

SOP 10: Annual Report (FQ_G Creation)

Version 2

Revision History Log:

Prev. Version #	Revision Date	Updated By	Changes Made	New Version #
1	March 2013	Bill Johnson, Chris Sergeant	Corrected filename typos, minor text revisions	2
-	September 2011	Chris Sergeant	Initial version	1

1.0 Summary

The annual report briefly introduces the context for freshwater water quality monitoring in SEAN, summarizes field efforts from the reporting year, provides summary figures and tables for the status and trends of core water quality parameters, offers short- and long-term (if applicable) trend interpretation, and discusses future monitoring program considerations. The continuous water quality sampling seasons generally runs May 1 through October 31. Annual reports summarize results of the continuous sampling seasons for all three SEAN parks (GLBA, KLGO, and SITK) and are completed by the Project Leader within three months of the completion of each monitoring season.

2.0 Annual Report Format and Content

The Annual Data Report follows the NPS Natural Resource Technical Report format (<http://www.nature.nps.gov/publications/NRPM/>) and includes:

1. **Executive Summary:** Intended for park superintendents and managers; review program purpose and design; summarize Results and Discussion
2. **Acknowledgements:** Field crew, logistical supporters, document reviewers, etc. should be thanked here
3. **Introduction:** Present the monitoring program context, goals, and objectives
4. **Methods:** Describe study areas, field and analytical techniques, and annual deviations from sampling prescribed in protocols
5. **Results:** Present tables and figures of annual and historical results; summarize long- and short-term trends and anomalous or system-specific observations
6. **Discussion:** Generalize main results in the context of monitoring program objectives, provide interpretation for long- and short-term trends or anomalies, briefly describe expected future sampling, what has gone well and should continue, and present recommendations and future considerations for new monitoring work

3.0 Contents of Results Section

In SEAN, four to five water quality parameters are measured hourly for six months each sampling season, producing thousands of lines of water quality data each year that must be concisely summarized. To achieve this goal and maintain long-term relevance, the results of each annual report are directly linked to the objectives described in the protocol narrative. This section

lists the essential data reporting that must accompany each objective and describes each of these report components in sub-sections. Each year, if the Project Leader discovers additional informative results, reporting can expand beyond the essential analyses listed below. Detailed analyses beyond the scope of this report should be considered for authoring a separate peer-reviewed manuscript. The Project Leader's priority is to promptly publish the annual technical report with the main components below:

- **Objectives 1 and 2:** Track the status and trends of each core water quality parameter; describe the timing and magnitude of seasonal and annual variation of each core water quality parameter; as data accumulates over time, compare short-term variation with observed long-term trends

Report components: annual sampling effort (Table SOP 10.1), water temperature summary (Figure SOP 10.1), monthly temperature means and ranges (Table SOP 10.2), conductivity/DO/pH box plot summaries (Figure SOP 10.2), Taiya River turbidity summary (like Figure SOP 10.1), appendices with complete seasonal time series (see Section 7.0 for R code)

- **Objective 3:** Evaluate whether state and/or federal water quality standards are met or exceeded

Report components: period of record (Table SOP 10.3), comparison of state water quality criteria to measured parameter means and ranges (if no standards were exceeded, no comparison table is required)

Tables are formatted in Excel and inserted into Word documents using Paste Special/Picture (Windows Metafile) commands; figures are produced and formatted in several common software packages (e.g., Excel, SigmaPlot, or R). When possible, results from all three rivers (Salmon, Taiya, and Indian) are consolidated into a single panel.

Code for automating production of seasonal time series appendices is included in Section 7.0.

Most results are summarized in graphical form. Brief narratives summarizing general trends or notable results support tables and figures.

3.1 Sampling Effort Table

A sampling effort table summarizes annual data collection in each river system. The table allows the reader to quickly determine if sampling issues were encountered and a full data set collected.

Table SOP 10.1. Example summary table of annual freshwater water quality sampling effort using 2012 data for the Salmon, Taiya, and Indian rivers. Continuous data is collected from May 1 through October 31 each year (and potentially through November depending on ice conditions and staffing capacity). Darker boxes denote a full month of sonde installation, lighter boxes a partial month. Superscripted numbers can be used to comment on protocol exceptions (e.g., a certain sensor was not working for part of the season). The Methods section provides more detailed explanations for gaps in the seasonal time series.

River	Month								Core parameters collected?
	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	
Salmon									Y
Taiya									Y
Indian									Y

 Full month
 Partial month

3.2 Core Parameter Time-Series Summaries

Water temperature plays an important role in the physiological and biological processes of stream communities. See section 1.7 of the freshwater water quality protocol narrative for an expanded discussion of the importance of temperature. This parameter is likely to be the most variable and immediately informative of the core water quality parameters. Figures illustrate daily mean values for the current reporting year and historical data set (Figure SOP 10.1), while tables summarize monthly continuous data (Table SOP 10.2).

To publish a daily mean or median value for any field parameter, the following minimum requirements apply (Wagner et al. 2006):

“... on days when less than 100 percent of the discrete time interval data are collected, both the expected daily maximum and minimum values must be present. Reporting daily mean values when less than 100 percent of the unit values are available is based on professional judgment and generally is determined by data trends, knowledge of site characteristics, and the influence of hydrologic events.”

In addition to mean daily temperature fluctuations over seasonal scales, measurements of all the core parameters are expected to demonstrate diel variation during discrete time periods, especially when high UV radiation drives photosynthesis-respiration cycles in the Salmon and Indian rivers. Diel variation in the Taiya River will be more controlled by daytime pulses of glacial melt. To examine these patterns, hourly time-series information is summarized in formatting style similar to figure SOP 10.1. The Project Leader can choose to examine representative diel cycles displayed over shorter time periods (e.g., 3 to 10 days). These snapshots can be contrasted among different systems and seasons (e.g., Taiya River vs. Salmon and Indian rivers on five warm, summer days and five cool, fall days; see Sergeant 2012a, b for

examples). It is expected that the magnitude of within-day fluctuations in core parameter values will be greater during summer days compared to fall.

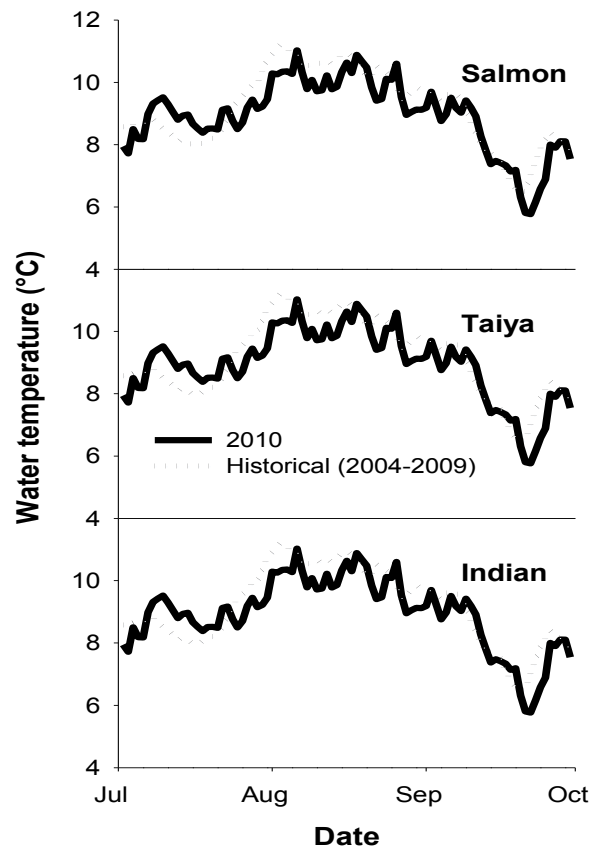


Figure SOP 10.1. Example water temperature summaries for the reporting year versus historical daily mean using artificial data in the Salmon, Taiya, and Indian rivers.

Table SOP 10.2. Example table of monthly mean, minimum daily mean, and maximum daily mean temperatures in the Salmon, Taiya, and Indian rivers.

Month	Salmon			Taiya			Indian		
	Mean daily average (SD)	Min	Max	Mean daily average (SD)	Min	Max	Mean daily average (SD)	Min	Max
May									
June									
July									
August									
September									
October									

3.3 Combined Conductivity, DO, and pH Box Plots

See section 1.7 of the freshwater water quality protocol narrative for an expanded discussion of the environmental importance of conductivity, DO, and pH. Given the expectation that these three parameters will remain relatively static, a time-series graph is not necessarily the most informative data summary. Box plots are the primary visual characterization for the reporting year (Figure SOP 10.2).

However, each season there may be important short-term peaks or valleys in parameter values during discrete time periods due to events such as atypically high flow or acute point source pollution. When these occur, a time-series graph during that time period is displayed following the general format of figure SOP 10.1. Each year, the Project Leader examines time-series graphs of conductivity, DO, and pH for short-duration, high magnitude events that warrant time-series summaries. In addition, R code for generating seasonal time series graphs for each parameter is found in Section 7.0.

3.4 Taiya River Turbidity

Due to strong glacial influence on the hydrologic and chemical characteristics of the Taiya River, turbidity was added as a regularly monitored water quality parameter. Taiya River turbidity is graphed as a single pane in the format of figure SOP 10.1.

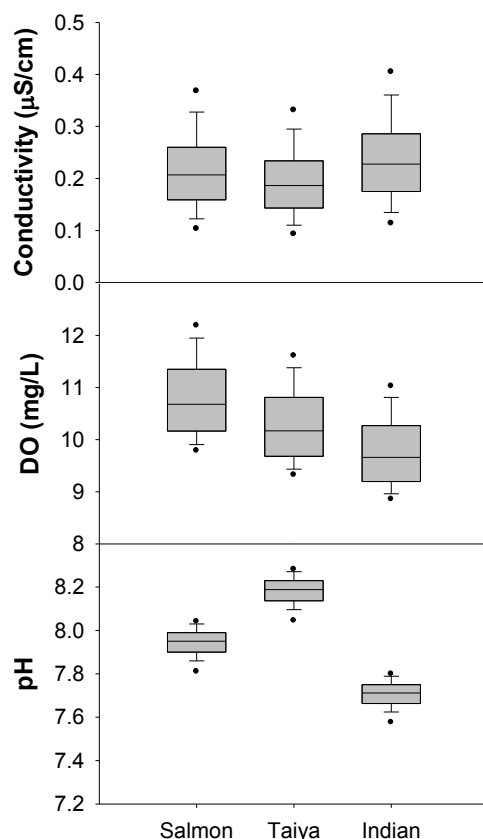


Figure SOP 10.2. Box plots summarizing artificial seasonal measurements for conductivity, dissolved oxygen concentration, and pH in the Salmon, Taiya, and Indian rivers. Horizontal lines within the boxes represent median values, horizontal lines bounding the lower and upper portion of the boxes represent 25th and 75th percentiles, lower and upper whiskers represent 10th and 90th percentiles, and single points represent 5th and 95th percentiles.

3.5 Period of Record and Summary Statistics

A table summarizing the period of record and summary statistics for all data collection will allow readers to quickly determine the breadth of SEAN freshwater water quality data collection efforts and general reference conditions in each monitored river system (Table SOP 10.3).

Table SOP 10.3. Example period of record for artificial freshwater water quality monitoring data collected and reported by SEAN.

River	Parameter	Period of Record	Number of observations	Summary statistics				
				Median	Mean	Standard deviation	Minimum	Maximum
Salmon	Conductivity (µS/cm)	1 January 2004 to 31 December 2011	840	0.207	0.214	0.075	0.055	0.388
	Dissolved Oxygen (mg/L)							
	Dissolved Oxygen (% Sat)							
	pH							
	Temperature (°C)							
Taiya	Conductivity (µS/cm)							
	Dissolved Oxygen (mg/L)							
	Dissolved Oxygen (% Sat)							
	pH							
	Temperature (°C)							
Indian	Conductivity (µS/cm)							
	Dissolved Oxygen (mg/L)							
	Dissolved Oxygen (% Sat)							
	pH							
	Temperature (°C)							
	Turbidity (NTUs)							

3.6 Water Quality Standards

A brief statement is made in the Results narrative on whether state water quality thresholds were exceeded (Table SOP 10.4). If state thresholds are approached or exceeded, a table comparing state standards versus observed parameter values will be displayed.

Table SOP 10.4. Currently, the most stringent Alaska Department of Environmental Conservation (ADEC) water quality standards (ADEC 2011). Superscript numbers denote the category of water quality standard.

Parameter	Criteria
Conductivity	None listed by ADEC
Dissolved oxygen (DO) ¹	DO must be greater than 7 mg/l in waters used by anadromous or resident fish. In no case may DO be less than 5 mg/l to a depth of 20 cm in the interstitial waters of gravel used by anadromous or resident fish for spawning (see note 2). For waters not used by anadromous or resident fish, DO must be greater than or equal to 5 mg/l. In no case may DO be greater than 17 mg/l. The concentration of total dissolved gas may not exceed 110% of saturation at any point of sample collection.
pH ¹	May not be less than 6.5 or greater than 8.5. May not vary more than 0.5 pH unit from natural conditions.
Temperature ^{1,2}	May not exceed 20°C at any time. The following maximum temperatures may not be exceeded, where applicable: Migration routes 15°C Spawning areas 13°C Rearing areas 15°C Egg & fry incubation 13°C For all other waters, the weekly average temperature may not exceed site-specific requirements needed to preserve normal species diversity or to prevent appearance of nuisance organisms.
Turbidity ³	May not exceed 5 NTU above natural conditions when the natural turbidity is 50 NTU or less, and may not have more than 10% increase in turbidity when the natural turbidity is more than 50 NTU, not to exceed a maximum increase of 15 NTU. May not exceed 5 NTU above natural turbidity for all lake waters.

¹ Growth and propagation of fish, shellfish, other aquatic life, and wildlife

² Water supply/aquaculture

³ Water recreation

4.0 Tips for Improving Readability of Results

1. **Monitoring program context:** To retain continuity across annual reports, build the results and narrative in the context of the monitoring program's objectives. Results that may be interesting but are unrelated to program objectives are placed in discrete sub-sections within the Results section but separate from the main results. If many interesting results occur, or a separate research or monitoring program needs to be discussed in relation to water quality results, an appendix will be added or a peer-review manuscript may be warranted.
2. **Parallel structure:** When listing results in graphs, tables, or narrative, consistently refer to rivers in alphabetical order by park: Salmon (GLBA), Taiya (KLGO), and Indian (SITK). When referring to combined water quality figures, list conductivity, dissolved oxygen, and pH in alphabetical order. Repeating these patterns throughout the annual report will allow the reader to develop a reading pattern and comprehend more quickly.
3. **Black and white:** Use only black and white or grayscale figures. This avoids problems with color-blindness or non-color printers.

5.0 Submission, Validation, and Dissemination of the Deliverable

The final version of FQ_G is reviewed by the SEAN Program Manager and generated as a PDF file by the Project Leader, who delivers it to the Data Manager for the validation checks defined in appendix D of the freshwater water quality monitoring protocol. After the valid report is certified by the Project Leader, the Data Manager installs the final PDF in the auxiliary repository, creates a web link for it, updates the Deliverable Product Tracking grid, and forwards the final FQ_G to the NPS IRMA Data Store.

1. *Program Manager Tasks*

1. Review the final Word report document.
2. Apply any essential corrections.
3. Forward to Project Leader.

2. *Project Leader Tasks*

1. Generate a PDF file from the original Word Document.
2. Submit both the PDF and DOCX files via email attachment to the Data Manager for validation. Specify in the message body it is deliverable FQ_G, as defined in protocol FQ-2013.1.

3. *Data Manager Tasks*

1. On receipt of the submission, assign the next formal Submission Number to this file, as found in the master Submission_Log table.
 1. Use the "Update Submission Log" web tool at the data management site:
http://165.83.57.239/0_submission_update.aspx.
 2. Complete Submission_Log details up through the Submission_Date column.

2. Save the attached files to the staging area for validation at:
\\inpglbafs03\data\SEAN_Data\Staging\FQ\FQ_G\nnnn where “nnnn” is the assigned submission number.
 3. Rename the files to FQ_G_yyyy.PDF and FQ_G_yyyy.DOCX, where “yyyy” is the year covered by the report.
 4. Validate the two files according to current criteria.
 5. Record validation summary data in the Submission_Log using the web tool.
 6. If submission fails mandatory criteria, reply with a “failure email” that includes:
 1. *The submission number assigned.*
 2. *The deliverable ID.*
 3. *The protocol ID.*
 4. *Documentation listing all the specific mandatory criteria failed.*
 7. If submission passes mandatory criteria, reply with a “success email” that includes:
 1. *The submission number assigned.*
 2. *The deliverable ID.*
 3. *The protocol ID.*
 4. *Documentation listing any specific optional criteria failed.*
 5. *Request to certify deliverable as complete.*
4. **Project Leader Tasks**
1. On receipt of a failure email:
 1. *Make corrections so the deliverable meets mandatory criteria.*
 2. *Make another submission with corrected deliverable candidate.*
 2. On receipt of a success email:
 1. *After reviewing any optional criteria violations, if the deliverable is acceptable reply with a “certification email” stating the deliverable is certified and may be disseminated.*
 2. *If it is unacceptable:*
 1. **Reply with a “withdrawal email,” stating the deliverable is withdrawn.**
 2. **Take remedial action to obtain a corrected deliverable.**
 3. **Restart the process from the beginning.**
5. **Data Manager Tasks**
1. On receipt of a withdrawal email:
 1. *Mark the withdrawal in the Submission_Log’s Status column using the web tool.*
 2. *File the email in the Data Manager’s email folder named “SEAN Data Management / FQ”.*
 3. *Terminate the process.*
 2. On receipt of a certification email:
 1. *File the email in the Data Manager’s email folder named “SEAN Data Management / FQ”.*
 2. *Due to the nature of these data, NO sensitive information is in the deliverable.*

3. *Copy the two submitted files to test environment at:*
[\\inpglbafs03\data\SEAN_Data_Mgmt\Web_Sites\SEAN-Integration\AuxRep\FQ\FQ_G\](#).
4. *Create web page link to the new PDF, but not the DOCX*
 1. **Mark the certification in the Status column in Submission_Log using the web tool.**
 2. **Propagate from test to production environment.**
 3. **Update the annual deliverable tracking spreadsheet showing date of completion for FQ_G**
5. *Verify that the final document is in the NPS IRMA Data Store and is marked for public access.*

6.0 Literature Cited

- Alaska Department of Environmental Conservation (ADEC). 2012. Water quality standards (18 AAC 70) amended as of April 8, 2012. Alaska Department of Environmental Conservation, Anchorage, Alaska. Available from <http://dec.alaska.gov/commish/regulations/pdfs/18%20AAC%2070.pdf> (accessed March 2013)
- Sergeant, C. J., W. F. Johnson, and B. J. Moynahan. 2012a. Southeast Alaska Network freshwater water quality monitoring program: 2010 annual report. Natural Resource Technical Report NPS/SEAN/NRTR—2012/547. National Park Service, Fort Collins, Colorado. Available from http://science.nature.nps.gov/im/units/sean/FQ_G_Menu.aspx (accessed March 2013)
- Sergeant, C. J., W. F. Johnson, and B. J. Moynahan. 2012b. Southeast Alaska Network freshwater water quality monitoring program: 2011 annual report. Natural Resource Technical Report NPS/SEAN/NRTR—2012/561. National Park Service, Fort Collins, Colorado. Available from http://science.nature.nps.gov/im/units/sean/FQ_G_Menu.aspx (accessed March 2013)
- Wagner, R.J., R. W. Boulger, Jr., C. J. Oblinger, and B. A. Smith. 2006. Guidelines and standard procedures for continuous water-quality monitors—Station operation, record computation, and data reporting: U.S. Geological Survey Techniques and Methods 1–D3. 51 pp. + 8 attachments. Available at <http://pubs.water.usgs.gov/tm1d3> (accessed 16 September 2011).

7.0 R code for producing seasonal time series figures

```
#####

# Creating hourly time series data for Appendix A of SEAN FQ annual report

# Script by Chris Sergeant, updated 14 February 2013

# This script reads in data directly from SEAN FQ database, creates NAs for
# parameters with an associated 'record_quality' of 2 or 3 (bad data),
# reformats date & time for graphing in R, subsets data by year and river,
# and exports high-res .png graphics into the specified file that can be
# directly pasted into annual reports. All graphs will have the same x and y
# axes for consistency and easy comparisons between rivers.

#####

#####START USER INPUT#####
#####

## Typically, you will want the date range below to include the entire calendar
## year for the year of interest
## Dates must be inside ' '

start.data = '2012-01-01'
end.data = '2012-12-31'

## Constrain graphing dates by entering preferred date range for x axis
## Dates must be inside "Date"

start.graph = "2012-04-15"
end.graph = "2012-11-20"

## Enter min/max values for y axes of each parameter to keep graphs
## comparable across rivers. Values must be inside c( )

temp.ylim = c(0.01,12.5)
cond.ylim = c(0.01,0.50)
do.ylim = c(6.5,14.4)
ph.ylim = c(6.4,8.2)
turb.ylim = c(0,200)

## Change filepath and filenames for each generated figure below
## Typically, you will only need to change the year at the end of each filepath
## Note that if you change the filepath, R needs a double backslash
## between folders

filepath.in = "U:\\FQ_Misc\\FQ_AppA_Figures\\Indian_2012.png"
filepath.sa = "U:\\FQ_Misc\\FQ_AppA_Figures\\Salmon_2012.png"
filepath.ta = "U:\\FQ_Misc\\FQ_AppA_Figures\\Taiya_2012.png"

#####
#####END USER INPUT#####
#####

## Make sure RODBC package is installed on machine (remove hashtags before
## install.packages if you need to download package):

## install.packages("RODBC")
```

Southeast Alaska Network freshwater water quality monitoring protocol version FQ-2013.1
SOP 10 copied verbatim from original Natural Resource Report NPS/SEAN/NRR-2013/651

```
## After entering user inputs, select all script (Ctrl-A), then run script (F5)
## Cross your fingers and hope it works!!!

## Read in data from SEAN database:

library(RODBC)
ch2 = odbcDriverConnect('driver={SQL Server};
  server=inpqlba27985\\standard;database=sean_staging_2008;
  trusted_connection=true')
#fq = sqlQuery(ch2,"select * from fq.tbl_fq_readings")
fq = sqlQuery(ch2,"SELECT * FROM fq.v_readings_with_delimiter_rows
  ORDER BY park, site, date_local")
odbcClose(ch2)

## Replace parameter values for cells with bad record quality with NA

fq$temperature[fq$temp_record_quality == 2 | fq$temp_record_quality == 3] = NA
fq$conductivity[fq$cond_record_quality == 2 | fq$cond_record_quality == 3] = NA
fq$sph[fq$sph_record_quality == 2 | fq$sph_record_quality == 3] = NA
fq$do_concentration[fq$do_record_quality == 2 | fq$do_record_quality == 3] = NA
fq$turbidity[fq$turb_record_quality == 2 | fq$turb_record_quality == 3] = NA

## Paste date and time columns together

date_time = paste(fq$date_local, fq$time_local)

## Add new date_time column to fq table

fq.new = cbind(fq,date_time)

#####
##### Indian River Appendix #####
#####

fq.indian = subset(fq.new,
  fq.new$site=="IN" &
  as.Date(fq.new$date_time) > start.data &
  as.Date(fq.new$date_time) < end.data)

## Specify filepath and change file name here
png(filepath.in, width=6, height=5,
  units="in", res=250)
par(mfrow=c(2,2),mar=c(2.5,2,1,1))

plot(as.Date(fq.indian$date_time), fq.indian$temperature,
  xlim=c(as.Date(start.graph),as.Date(end.graph)),
  ylim= temp.ylim,
  cex.axis = 0.75,
  xlab="",
  ylab="",
  main="",
  type="l")
mtext("Temperature (°C)", side = 3, line=-1.1, adj = 0.95,
  font = 2, cex = 0.75)

plot(as.Date(fq.indian$date_time), fq.indian$conductivity,
  xlim=c(as.Date(start.graph),as.Date(end.graph)),
  ylim=cond.ylim,
  cex.axis = 0.75,
  xlab="",
  ylab="",
  main="")
```

```

    type="l")
mtext("Specific conductance (mS/cm)", side = 3, line=-1.1, adj = 0.95,
      font = 2, cex = 0.75)

plot(as.Date(fq.indian$date_time), fq.indian$do_concentration,
      xlim=c(as.Date(start.graph),as.Date(end.graph)),
      ylim=do.ylim,
      cex.axis = 0.75,
      xlab="",
      ylab="",
      main="",
      type="l")
mtext("Dissolved oxygen (mg/L)", side = 3, line=-1.1, adj = 0.95,
      font = 2, cex = 0.75)

plot(as.Date(fq.indian$date_time), fq.indian$ph,
      xlim=c(as.Date(start.graph),as.Date(end.graph)),
      ylim=ph.ylim,
      cex.axis = 0.75,
      xlab="",
      ylab="",
      main="",
      type="l")
mtext("pH", side = 3, line=-1.1, adj = 0.95,
      font = 2, cex = 0.75)

dev.off()

#####
#### Salmon River Appendix #####
#####

fq.salmon = subset(fq.new,
  fq.new$site=="SA" &
  as.Date(fq.new$date_time) > start.data &
  as.Date(fq.new$date_time) < end.data)

## Specify filepath and change file name here
png(filepath.sa, width=6, height=5,
      units="in", res=250)
par(mfrow=c(2,2),mar=c(2.5,2,1,1))

plot(as.Date(fq.salmon$date_time), fq.salmon$temperature,
      xlim=c(as.Date(start.graph),as.Date(end.graph)),
      ylim=temp.ylim,
      cex.axis = 0.75,
      xlab="",
      ylab="",
      main="",
      type="l")
mtext("Temperature (°C)", side = 3, line=-1.1, adj = 0.95,
      font = 2, cex = 0.75)

plot(as.Date(fq.salmon$date_time), fq.salmon$conductivity,
      xlim=c(as.Date(start.graph),as.Date(end.graph)),
      ylim=cond.ylim,
      cex.axis = 0.75,
      xlab="",
      ylab="",
      main="",
      type="l")
mtext("Specific conductance (mS/cm)", side = 3, line=-1.1, adj = 0.95,
      font = 2, cex = 0.75)

```

```

plot(as.Date(fq.salmon$date_time), fq.salmon$do_concentration,
     xlim=c(as.Date(start.graph), as.Date(end.graph)),
     ylim=do.ylim,
     cex.axis = 0.75,
     xlab="",
     ylab="",
     main="",
     type="l")
mtext("Dissolved oxygen (mg/L)", side = 3, line=-1.1, adj = 0.95,
      font = 2, cex = 0.75)

plot(as.Date(fq.salmon$date_time), fq.salmon$ph,
     xlim=c(as.Date(start.graph), as.Date(end.graph)),
     ylim=ph.ylim,
     cex.axis = 0.75,
     xlab="",
     ylab="",
     main="",
     type="l")
mtext("pH", side = 3, line=-1.1, adj = 0.95,
      font = 2, cex = 0.75)

dev.off()

#####
##### Taiya River Appendix #####
#####

fq.taiya = subset(fq.new,
                  fq.new$site=="TA" &
                  as.Date(fq.new$date_time) > start.data &
                  as.Date(fq.new$date_time) < end.data)

## Specify filepath and change file name here
png(filepath.ta, width=6, height=5,
     units="in", res=250)
par(mfrow=c(3,2), mar=c(2.5,2,1,1))

plot(as.Date(fq.taiya$date_time), fq.taiya$temperature,
     xlim=c(as.Date(start.graph), as.Date(end.graph)),
     ylim=temp.ylim,
     cex.axis = 0.75,
     xlab="",
     ylab="",
     main="",
     type="l")
#segments(as.Date("2011-07-26"), 5.45, as.Date("2011-09-14"), 5.43,
#         col = "white", lwd = 2)
mtext("Temperature (°C)", side = 3, line=-1.1, adj = 0.95,
      font = 2, cex = 0.75)

plot(as.Date(fq.taiya$date_time), fq.taiya$conductivity,
     xlim=c(as.Date(start.graph), as.Date(end.graph)),
     ylim=cond.ylim,
     cex.axis = 0.75,
     xlab="",
     ylab="",
     main="",
     type="l")
#segments(as.Date("2011-07-26"), 0.02, as.Date("2011-09-14"), 0.031,
#         col = "white", lwd = 2)
mtext("Specific conductance (mS/cm)", side = 3, line=-1.1, adj = 0.95,

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```
font = 2, cex = 0.75)

plot(as.Date(fq.taiya$date_time), fq.taiya$do_concentration,
     xlim=c(as.Date(start.graph), as.Date(end.graph)),
     ylim=do.ylim,
     cex.axis = 0.75,
     xlab="",
     ylab="",
     main="",
     type="l")
#segments(as.Date("2011-07-26"), 12.61, as.Date("2011-09-14"), 12.46,
#         col = "white", lwd = 2)
mtext("Dissolved oxygen (mg/L)", side = 3, line=-1.1, adj = 0.4,
      font = 2, cex = 0.75)

plot(as.Date(fq.taiya$date_time), fq.taiya$ph,
     xlim=c(as.Date(start.graph), as.Date(end.graph)),
     ylim=ph.ylim,
     cex.axis = 0.75,
     xlab="",
     ylab="",
     main="",
     type="l")
#segments(as.Date("2011-07-26"), 7.26, as.Date("2011-09-14"), 7.47,
#         col = "white", lwd = 2)
mtext("pH", side = 3, line=-1.1, adj = 0.75,
      font = 2, cex = 0.75)

plot(as.Date(fq.taiya$date_time), fq.taiya$turbidity,
     xlim=c(as.Date(start.graph), as.Date(end.graph)),
     ylim=turb.ylim,
     cex.axis = 0.75,
     xlab="",
     ylab="",
     main="",
     type="l")
#segments(as.Date("2011-07-26"), 56.7, as.Date("2011-09-13"), 131,
#         col = "white", lwd = 2)
mtext("Turbidity (NTU)", side = 3, line=-1.1, adj = 0.75,
      font = 2, cex = 0.75)

dev.off()
```

