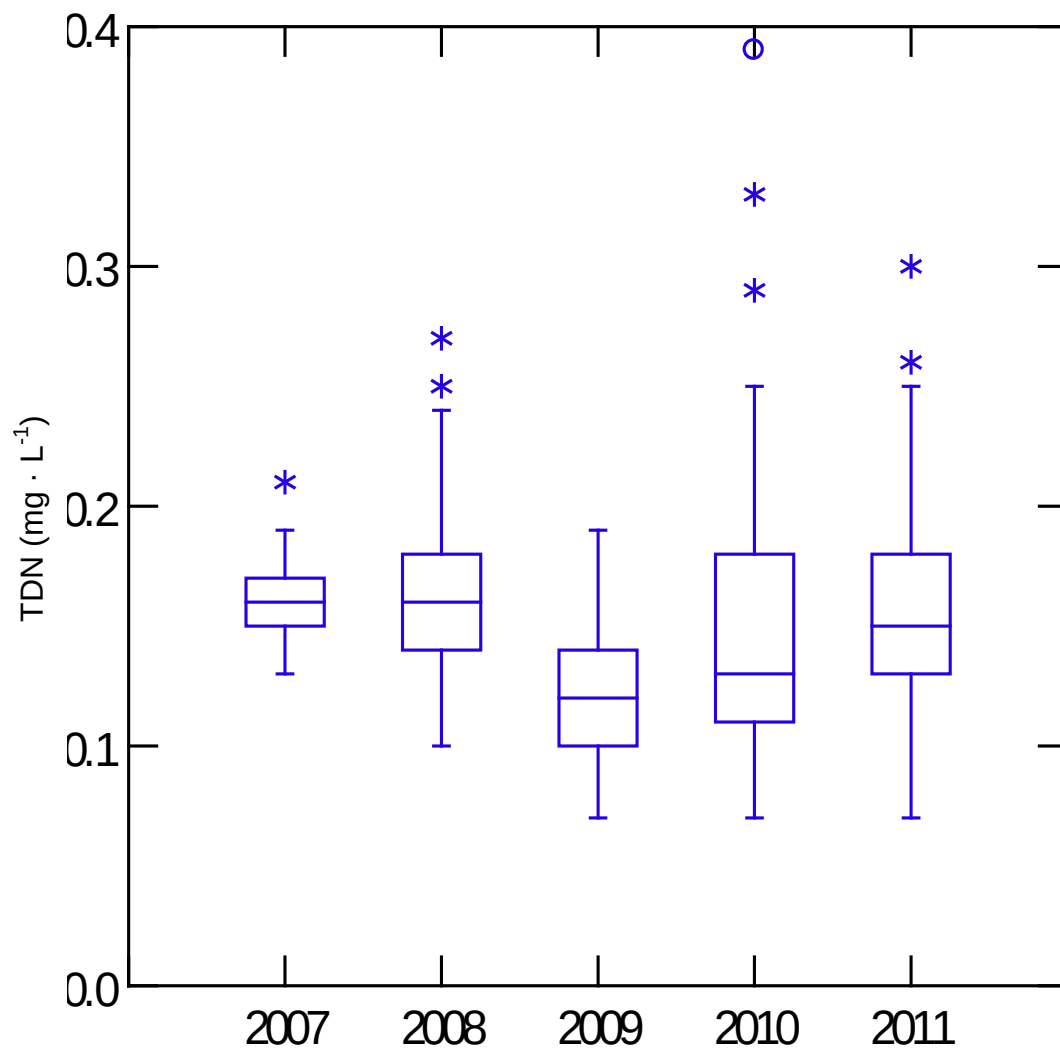


Figure 8. Box plots of Total Dissolved Nitrogen in Waikolu Stream.

Nitrate + Nitrite

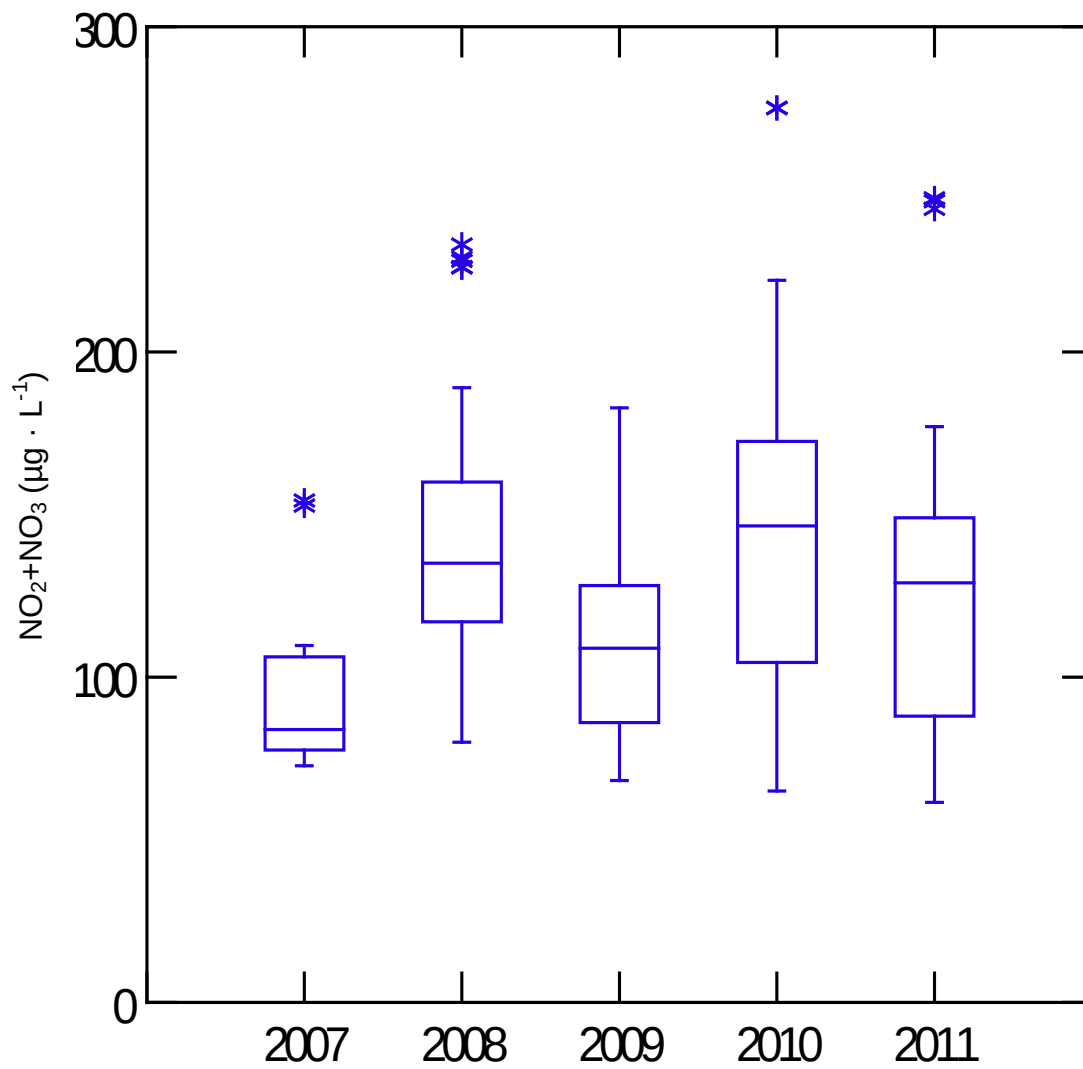


Figure 9. Box plots of nitrate + nitrite in Waikolu Stream.

Chlorophyll

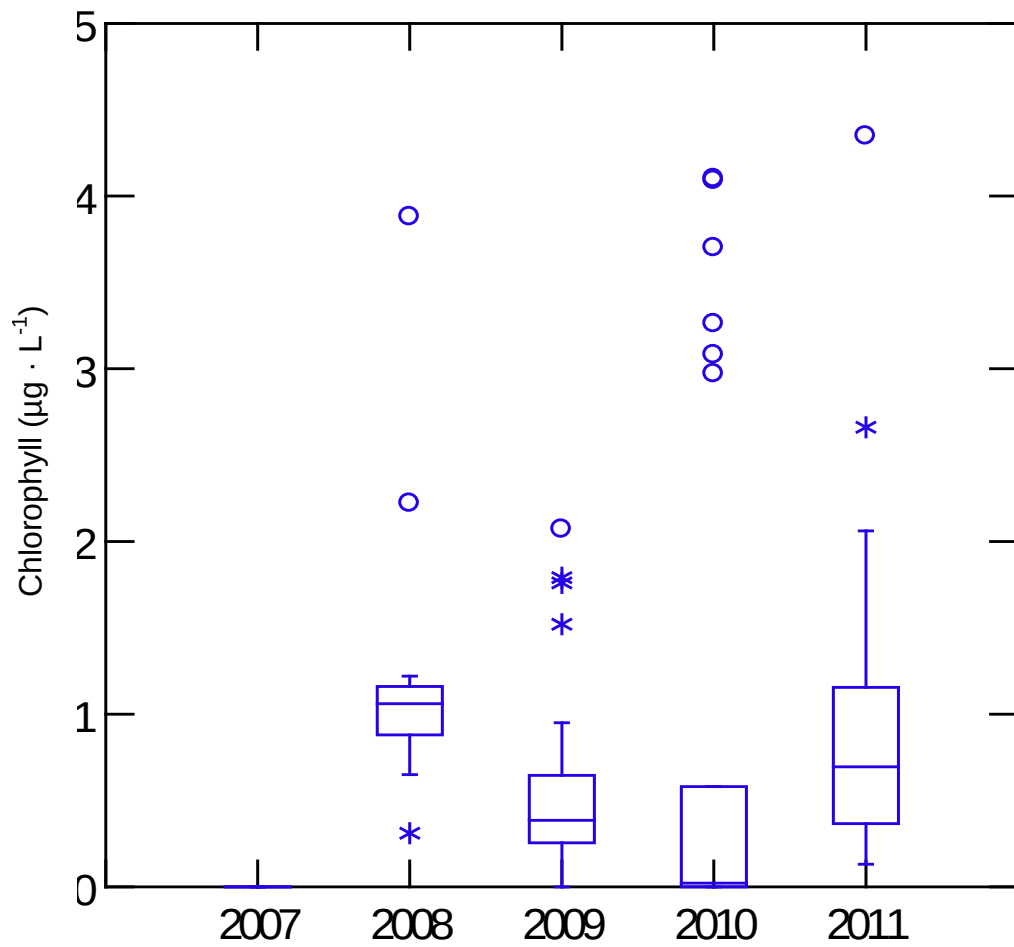


Figure 10. Box plots of chlorophyll in Waikolu Stream.

Oxygen Concentration

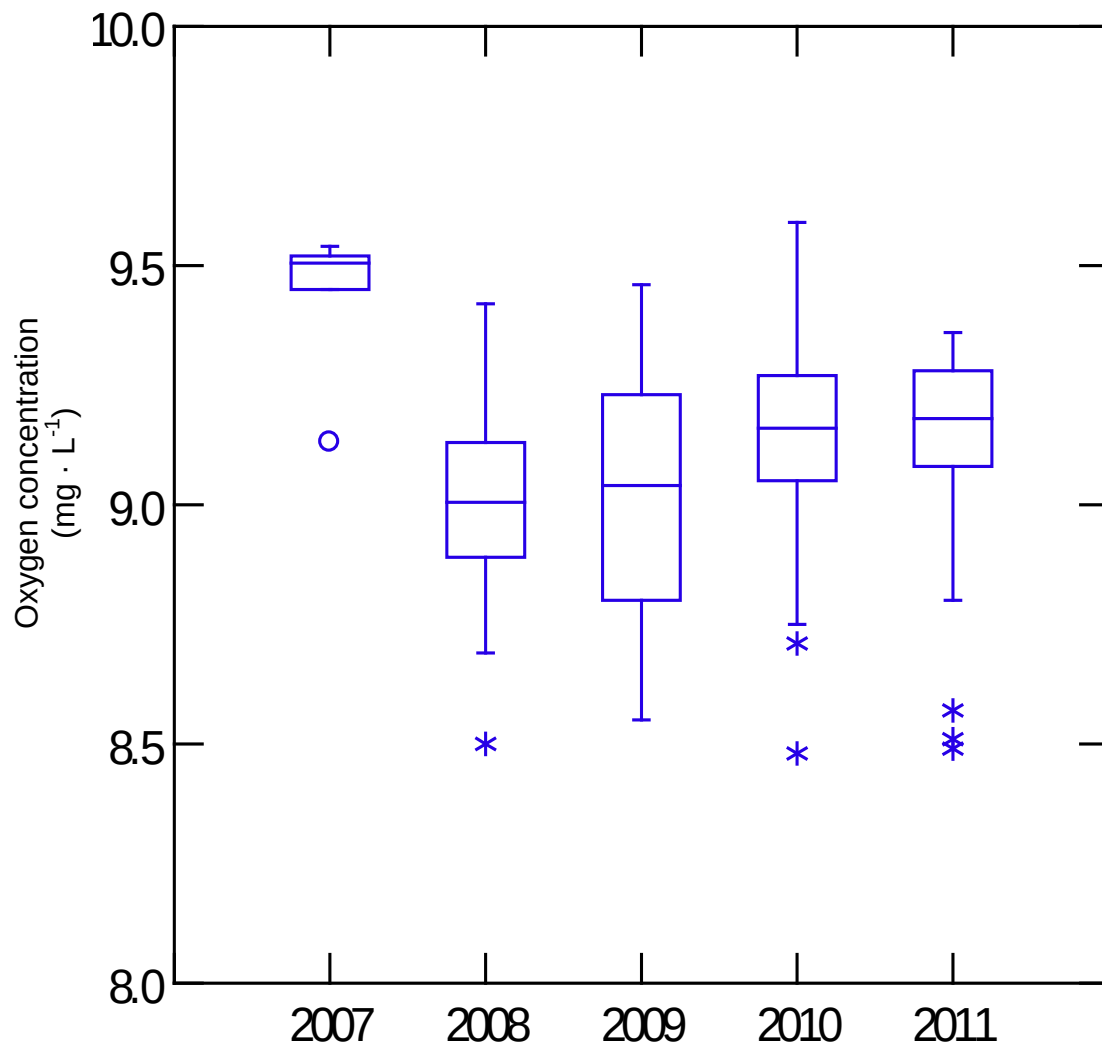


Figure 11. Box plots of oxygen concentration in Waikolu Stream.

Oxygen Saturation

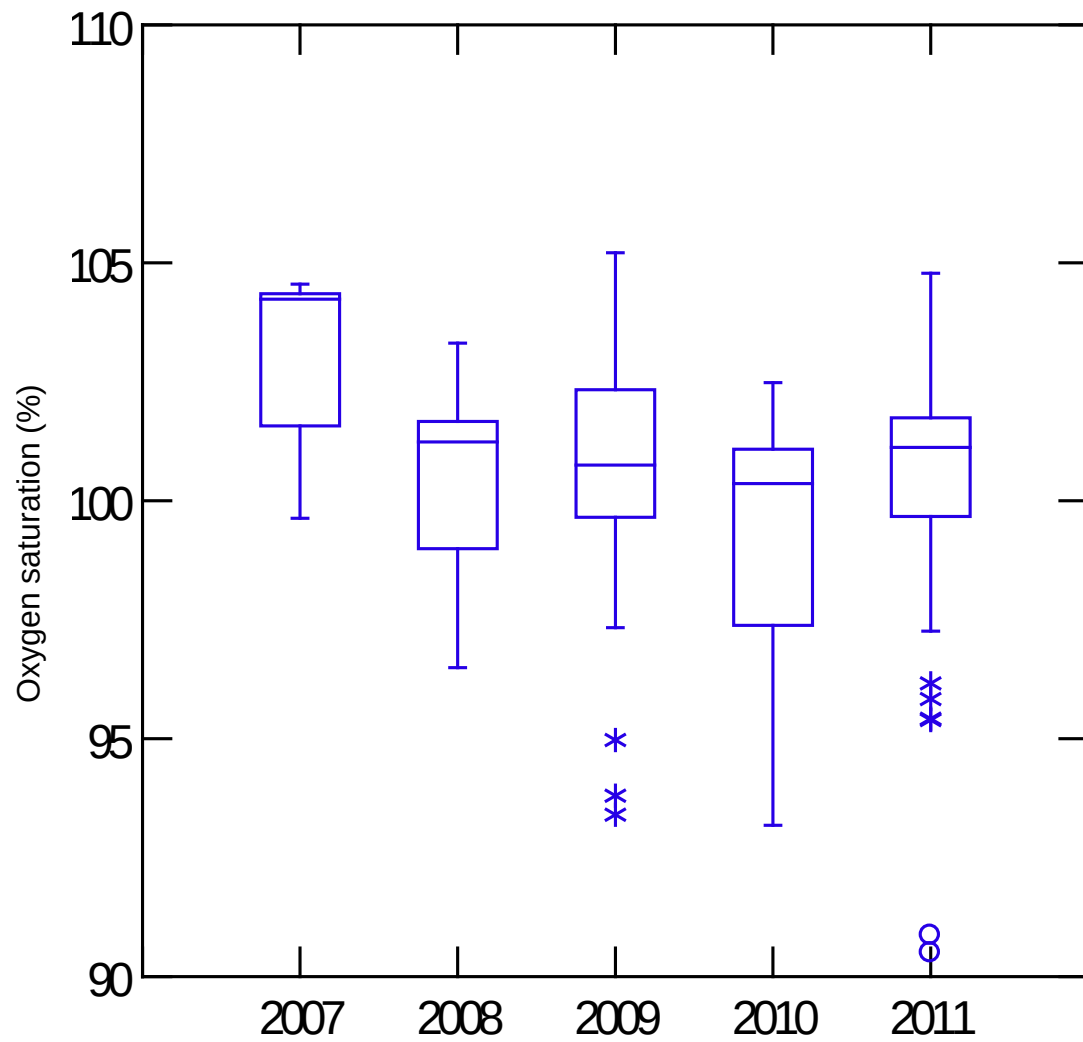


Figure 12. Box plots of oxygen saturation in Waikolu Stream.

pH

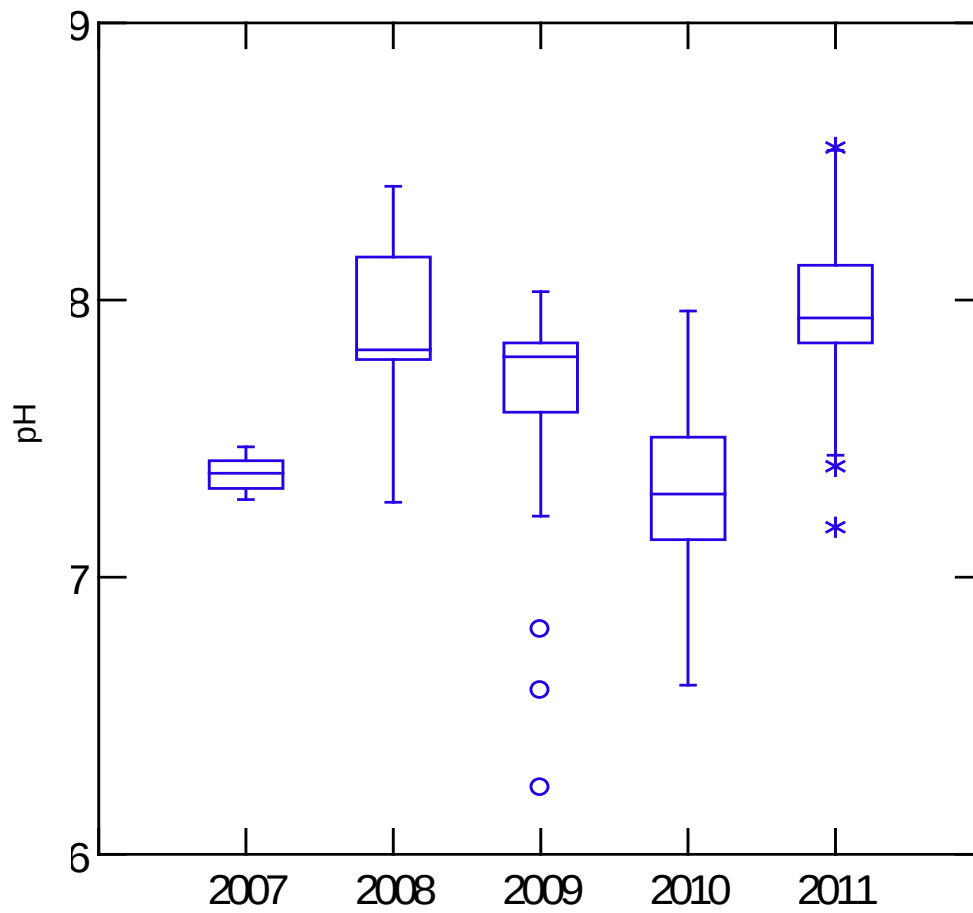


Figure 13. Box plots of pH in Waikolu Stream.

Salinity

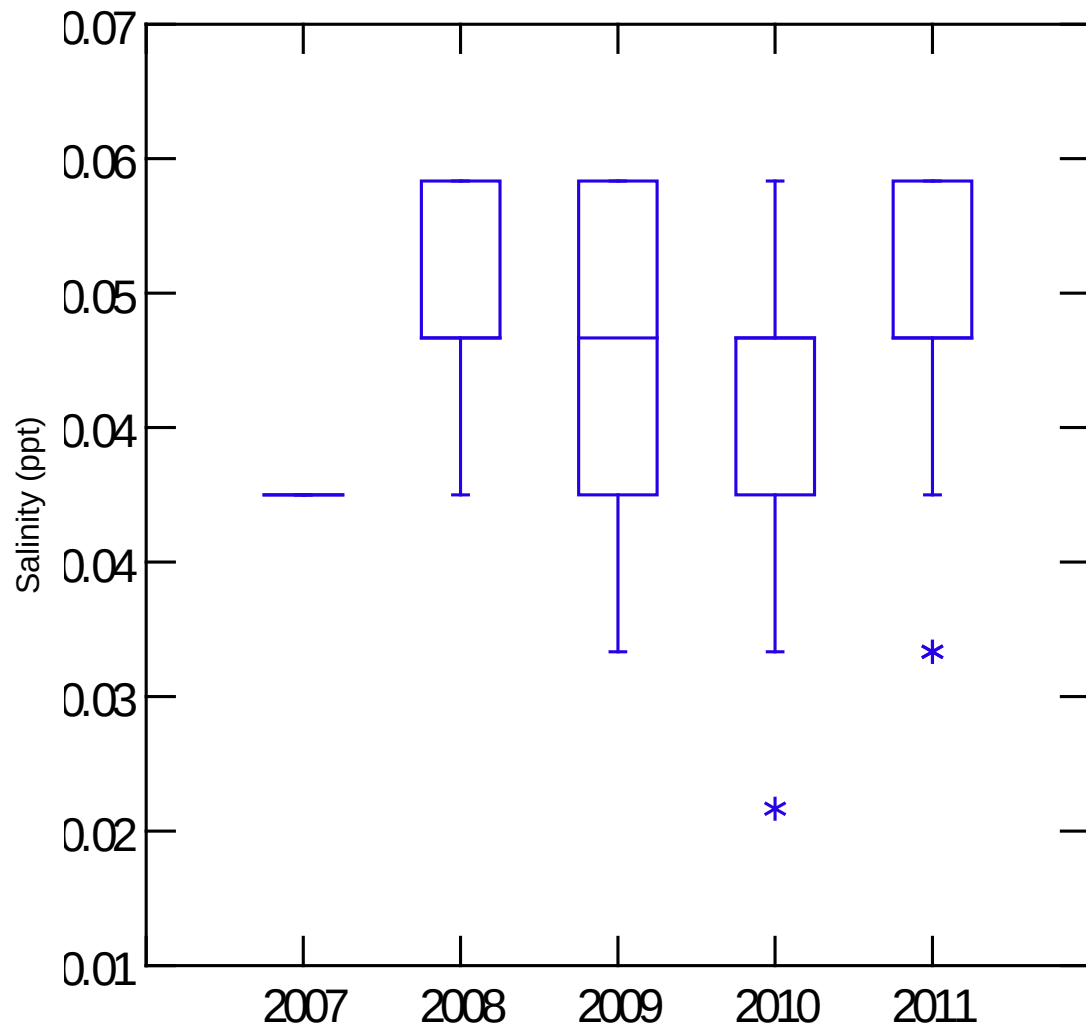


Figure 14. Box plots of salinity in Waikolu Stream.

Specific Conductance

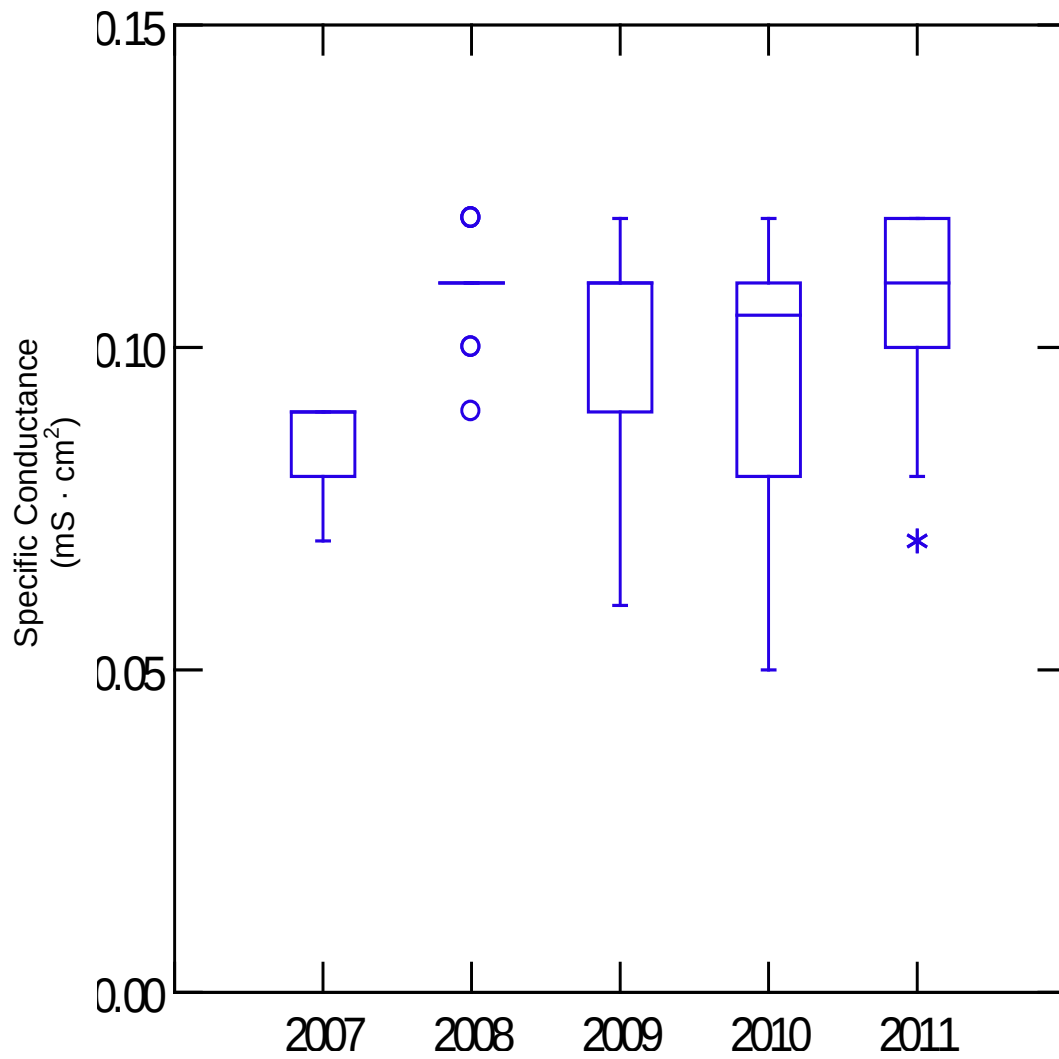


Figure 15. Box plots of specific conductance in Waikolu Stream.

Temperature

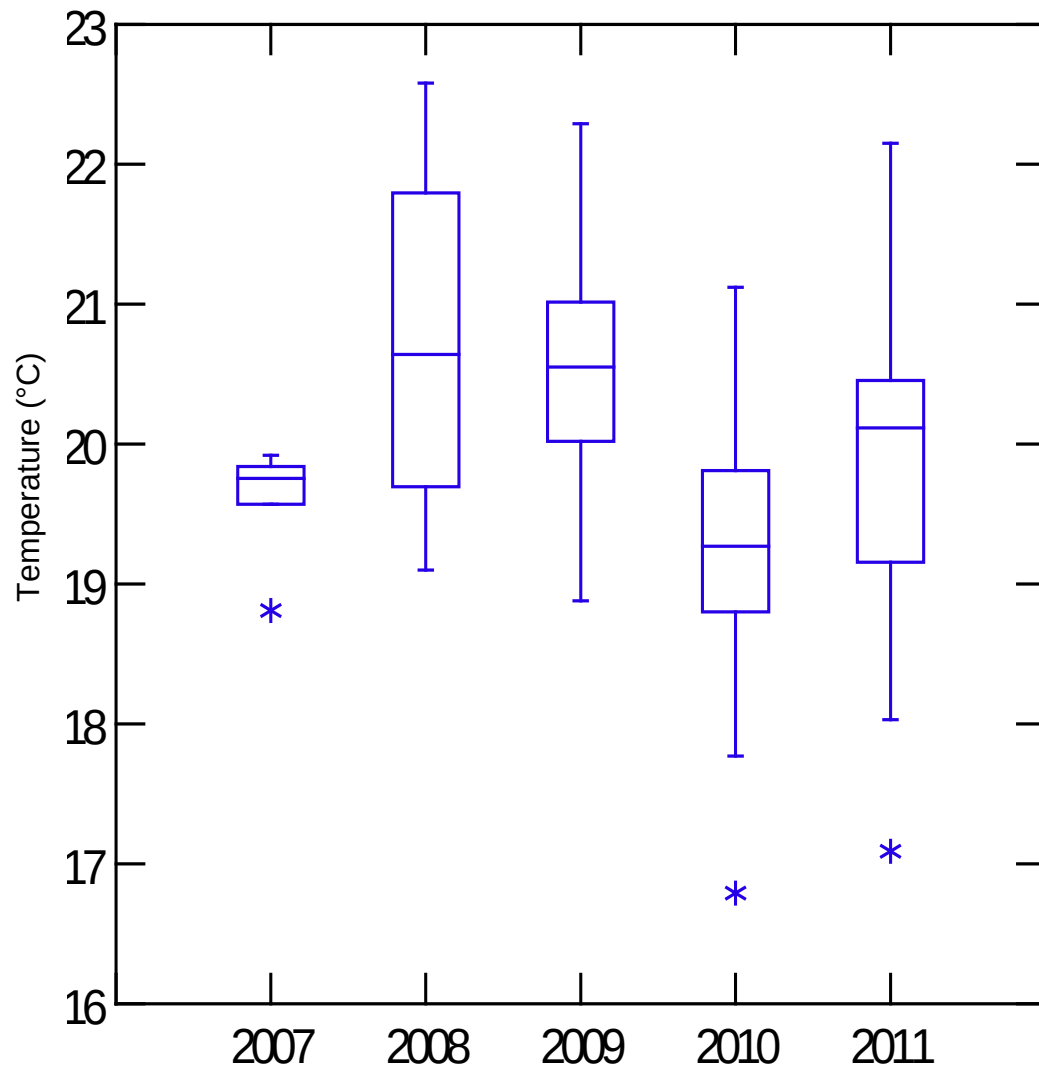


Figure 16. Box plots of temperature in Waikolu Stream.

Turbidity

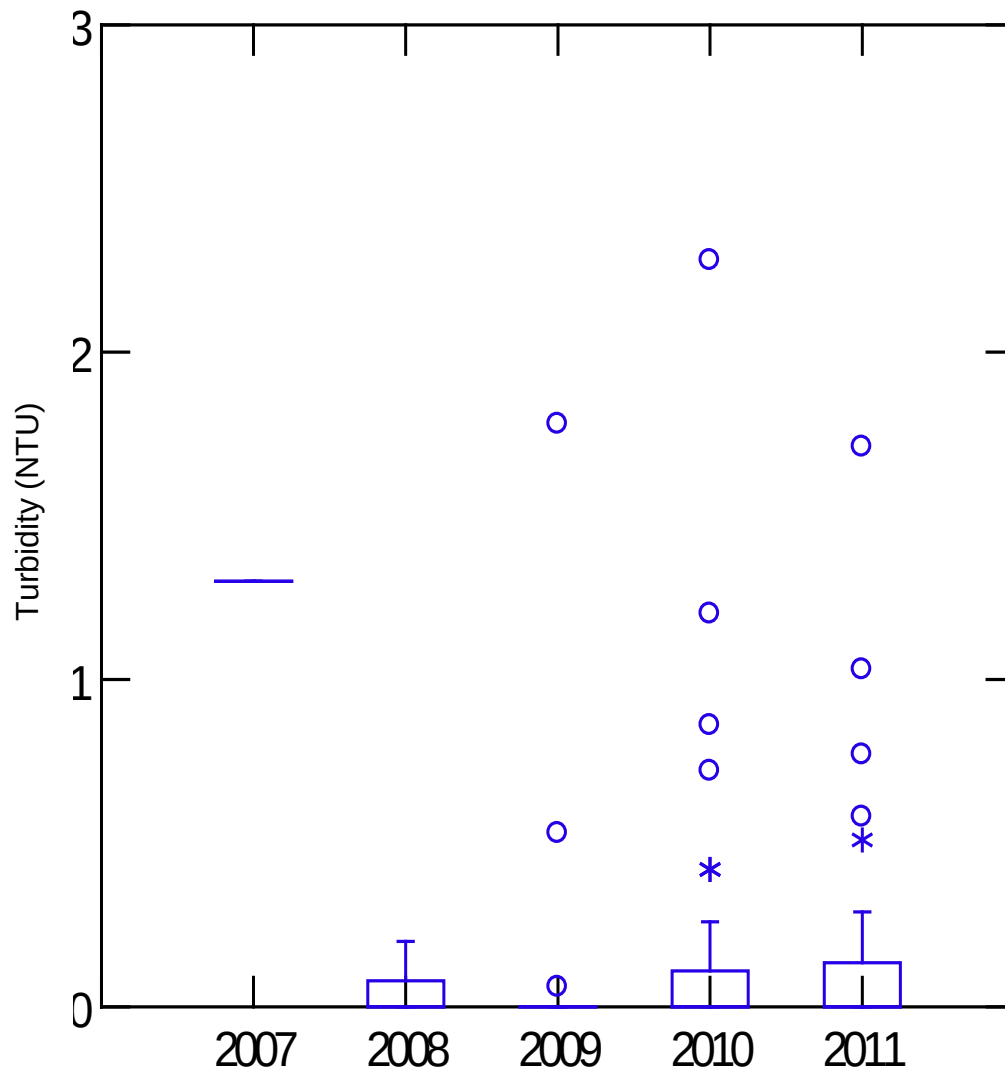


Figure 17. Box plots of turbidity in Waikolu Stream.

Discussion

Waikolu Stream regularly exceeded state water quality criteria. Because dissolved nutrient concentrations do not include particulate nutrient concentrations, total nutrient concentrations, in which state criteria are written, will be higher in the stream. Thus while the nutrient levels in the stream exceeded the state TP criteria in the dry seasons of each year based on dissolved nutrients alone, the stream may in fact exceed state criteria at all times due to additional phosphorus in particulate form. Likewise while TDN did not exceed criteria, the stream may exceed criteria when particulate nitrogen is also considered. The stream exceeded nitrate + nitrite concentrations at all times.

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