

The dataRetrieval R package

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1 Introduction to dataRetrieval

The dataRetrieval package was created to simplify the process of loading hydrologic data into the R environment. It has been specifically designed to work seamlessly with the EGRET R package: Exploration and Graphics for RivEr Trends. See: <https://github.com/USGS-R/EGRET/wiki> for information on EGRET. EGRET is designed to provide analysis of water quality data sets using the Weighted Regressions on Time, Discharge and Season (WRTDS) method as well as analysis of discharge trends using robust time-series smoothing techniques. Both of these capabilities provide both tabular and graphical analyses of long-term data sets.

The dataRetrieval package is designed to retrieve many of the major data types of U.S. Geological Survey (USGS) hydrologic data that are available on the Web. Users may also load data from other sources (text files, spreadsheets) using dataRetrieval. Section 2 provides examples of how one can obtain raw data from USGS sources on the Web and load them into dataframes within the R environment. The functionality described in section 2 is for general use and is not tailored for the specific uses of the EGRET package. The functionality described in section 5 is tailored specifically to obtaining input from the Web and structuring it for use in the EGRET package. The functionality described in section 5.5 is for converting hydrologic data from user-supplied files and structuring it specifically for use in the EGRET package.

For information on getting started in R and installing the package, see (7): Getting Started. Any use of trade, firm, or product names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

A quick workflow for major dataRetrieval functions:

```
library(dataRetrieval)
# Choptank River near Greensboro, MD
siteNumber <- "01491000"
ChoptankInfo <- getNWISSiteInfo(siteNumber)
parameterCd <- "00060"

#Raw daily data:
rawDailyData <- retrieveNWISdvData(siteNumber,parameterCd,
                                   "1980-01-01", "2010-01-01")
# Data compiled for EGRET analysis
Daily <- getNWISDaily(siteNumber,parameterCd,
                      "1980-01-01", "2010-01-01")

# Sample data Nitrate:
parameterCd <- "00618"
Sample <- getNWISSample(siteNumber,parameterCd,
                        "1980-01-01", "2010-01-01")

# Metadata on site and nitrate:
INFO <- getMetaData(siteNumber,parameterCd)
```

```
# Merge discharge and nitrate data to one dataframe:
Sample <- mergeReport()
```

2 USGS Web Retrievals

In this section, five examples of Web retrievals document how to get raw data. This data includes site information (2.1), measured parameter information (2.2), historical daily values (2.3), unit values (which include real-time data but can also include other sensor data stored at regular time intervals) (2.4), and water quality data (2.5) or (3). We will use the Choptank River near Greensboro, MD as an example. Daily discharge measurements are available as far back as 1948. Additionally, nitrate has been measured since 1964.

The USGS organizes hydrologic data in a standard structure. Streamgages are located throughout the United States, and each streamgage has a unique ID (referred in this document and throughout the dataRetrieval package as “siteNumber”). Often (but not always), these ID’s are 8 digits. The first step to finding data is discovering this siteNumber. There are many ways to do this, one is the National Water Information System: Mapper <http://maps.waterdata.usgs.gov/mapper/index.html>.

Once the siteNumber is known, the next required input for USGS data retrievals is the “parameter code”. This is a 5-digit code that specifies the measured parameter being requested. For example, parameter code 00631 represents “Nitrate plus nitrite, water, filtered, milligrams per liter as nitrogen”, with units of “mg/l as N”. A complete list of possible USGS parameter codes can be found at <http://nwis.waterdata.usgs.gov/usa/nwis/pmcodes?help>.

Not every station will measure all parameters. A short list of commonly measured parameters is shown in Table 1.

Table 1. Common USGS Parameter Codes

pCode	shortName
00060	Discharge [ft ³ /s]
00065	Gage height [ft]
00010	Temperature [C]
00045	Precipitation [in]
00400	pH

A complete list (as of September 25, 2013) is available as data attached to the package. It is accessed by the following:

```
library(dataRetrieval)
parameterCdFile <- parameterCdFile
names(parameterCdFile)

[1] "parameter_cd" "parameter_group_nm"
```

```
[3] "parameter_nm"      "casrn"
[5] "srsname"           "parameter_units"
```

For unit values data (sensor data measured at regular time intervals such as 15 minutes or hourly), knowing the parameter code and siteNumber is enough to make a request for data. For most variables that are measured on a continuous basis, the USGS also stores the historical data as daily values. These daily values are statistical summaries of the continuous data, e.g. maximum, minimum, mean, or median. The different statistics are specified by a 5-digit statistics code. A complete list of statistic codes can be found [here](http://nwis.waterdata.usgs.gov/nwis/help/?read_file=stat&format=table):

http://nwis.waterdata.usgs.gov/nwis/help/?read_file=stat&format=table

Some common codes are shown in Table 2.

Table 2. Commonly used USGS Stat Codes

StatCode	shortName
00001	Maximum
00002	Minimum
00003	Mean
00008	Median

Examples for using these siteNumber's, parameter codes, and stat codes will be presented in subsequent sections.

2.1 Site Information

2.1.1 getNWISSiteInfo

Use the `getNWISSiteInfo` function to obtain all of the information available for a particular USGS site such as full station name, drainage area, latitude, and longitude. `getNWISSiteInfo` can also access information about multiple sites with a vector input.

```
siteNumbers <- c("01491000", "01645000")
siteINFO <- getNWISSiteInfo(siteNumbers)
```

A specific example piece of information can be retrieved, in this case a station name, as follows:

```
siteINFO$station.nm

[1] "CHOPTANK RIVER NEAR GREENSBORO, MD"
[2] "SENECA CREEK AT DAWSONVILLE, MD"
```

Site information is obtained from <http://waterservices.usgs.gov/rest/Site-Test-Tool.html>

2.1.2 getNWISDataAvailability

To discover what data is available for a particular USGS site, including measured parameters, period of record, and number of samples (count), use the `getNWISDataAvailability` function. It is possible to limit the retrieval information to a subset of types ("dv", "uv", or "qw"). In the following example, we limit the retrieved Choptank data to only daily data. Leaving the "type" argument blank returns all of the available data for that site.

```
# Continuing from the previous example:
# This pulls out just the daily data:

dailyDataAvailable <- getNWISDataAvailability(siteNumbers,
                                              type="dv")
```

Table 3. Daily mean data available at the Choptank River near Greensboro, MD. [Some columns deleted for space considerations]

siteNumber	srsname	startDate	endDate	count	units	statCd
01491000	Temperature, water	1988-10-01	2012-05-09	894	deg C	00001
01491000	Temperature, water	2010-10-01	2012-05-09	529	deg C	00002
01491000	Temperature, water	2010-10-01	2012-05-09	529	deg C	00003
01491000	Stream flow, mean. daily	1948-01-01	2014-09-21	24371	ft ³ /s	00003
01645000	Stream flow, mean. daily	1930-09-26	2014-09-21	30675	ft ³ /s	00003
01491000	Specific conductance	2010-10-01	2012-05-09	527	μS/cm @25C	00003
01491000	Specific conductance	2010-10-01	2012-05-09	527	μS/cm @25C	00001
01491000	Specific conductance	2010-10-01	2012-05-09	527	μS/cm @25C	00002
01491000	Suspended sediment concentration (SSC)	1980-10-01	1991-09-30	3651	mg/l	00003
01491000	Suspended sediment discharge	1980-10-01	1991-09-30	3652	tons/day	00003

See Section 8 for instructions on converting an R dataframe to a table in Microsoft® software Excel or Word to display a data availability table similar to Table 3. Excel, Microsoft, PowerPoint, Windows, and Word are registered trademarks of Microsoft Corporation in the United States and other countries.

2.2 Parameter Information

To obtain all of the available information concerning a measured parameter (or multiple parameters), use the `getNWISPcodeInfo` function:

```
# Using defaults:
parameterCd <- "00618"
parameterINFO <- getNWISPcodeInfo(parameterCd)
colnames(parameterINFO)

[1] "parameter_cd"          "parameter_group_nm"
```

```
[3] "parameter_nm"      "casrn"
[5] "srsname"           "parameter_units"
```

A specific example piece of information, in this case parameter name, can be obtained as follows:

```
parameterINFO$parameter_nm
[1] "Nitrate, water, filtered, milligrams per liter as nitrogen"
```

Parameter information can be obtained from <http://nwis.waterdata.usgs.gov/usa/nwis/pmcodes>

2.3 Daily Values

To obtain daily records of USGS data, use the `retrieveNWISdvData` function. The arguments for this function are `siteNumber`, `parameterCd`, `startDate`, `endDate`, `statCd`, and a logical (TRUE/FALSE) `interactive`. There are 2 default arguments: `statCd` (defaults to "00003"), and `interactive` (defaults to TRUE). If you want to use the default values, you do not need to list them in the function call. By setting the "interactive" option to FALSE, the operation of the function will advance automatically. It might make more sense to run large batch collections with the interactive option set to FALSE.

The dates (start and end) must be in the format "YYYY-MM-DD" (note: the user must include the quotes). Setting the start date to "" (no space) will prompt the program to ask for the earliest date, and setting the end date to "" (no space) will prompt for the latest available date.

```
# Continuing with our Choptank River example
siteNumber <- "01491000"
parameterCd <- "00060" # Discharge
startDate <- "" # Will request earliest date
endDate <- "" # Will request latest date

discharge <- retrieveNWISdvData(siteNumber,
                                parameterCd, startDate, endDate)
names(discharge)

[1] "agency_cd"      "site_no"
[3] "datetime"       "X02_00060_00003"
[5] "X02_00060_00003_cd"
```

The column "datetime" in the returned dataframe is automatically imported as a variable of class "Date" in R. Each requested parameter has a value and remark code column. The names of these columns depend on the requested parameter and stat code combinations. USGS remark codes are often "A" (approved for publication) or "P" (provisional data subject to revision). A more complete list of remark codes can be found here: <http://nwis.waterdata.usgs.gov/usa/nwis/pmcodes>

Another example that doesn't use the defaults would be a request for mean and maximum daily temperature and discharge in early 2012:

```
parameterCd <- c("00010", "00060") # Temperature and discharge
statCd <- c("00001", "00003") # Mean and maximum
startDate <- "2012-01-01"
endDate <- "2012-05-01"

temperatureAndFlow <- retrieveNWISdvData(siteNumber, parameterCd,
  startDate, endDate, statCd=statCd)
```

Daily data is pulled from <http://waterservices.usgs.gov/rest/DV-Test-Tool.html>.

The column names can be automatically adjusted based on the parameter and statistic codes using the `renameColumns` function. This is not necessary, but may be useful when analyzing the data.

```
names(temperatureAndFlow)

[1] "agency_cd"          "site_no"
[3] "datetime"           "X01_00010_00001"
[5] "X01_00010_00001_cd" "X01_00010_00003"
[7] "X01_00010_00003_cd" "X02_00060_00003"
[9] "X02_00060_00003_cd"

temperatureAndFlow <- renameColumns(temperatureAndFlow)
names(temperatureAndFlow)

[1] "agency_cd"
[2] "site_no"
[3] "datetime"
[4] "Temperature_water_degrees_Celsius_Max_01"
[5] "Temperature_water_degrees_Celsius_Max_01_cd"
[6] "Temperature_water_degrees_Celsius_01"
[7] "Temperature_water_degrees_Celsius_01_cd"
[8] "Discharge_cubic_feet_per_second"
[9] "Discharge_cubic_feet_per_second_cd"
```

An example of plotting the above data (Figure 1):

```
par(mar=c(5,5,5,5)) #sets the size of the plot window

with(temperatureAndFlow, plot(
  datetime, Temperature_water_degrees_Celsius_Max_01,
  xlab="Date", ylab="Max Temperature [C]"
))
par(new=TRUE)
with(temperatureAndFlow, plot(
  datetime, Discharge_cubic_feet_per_second,
  col="red", type="l", xaxt="n", yaxt="n", xlab="", ylab="", axes=FALSE
))
```


CHOPTANK RIVER NEAR GREENSBORO, MD 2012

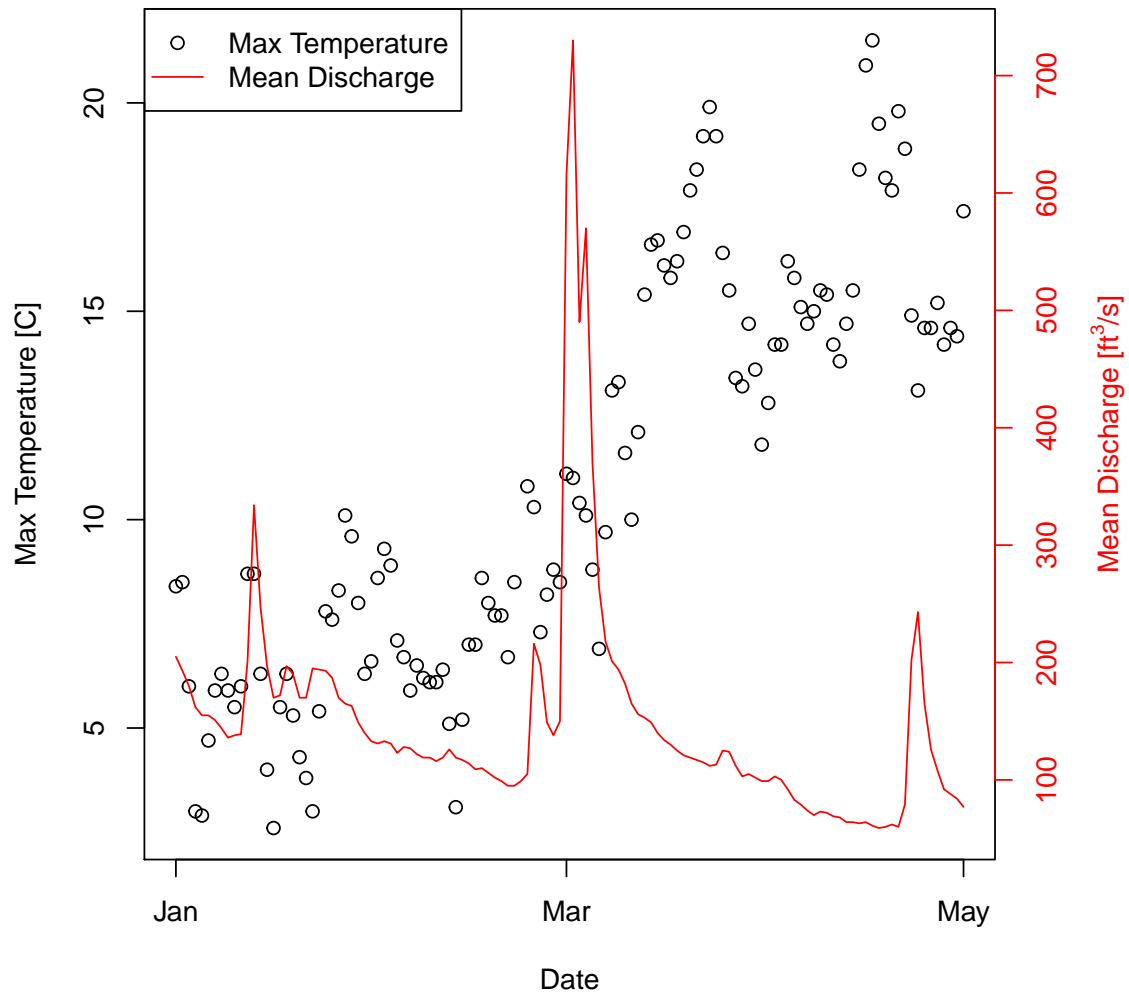


Figure 1. Temperature and discharge plot of Choptank River in 2012.

```
axis(4,col="red",col.axis="red")
mtext(expression(paste("Mean Discharge [ft" "^3", "/s]",
                        sep="")),side=4,line=3,col="red")
title(paste(siteINFO$station.nm[1],"2012",sep=" "))
legend("topleft", c("Max Temperature", "Mean Discharge"),
      col=c("black", "red"),lty=c(NA,1),pch=c(1,NA))
```

There are occasions where NWIS values are not reported as numbers, instead there might be text

describing a certain event such as “Ice.” Any value that cannot be converted to a number will be reported as NA in this package (not including remark code columns).

2.4 Unit Values

Any data collected at regular time intervals (such as 15-minute or hourly) are known as “unit values.” Many of these are delivered on a real time basis and very recent data (even less than an hour old in many cases) are available through the function `retrieveNWISunitData`. Some of these unit values are available for many years, and some are only available for a recent time period such as 120 days. Here is an example of a retrieval of such data.

```
parameterCd <- "00060" # Discharge
startDate <- "2012-05-12"
endDate <- "2012-05-13"
dischargeToday <- retrieveNWISunitData(siteNumber, parameterCd,
                                       startDate, endDate)
```

The retrieval produces the following dataframe:

	agency_cd	site_no		datetime	tz_cd
1	USGS	01491000	2012-05-12	00:00:00	EST
2	USGS	01491000	2012-05-12	00:15:00	EST
3	USGS	01491000	2012-05-12	00:30:00	EST
4	USGS	01491000	2012-05-12	00:45:00	EST
5	USGS	01491000	2012-05-12	01:00:00	EST
6	USGS	01491000	2012-05-12	01:15:00	EST
	X02_00060_00011		X02_00060_00011_cd		
1		83		A	
2		83		A	
3		83		A	
4		83		A	
5		85		A	
6		83		A	

Note that time now becomes important, so the variable `datetime` is a `POSIXct`, and the time zone is included in a separate column. Data are retrieved from <http://waterservices.usgs.gov/rest/IV-Test-Tool.html>. There are occasions where NWIS values are not reported as numbers, instead a common example is “Ice.” Any value that cannot be converted to a number will be reported as NA in this package.

2.5 Water Quality Values

To get USGS water quality data from water samples collected at the streamgage or other monitoring site (as distinct from unit values collected through some type of automatic monitor) we can use the function `retrieveNWISqwData`, with the input arguments: `siteNumber`, `parameterCd`, `startDate`, `endDate`, and `interactive` (similar to `retrieveNWISunitData` and `retrieveNWISdvData`). Additionally, the argument `"expanded"` is a logical input that allows the user to choose between a simple return of datetimes/qualifier/values (`expanded=FALSE`), or a more complete and verbose output (`expanded=TRUE`). `Expanded = TRUE` includes such columns as remark codes, value qualifying text, and detection level.

```
# Dissolved Nitrate parameter codes:
parameterCd <- c("00618", "71851")
startDate <- "1985-10-01"
endDate <- "2012-09-30"

dissolvedNitrate <- retrieveNWISqwData(siteNumber, parameterCd,
                                       startDate, endDate, expanded=TRUE)
names(dissolvedNitrate)

[1] "dateTime"          "site"
[3] "dateTimeEnd"        "remark_cd_00618"
[5] "result_va_00618"    "val_qual_tx_00618"
[7] "meth_cd_00618"      "dqi_cd_00618"
[9] "rpt_lev_va_00618"   "rpt_lev_cd_00618"
[11] "remark_cd_71851"    "result_va_71851"
[13] "val_qual_tx_71851"  "meth_cd_71851"
[15] "dqi_cd_71851"       "rpt_lev_va_71851"
[17] "rpt_lev_cd_71851"

with(dissolvedNitrate, plot(
  dateTime, result_va_00618,
  xlab="Date", ylab = paste(parameterINFO$srsname,
                             "(", parameterINFO$parameter_units, ")")
))
title(siteINFO$station.nm[1])
```

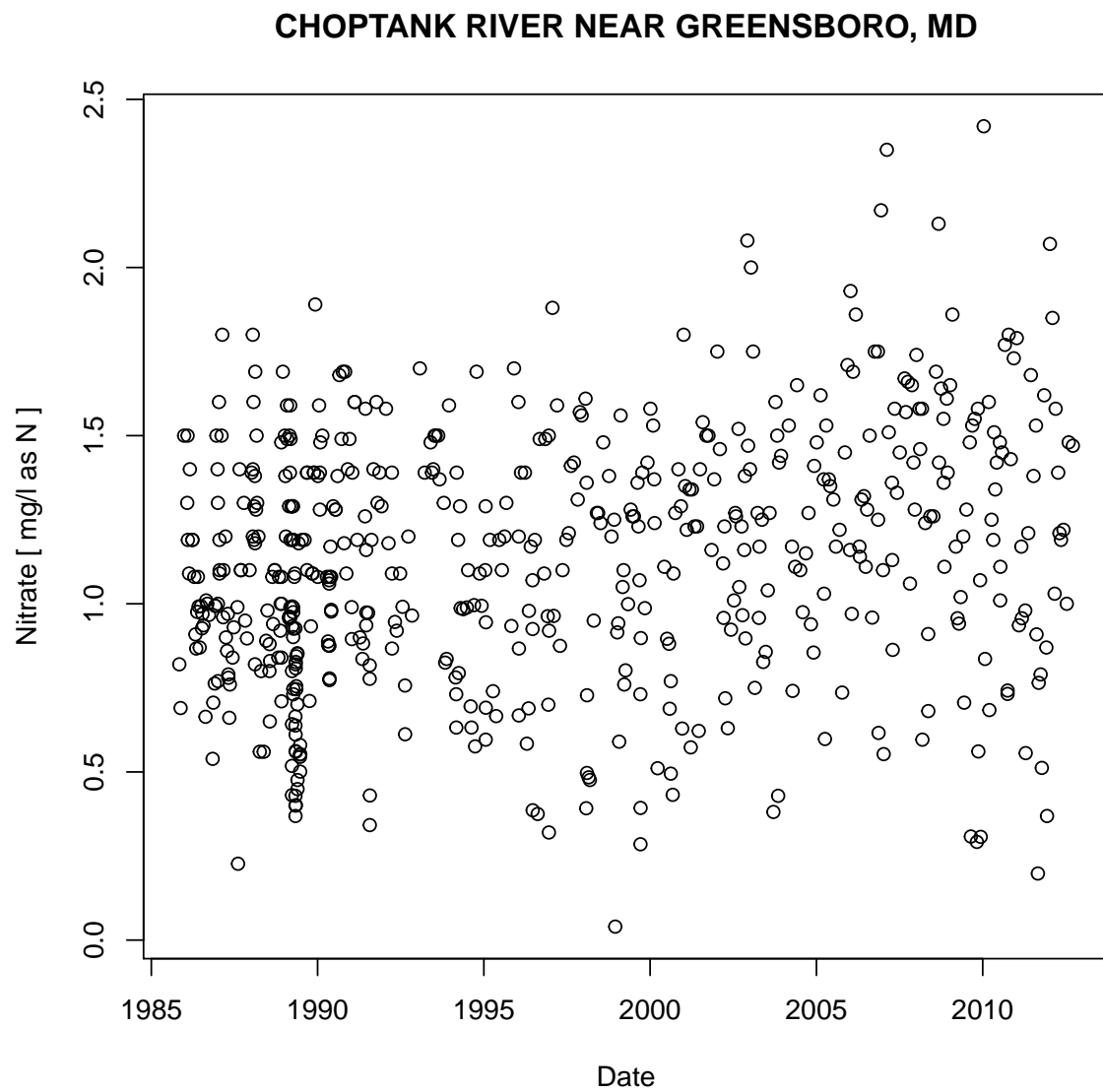


Figure 2. Nitrate, water, filtered, milligrams per liter as nitrogen at CHOPTANK RIVER NEAR GREENSBORO, MD

2.6 URL Construction

There may be times when you might be interested in seeing the URL (Web address) that was used to obtain the raw data. The `constructNWISURL` function returns the URL. In addition to input variables that have been described, there is a new argument "service". The service argument can be "dv" (daily values), "uv" (unit values), "qw" (NWIS water quality values), or "wqp" (general Water Quality Portal values).

```
# Dissolved Nitrate parameter codes:
pCode <- c("00618", "71851")
startDate <- "1964-06-11"
endDate <- "2012-12-18"
url_qw <- constructNWISURL(siteNumber, pCode, startDate, endDate, 'qw')
url_dv <- constructNWISURL(siteNumber, "00060", startDate, endDate,
                           'dv', statCd="00003")
url_uv <- constructNWISURL(siteNumber, "00060", startDate, endDate, 'uv')
```

3 Water Quality Portal Web Retrievals

There are additional water quality data sets available from the Water Quality Data Portal (<http://www.waterqualitydata.us/>). These data sets can be housed in either the STORET (data from EPA), NWIS database (data from USGS), STEWARDS database (USDA), and additional databases are slated to be included. Because only USGS uses parameter codes, a "characteristic name" must be supplied. The `retrieveWQPqwData` function can take either a USGS parameter code, or a more general characteristic name in the `parameterCd` input argument. The Water Quality Data Portal includes data discovery tools and information on characteristic names. The following example retrieves specific conductance from a DNR site in Wisconsin.

```
specificCond <- retrieveWQPqwData('WIDNR_WQX-10032762',
                                  'Specific conductance', '2011-05-01', '2011-09-30')
```

4 Generalized Retrievals

The previous examples all took specific input arguments: `siteNumber`, `parameterCd` (or characteristic name), `startDate`, `endDate`, etc. However, the Web services that supply the data can accept a wide variety of additional arguments.

4.0.1 NWIS sites

The function `getNWISSites` can be used to discover NWIS sites based on any query that the NWIS Site Service offers. This is done by using the `"..."` argument, which allows the user to use any

arbitrary input argument. We can then use the service here:

<http://waterservices.usgs.gov/rest/Site-Test-Tool.html>

to discover many options for searching for NWIS sites. For example, you may want to search for sites in a lat/lon bounding box, or only sites tidal streams, or sites with water quality samples, sites above a certain altitude, etc. The results of this site query generate a URL. For example, the tool provided a search within a specified bounding box, for sites that have daily discharge (parameter code = 00060) and temperature (parameter code = 00010). The generated URL is:

<http://waterservices.usgs.gov/nwis/site/?format=rdb&bBox=-83.0,36.5,-81.0,38.5¶meterCd=00010,00060&hasDataTypeCd=dv>

The following dataRetrieval code can be used to get those sites:

```
sites <- getNWISSites (bBox="-83.0,36.5,-81.0,38.5",
                      parameterCd="00010,00060",
                      hasDataTypeCd="dv")

names(sites)

[1] "agency_cd"           "site_no"
[3] "station_nm"          "site_tp_cd"
[5] "dec_lat_va"          "dec_long_va"
[7] "coord_acy_cd"        "dec_coord_datum_cd"
[9] "alt_va"              "alt_acy_va"
[11] "alt_datum_cd"        "huc_cd"

nrow(sites)

[1] 205
```

4.0.2 NWIS data

For NWIS data, the function `getNWISData` can be used. The argument listed in the R help file is `"..."` and `"service"` (only for data requests). Table 4 describes the services are available.

Table 4. NWIS general data calls

Service	Description	Reference URL
daily values	dv	http://waterservices.usgs.gov/rest/DV-Test-Tool.html
instantaneous	iv	http://waterservices.usgs.gov/rest/IV-Test-Tool.html
groundwater levels	gwlevels	http://waterservices.usgs.gov/rest/GW-Levels-Test-Tool.html
water quality	qwdata	http://nwis.waterdata.usgs.gov/nwis/qwdata

The `"..."` argument allows the user to create their own queries based on the instructions found in the web links above. The links provide instructions on how to create a URL to request data. Perhaps you

want sites only in Wisconsin, with a drainage area less than 50 mi², and the most recent daily discharge data. That request would be done as follows:

```
dischargeWI <- getNWISData(stateCd="WI",
                           parameterCd="00060",
                           drainAreaMin="50",
                           statCd="00003")

names(dischargeWI)

[1] "agency_cd"          "site_no"
[3] "datetime"           "X01_00060_00003"
[5] "X01_00060_00003_cd"

nrow(dischargeWI)

[1] 282
```

4.0.3 Water Quality Portal sites

Just as with NWIS, the Water Quality Portal (WQP) offers a variety of ways to search for sites and request data. The possible Web service arguments for WQP site searches is found here:

http://www.waterqualitydata.us/webservices_documentation.jsp

To discover available sites in the WQP in New Jersey that have measured Chloride, use the function `getWQPSites`.

```
sitesNJ <- getWQPSites(statecode="US:34",
                       characteristicName="Chloride")
```

4.0.4 Water Quality Portal data

Finally, to get data from the WQP using generalized Web service calls, use the function `getWQPData`. For example, to get all the pH data in Wisconsin:

```
dataPH <- getWQPData(statecode="US:55",
                     characteristicName="pH")
```

5 Data Retrievals Structured For Use In The EGRET Package

Rather than using the raw data as retrieved by the Web, the `dataRetrieval` package also includes functions that return the data in a structure that has been designed to work with the EGRET R package (<https://github.com/USGS-R/EGRET/wiki>). In general, these dataframes may be much more “R-friendly” than the raw data, and will contain additional date information that allows for efficient data

analysis.

In this section, we use 3 dataRetrieval functions to get sufficient data to perform an EGRET analysis. We will continue analyzing the Choptank River. We retrieve essentially the same data that were retrieved in section 2, but in this case the data are structured into three EGRET-specific dataframes. The daily discharge data are placed in a dataframe called Daily. The nitrate sample data are placed in a dataframe called Sample. The data about the site and the parameter are placed in a dataframe called INFO. Although these dataframes were designed to work with the EGRET R package, they can be very useful for a wide range of hydrology studies that don't use EGRET.

5.1 INFO Data

The getMetaData function obtains metadata, or data about the streamgage and measured parameters. This function combines getNWISSiteInfo and getNWISPCODEInfo, producing one dataframe called INFO.

```
parameterCd <- "00618"
INFO <- getMetaData(siteNumber, parameterCd, interactive=FALSE)
```

5.2 Daily Data

The getNWISDaily function retrieves the daily values (discharge in this case). It requires the inputs siteNumber, parameterCd, startDate, endDate, interactive, and convert. Most of these arguments are described in section 2, however "convert" is a new argument (that defaults to TRUE). The convert argument tells the program to convert the values from cubic feet per second (ft³/s) to cubic meters per second (m³/s) as shown in the example Daily data frame in Table 5. For EGRET applications with NWIS Web retrieval, do not use this argument (the default is TRUE), EGRET assumes that discharge is always stored in units of cubic meters per second. If you don't want this conversion and are not using EGRET, set convert=FALSE in the function call.

```
siteNumber <- "01491000"
startDate <- "2000-01-01"
endDate <- "2013-01-01"
# This call will get NWIS (ft3/s) data , and convert it to m3/s:
Daily <- getNWISDaily(siteNumber, "00060", startDate, endDate)

There are 4750 data points, and 4750 days.
```

If discharge values are negative or zero, the code will set all of these values to zero and then add a small constant to all of the daily discharge values. This constant is 0.001 times the mean discharge. The code will also report on the number of zero and negative values and the size of the constant. Use EGRET analysis only if the number of zero values is a very small fraction of the total days in the record (say less than 0.1% of the days), and there are no negative discharge values. Columns Q7 and Q30 are the 7 and 30 day running averages for the 7 or 30 days ending on this specific date. Table 5 lists details of

Table 5. Daily dataframe

ColumnName	Type	Description	Units
Date	Date	Date	date
Q	number	Discharge in m ³ /s	m ³ /s
Julian	number	Number of days since January 1, 1850	days
Month	integer	Month of the year [1-12]	months
Day	integer	Day of the year [1-366]	days
DecYear	number	Decimal year	years
MonthSeq	integer	Number of months since January 1, 1850	months
Qualifier	string	Qualifying code	character
i	integer	Index of days, starting with 1	days
LogQ	number	Natural logarithm of Q	numeric
Q7	number	7 day running average of Q	m ³ /s
Q30	number	30 day running average of Q	m ³ /s

the Daily data frame.

Notice that the “Day of the year” column can span from 1 to 366. The 366 accounts for leap years. Every day has a consistent day of the year. This means, February 28th is always the 59th day of the year, Feb. 29th is always the 60th day of the year, and March 1st is always the 61st day of the year whether or not it is a leap year.

5.3 Sample Data

The `getNWISSample` function retrieves USGS sample data from NWIS. The arguments for this function are also `siteNumber`, `parameterCd`, `startDate`, `endDate`, `interactive`. These are the same inputs as `retrieveWQPqwData` or `getWQPData` as described in the previous section.

```
parameterCd <- "00618"
Sample <-getNWISSample(siteNumber,parameterCd,
  startDate, endDate)
```

The `getWQPSample` function retrieves Water Quality Portal sample data (STORET, NWIS, STEWARDS). The arguments for this function are `siteNumber`, `characteristicName`, `startDate`, `endDate`, `interactive`. Table 6 lists details of the Sample data frame.

```
site <- 'WIDNR_WQX-10032762'
characteristicName <- 'Specific conductance'
Sample <-getWQPSample(site,characteristicName,
  startDate, endDate)
```

Table 6. Sample dataframe

ColumnName	Type	Description	Units
Date	Date	Date	date
ConcLow	number	Lower limit of concentration	mg/L
ConcHigh	number	Upper limit of concentration	mg/L
Uncen	integer	Uncensored data (1=true, 0=false)	integer
ConcAve	number	Average of ConcLow and ConcHigh	mg/L
Julian	number	Number of days since January 1, 1850	days
Month	integer	Month of the year [1-12]	months
Day	integer	Day of the year [1-366]	days
DecYear	number	Decimal year	years
MonthSeq	integer	Number of months since January 1, 1850	months
SinDY	number	Sine of DecYear	numeric
CosDY	number	Cosine of DecYear	numeric
Q ¹	number	Discharge	m ³ /s
LogQ ¹	number	Natural logarithm of discharge	numeric

¹ Discharge columns are populated from data in the Daily dataframe after calling the `mergeReport` function.

Notice that the “Day of the year” column can span from 1 to 366. The 366 accounts for leap years. Every day has a consistent day of the year. This means, February 28th is always the 59th day of the year, Feb. 29th is always the 60th day of the year, and March 1st is always the 61st day of the year whether or not it is a leap year.

Section 5.4 is about summing multiple constituents, including how interval censoring is used. Since the Sample data frame is structured to only contain one constituent, when more than one parameter codes are requested, the `getNWISSample` function will sum the values of each constituent as described below.

5.4 Censored Values: Summation Explanation

In the typical case where none of the data are censored (that is, no values are reported as “less-than” values), the `ConcLow` = `ConcHigh` = `ConcAve` and `Uncen` = 1 are equal to the reported value. For the most common type of censoring, where a value is reported as less than the reporting limit, then `ConcLow` = NA, `ConcHigh` = reporting limit, `ConcAve` = 0.5 * reporting limit, and `Uncen` = 0.

To illustrate how the `dataRetrieval` package handles a more complex censoring problem, let us say that in 2004 and earlier, we computed total phosphorus (tp) as the sum of dissolved phosphorus (dp) and particulate phosphorus (pp). From 2005 and onward, we have direct measurements of total phosphorus (tp). A small subset of this fictional data looks like Table 7.

The `dataRetrieval` package will “add up” all the values in a given row to form the total for that sample

Table 7. Example data

cdate	rdp	dp	rpp	pp	rtp	tp
2003-02-15		0.020		0.500		
2003-06-30	<	0.010		0.300		
2004-09-15	<	0.005	<	0.200		
2005-01-30						0.430
2005-05-30					<	0.050
2005-10-30					<	0.020

when using the Sample dataframe. Thus, you only want to enter data that should be added together. If you want a dataframe with multiple constituents that are not summed, do not use `getNWISSample`, `getWQPsample`, or `getUserSample`. The raw data functions: `getWQPData`, `retrieveNWISqwData`, `retrieveWQPqwData`, `getWQPData` will not sum constituents, but leave them in their individual columns.

For example, we might know the value for dp on 5/30/2005, but we don't want to put it in the table because under the rules of this data set, we are not supposed to add it in to the values in 2005.

For every sample, the EGRET package requires a pair of numbers to define an interval in which the true value lies (ConcLow and ConcHigh). In a simple uncensored case (the reported value is above the detection limit), ConcLow equals ConcHigh and the interval collapses down to a single point. In a simple censored case, the value might be reported as <0.2, then ConcLow=NA and ConcHigh=0.2. We use NA instead of 0 as a way to elegantly handle future logarithm calculations.

For the more complex example case, let us say dp is reported as <0.01 and pp is reported as 0.3. We know that the total must be at least 0.3 and could be as much as 0.31. Therefore, ConcLow=0.3 and ConcHigh=0.31. Another case would be if dp is reported as <0.005 and pp is reported <0.2. We know in this case that the true value could be as low as zero, but could be as high as 0.205. Therefore, in this case, ConcLow=NA and ConcHigh=0.205. The Sample dataframe for the example data would be:

Sample							
	Date	ConcLow	ConcHigh	Uncen	ConcAve	Julian	Month
1	2003-02-15	0.52	0.520	1	0.5200	55927	2
2	2003-06-30	0.30	0.310	0	0.3050	56062	6
3	2004-09-15	NA	0.205	0	0.1025	56505	9
4	2005-01-30	0.43	0.430	1	0.4300	56642	1
5	2005-05-30	NA	0.050	0	0.0250	56762	5
6	2005-10-30	NA	0.020	0	0.0100	56915	10
	Day	DecYear	MonthSeq	SinDY	CosDY		
1	46	2003	1838	0.70253	0.7117		
2	182	2003	1842	0.03872	-0.9993		
3	259	2005	1857	-0.96134	-0.2754		
4	30	2005	1861	0.48251	0.8759		
5	151	2005	1865	0.54163	-0.8406		

```
6 304      2006      1870 -0.88205  0.4712
```

Section 5.5 discusses inputting user-generated files. The functions `getUserSample` and `getNWISSample` assume summation with interval censoring inputs, and are discussed in sections 5.5.1 and 5.5.2.

5.5 User-Generated Data Files

In addition to retrieving data from the USGS Web services, the `dataRetrieval` package also includes functions to generate the Daily and Sample data frame from local files.

5.5.1 `getUserDaily`

The `getUserDaily` function will load a user-supplied text file and convert it to the Daily dataframe. The file should have two columns, the first dates, the second values. The dates are formatted either mm/dd/yyyy or yyyy-mm-dd. Using a 4-digit year is required. This function has the following inputs: `filePath`, `fileName`, `hasHeader` (TRUE/FALSE), `separator`, `qUnit`, and `interactive` (TRUE/FALSE). `filePath` is a string that defines the path to your file, and the string can either be a full path, or path relative to your R working directory. The input `fileName` is a string that defines the file name (including the extension).

Text files that contain this sort of data require some sort of a separator, for example, a “csv” file (comma-separated value) file uses a comma to separate the date and value column. A tab delimited file would use a tab (“\t”) rather than the comma (“,”). Define the type of separator you choose to use in the function call in the “separator” argument, the default is “,”. Another function input is a logical variable: `hasHeader`. The default is TRUE. If your data does not have column names, set this variable to FALSE.

Finally, `qUnit` is a numeric argument that defines the discharge units used in the input file. The default is `qUnit = 1` which assumes discharge is in cubic feet per second. If the discharge in the file is already in cubic meters per second then set `qUnit = 2`. If it is in some other units (like liters per second or acre-feet per day), the user must pre-process the data with a unit conversion that changes it to either cubic feet per second or cubic meters per second.

So, if you have a file called “ChoptankRiverFlow.txt” located in a folder called “RData” on the C drive (this example is for the Windows® operating systems), and the file is structured as follows (tab-separated):

```
date  Qdaily
10/1/1999  107
10/2/1999  85
10/3/1999  76
10/4/1999  76
10/5/1999  113
10/6/1999  98
```

...

The call to open this file, convert the discharge to cubic meters per second, and populate the Daily data frame would be:

```
fileName <- "ChoptankRiverFlow.txt"
filePath <- "C:/RData/"
Daily <- getFileDaily(filePath, fileName,
                      separator="\t")
```

Microsoft® Excel files can be a bit tricky to import into R directly. The simplest way to get Excel data into R is to open the Excel file in Excel, then save it as a .csv file (comma-separated values).

5.5.2 getUserSample

The `getUserSample` function will import a user-generated file and populate the Sample dataframe. The difference between sample data and discharge data is that the code requires a third column that contains a remark code, either blank or "<", which will tell the program that the data were “left-censored” (or, below the detection limit of the sensor). Therefore, the data must be in the form: date, remark, value. An example of a comma-delimited file is:

```
cdate;remarkCode;Nitrate
10/7/1999,,1.4
11/4/1999,<,0.99
12/3/1999,,1.42
1/4/2000,,1.59
2/3/2000,,1.54
...
```

The call to open this file, and populate the Sample dataframe is:

```
fileName <- "ChoptankRiverNitrate.csv"
filePath <- "C:/RData/"
Sample <- getUserSample(filePath, fileName,
                        separator=",")
```

When multiple constituents are to be summed, the format can be date, remark_A, value_A, remark_b, value_b, etc... A tab-separated example might look like the file below, where the columns are date, remark dissolved phosphate (rdp), dissolved phosphate (dp), remark particulate phosphorus (rpp), particulate phosphorus (pp), remark total phosphate (rtp), and total phosphate (tp):

```
date  rdp dp rpp pp rtp tp
2003-02-15 0.020 0.500
2003-06-30 <0.010 0.300
2004-09-15 <0.005 <0.200
2005-01-30 0.430
```

```
2005-05-30 <0.050
2005-10-30 <0.020
...
```

```
fileName <- "ChoptankPhosphorus.txt"
filePath <- "C:/RData/"
Sample <-getUserSample(filePath,fileName,
                        separator="\t")
```

5.6 Merge Report

Finally, there is a function called `mergeReport` that will look at both the Daily and Sample dataframe, and populate Q and LogQ columns into the Sample dataframe. The default arguments are Daily and Sample, however if you want to use other similarly structured dataframes, you can specify `localDaily` or `localSample`. Once `mergeReport` has been run, the Sample dataframe will be augmented with the daily discharges for all the days with samples. None of the water quality functions in EGRET will work without first having run the `mergeReport` function.

```
siteNumber <- "01491000"
parameterCd <- "00631" # Nitrate
startDate <- "2000-01-01"
endDate <- "2013-01-01"
```

```
Daily <- getNWISDaily(siteNumber, "00060", startDate, endDate)
```

There are 4750 data points, and 4750 days.

```
Sample <- getNWISSample(siteNumber,parameterCd, startDate, endDate)
Sample <- mergeReport()
```

```
Discharge Record is 4750 days long, which is 13 years
First day of the discharge record is 2000-01-01 and last day is 2013-01-01
The water quality record has 222 samples
The first sample is from 2000-01-04 and the last sample is from 2012-12-18
Discharge: Minimum, mean and maximum 0.00991 4.55 246
Concentration: Minimum, mean and maximum 0.2 1.2 2.4
Percentage of the sample values that are censored is 0 %
```

```
head(Sample)
```

	Date	Q	LogQ	ConcLow	ConcHigh	Uncen	ConcAve
1	2000-01-04	2.747	1.0104	1.59	1.59	1	1.59
2	2000-02-03	3.936	1.3702	1.54	1.54	1	1.54
3	2000-02-15	10.845	2.3837	1.37	1.37	1	1.37
4	2000-02-19	15.518	2.7420	1.24	1.24	1	1.24

5	2000-03-23	56.917	4.0416	0.52	0.52	1	0.52
6	2000-06-05	1.812	0.5946	1.11	1.11	1	1.11
	Julian	Month	Day	DecYear	MonthSeq	SinDY	CosDY
1	54789	1	4	2000	1801	0.05576	0.9984
2	54819	2	34	2000	1802	0.54031	0.8415
3	54831	2	46	2000	1802	0.70101	0.7132
4	54835	2	50	2000	1802	0.74829	0.6634
5	54868	3	83	2000	1803	0.98742	0.1581
6	54942	6	157	2000	1806	0.44325	-0.8964

5.7 EGRET Plots

The Daily, Sample, and INFO dataframes (described in Secs. 5.1 - 5.3) are specifically formatted to be used with the EGRET package. The EGRET package has powerful modeling capabilities that use WRTDS, but EGRET also has graphing and tabular tools for exploring the data without using the WRTDS algorithm. See the EGRET vignette, user guide, and/or wiki (<https://github.com/USGS-R/EGRET/wiki>) for detailed information. Figure 3 shows one of the plotting functions that can be used directly from the dataRetrieval dataframes.

```
# Continuing Choptank example from the previous sections
library(EGRET)
multiPlotDataOverview()
```

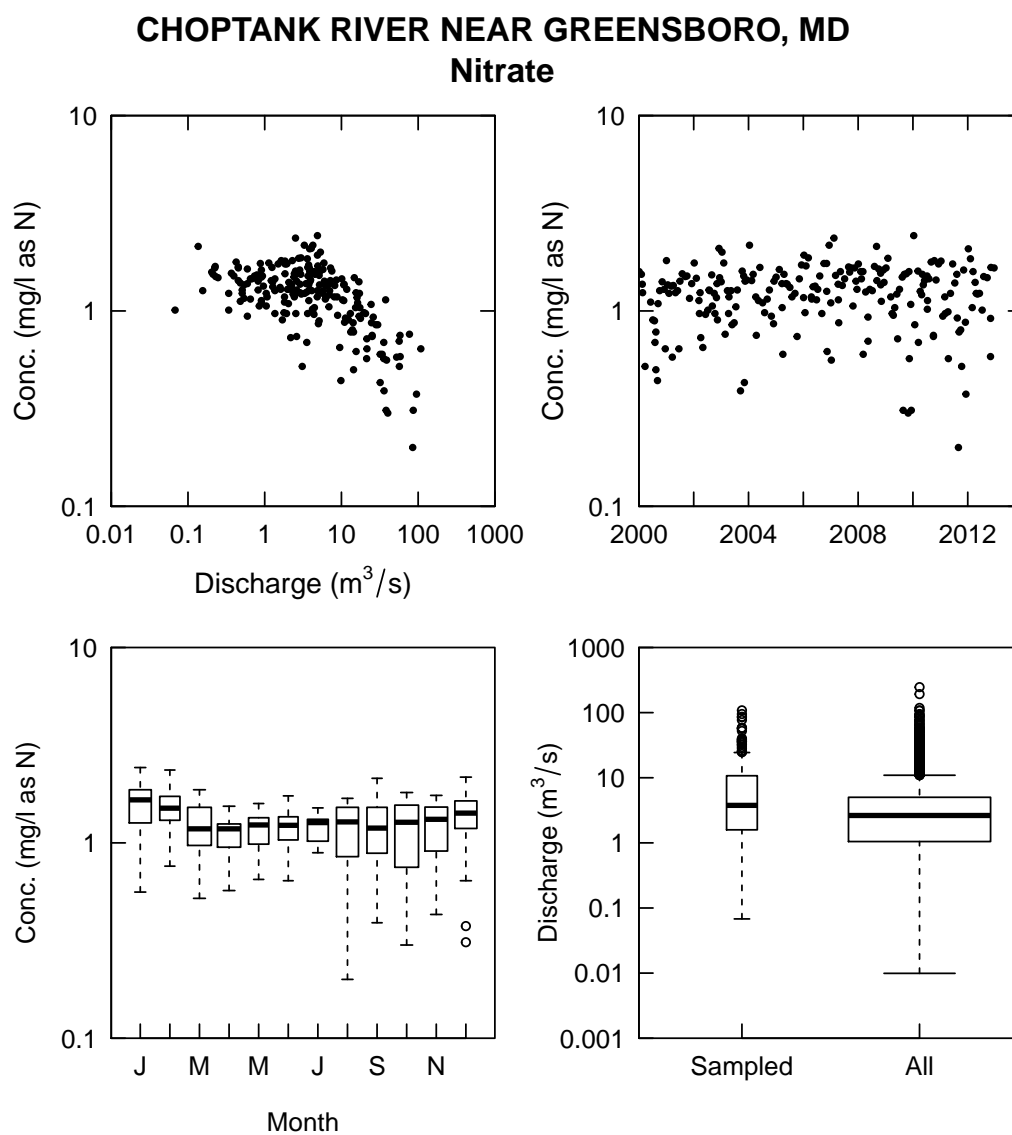


Figure 3. Default `multiPlotDataOverview`

6 Summary

Tables 8,9, and 10 summarize the data retrieval functions:

Table 8. dataRetrieval functions

Data Type	Function Name	Description
Daily	retrieveNWISdvData	Raw USGS daily data
Daily ¹	getNWISDaily	USGS daily values
Daily ¹	getUserDaily	User generated daily data
Sample	retrieveNWISqwData	Raw USGS water quality data
Sample	retrieveWQPqwData	Raw Water Quality Data Portal data
Sample	getWQPData	General Water Quality Portal
Sample ¹	getNWISSample	USGS water quality data
Sample ¹	getWQPSample	Water Quality Data Portal data
Sample ¹	getUserSample	User generated sample data
Unit	retrieveNWISunitData	Raw USGS instantaneous data
Information ¹	getMetaData	USGS station and parameter code information
Information	getNWISPCodeInfo	USGS parameter code information
Information	getNWISSiteInfo	USGS station information
Information	getNWISDataAvailability	Data available at USGS stations

¹ Indicates that the function creates a data frame suitable for use in EGRET software

Table 9. dataRetrieval functions organization

Source	Site Query	Meta Data	Raw Data	EGRET Data
NWIS: <i>Daily</i> <i>Unit/Instantaneous</i> <i>Groundwater</i> <i>Water Quality</i>	getNWISSites		getNWISData	
		getNWISSiteInfo	retrieveNWISdvData	getNWISDaily
	getNWISDataAvailability	getNWISPCodeInfo	retrieveNWISunitData	
		getNWISInfo	retrieveNWISqwData	getNWISSample
Water Quality Portal: <i>USGS</i> <i>EPA</i> <i>USDA</i>	getWQPSites	getWQPInfo	retrieveWQPqwData	getWQPSample
			getWQPData	
User-supplied files: <i>Daily</i> <i>Sample</i> <i>Site Information</i>				getUserDaily
		getUserInfo		getUserSample

Table 10. dataRetrieval function organization

Function Name	Description
compressData	Converts value/qualifier into ConcLow, ConcHigh, Uncen
getRDB1Data	Retrieves and converts RDB data to dataframe
getWaterML1Data	Retrieves and converts WaterML1 data to dataframe
getWaterML2Data	Retrieves and converts WaterML2 data to dataframe
mergeReport	Merges flow data from the daily record into the sample record
populateDateColumns	Generates Julian, Month, Day, DecYear, and MonthSeq columns
removeDuplicates	Removes duplicated rows
renameColumns	Renames columns from raw data retrievals

7 Getting Started in R

This section describes the options for downloading and installing the dataRetrieval package.

7.1 New to R?

If you are new to R, you will need to first install the latest version of R, which can be found here: <http://www.r-project.org/>.

At any time, you can get information about any function in R by typing a question mark before the functions name. This will open a file (in RStudio, in the Help window) that describes the function, the required arguments, and provides working examples.

```
?removeDuplicates
```

This will open a help file similar to Figure 4.

To see the raw code for a particular code, type the name of the function, without parentheses.:

```
removeDuplicates
function (localSample = Sample)
{
  Sample1 <- localSample[!duplicated(localSample[c("DecYear",
    "ConcHigh")]), ]
  return(Sample1)
}
<environment: namespace:dataRetrieval>
```

Additionally, many R packages have vignette files attached (such as this paper). To view the vignette:

```
vignette(dataRetrieval)
```

Remove Duplicates

Description

Removes observations from the data frame `Sample` when the observation has the identical date and value as another observation

Usage

```
removeDuplicates(localSample = Sample)
```

Arguments

`localSample` dataframe with at least `DecYear` and `ConcHigh`, default name is `Sample`

Value

`Sample1` dataframe

Examples

```
DecYear <- c('1985.01', '1985.01', '1985.02', '1985.02', '1985.03')
ConcHigh <- c(1,2,3,3,5)
dataInput <- data.frame(DecYear, ConcHigh, stringsAsFactors=FALSE)
removeDuplicates(dataInput)
```

[Package *dataRetrieval* version 1.3.0 [Index](#)]

Figure 4. A simple R help file

7.2 R User: Installing dataRetrieval

The following command installs dataRetrieval and subsequent required packages:

```
install.packages("dataRetrieval",  
repos=c("http://usgs-r.github.com", "http://cran.us.r-project.org"),  
dependencies=TRUE,  
type="both")
```

After installing the package, you need to open the library each time you re-start R. This is done with the simple command:

```
library(dataRetrieval)
```

8 Creating tables in Microsoft® software from R

There are a few steps that are required in order to create a table in Microsoft® software (Excel, Word, PowerPoint, etc.) from an R dataframe. There are certainly a variety of good methods, one of which is detailed here. The example we will step through here will be to create a table in Microsoft Excel based on the dataframe tableData:

```
availableData <- getNWISDataAvailability(siteNumber)  
dailyData <- availableData["dv" == availableData$service,]  
dailyData <- dailyData["00003" == dailyData$statCd,]
```

```
tableData <- with(dailyData,  
  data.frame(  
    shortName=srsname,  
    Start=startDate,  
    End=endDate,  
    Count=count,  
    Units=parameter_units)  
)
```

tableData

	shortName	Start
1	Temperature, water	2010-10-01
2	Stream flow, mean. daily	1948-01-01
3	Specific conductance	2010-10-01
4	Suspended sediment concentration (SSC)	1980-10-01
5	Suspended sediment discharge	1980-10-01
	End Count	Units
1	2012-05-09 529	deg C
2	2014-09-21 24371	ft3/s
3	2012-05-09 527	uS/cm @25C

```
4 1991-09-30 3651 mg/l
5 1991-09-30 3652 tons/day
```

First, save the dataframe as a tab delimited file (you don't want to use comma delimited because there are commas in some of the data elements):

```
write.table(tableData, file="tableData.tsv", sep="\t",
            row.names = FALSE, quote=FALSE)
```

This will save a file in your working directory called tableData.tsv. You can see your working directory by typing `getwd()` in the R console. Opening the file in a general-purpose text editor, you should see the following:

```
shortName Start End Count Units
Temperature, water 2010-10-01 2012-06-24 575 deg C
Stream flow, mean. daily 1948-01-01 2013-03-13 23814 ft3/s
Specific conductance 2010-10-01 2012-06-24 551 uS/cm @25C
Suspended sediment concentration (SSC) 1980-10-01 1991-09-30 3651 mg/l
Suspended sediment discharge 1980-10-01 1991-09-30 3652 tons/day
```

Next, follow the steps below to open this file in Excel:

1. Open Excel
2. Click on the File tab
3. Click on the Open option
4. Navigate to the working directory (as shown in the results of `getwd()`)
5. Next to the File name text box, change the dropdown type to All Files (*.*)
6. Double click tableData.tsv
7. A text import wizard will open up, in the first window, choose the Delimited radio button if it is not automatically picked, then click on Next.
8. In the second window, click on the Tab delimiter if it is not automatically checked, then click Finished.
9. Use the many formatting tools within Excel to customize the table

From Excel, it is simple to copy and paste the tables in other Microsoft® software. An example using one of the default Excel table formats is here.

shortName	Start	End	Count	Units
Temperature, water	10/1/2010	6/24/2012	575	deg C
Stream flow, mean. daily	1/1/1948	3/13/2013	23814	cfs
Specific conductance	10/1/2010	6/24/2012	551	uS/cm @25C
Suspended sediment concentration (SSC)	10/1/1980	9/30/1991	3651	mg/l
Suspended sediment discharge	10/1/1980	9/30/1991	3652	tons/day

Figure 5. A simple table produced in Microsoft® Excel. Additional formatting will be required, for example converting u to μ

9 Disclaimer

This information is preliminary and is subject to revision. It is being provided to meet the need for timely best science. The information is provided on the condition that neither the U.S. Geological Survey nor the U.S. Government may be held liable for any damages resulting from the authorized or unauthorized use of the information.