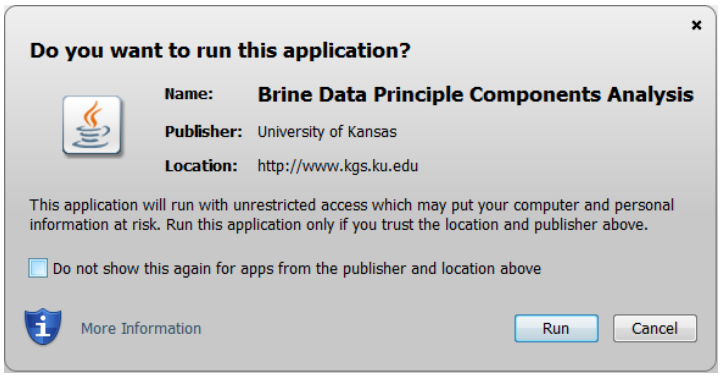
Brine Principal Components Analysis Java Applet

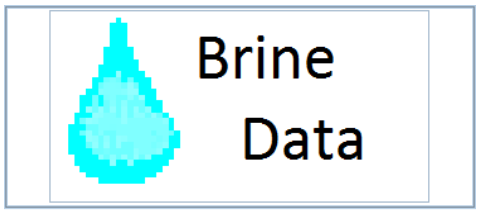
by John R. Victorine

Introduction

To access Profile go to http://www.kgs.ku.edu/PRS/Ozark/Software/PC/. At the top of the web page there is a menu "Main Page|Applet|Download|Help|Copyright & Disclaimer|". Select the "Applet" menu option a "Warning - Security" Dialog will appear. The program has to be able to read and write to the user's PC and access the Kansas Geological Survey (KGS) Database and File Server, ORACLE requires this dialog.



The program does not save your files to KGS, but allows you to access the KGS for well information that may be missing in your Kansas Data. The program does not use Cookies or any hidden software it only reads the CSV & XML files for the Principal Components Analysis Session and writes a CSV, XML and PNG Files to your PC to save the Brine data imported. The blue shield on the warning dialog is a symbol that the Java web app is created by a trusted source, which is the University of Kansas. Select the "Run" Button, which will show the Brine Data "Enter" Panel illustrated below,



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Loading Brine Data

Click the "Brine Data Enter" Icon Button, which will show the "Load Data" Dialog. The dialog below displays an example of the DOE CO_2 2015-10-12 Comma Separated Values (CSV) ASCII File, downloaded using the "PC: Read Brine Data by" panel. The radio buttons & icon buttons in the Data Source Panel assists the user in loading brine data into the Brine Data - Principal Component Applet. The DOE CO_2 2015-10-12 CSV ASCII File can be downloaded from the following URL address,

CSV: http://www.kgs.ku.edu/PRS/Ozark/Software/PC/DOE_CO2_Wells_2015_10_12.csv or
ZIP: http://www.kgs.ku.edu/PRS/Ozark/Software/PC/DOE_CO2_Wells_2015_10_12.zip

This file is the output file for an ORACLE PL/SQL stored procedure that accesses the DOE CO2 Project Brine Database Table,
http://chasm.kgs.ku.edu/ords/iqstrat.co2_brine_summary_csv_pkg.build_web_page .

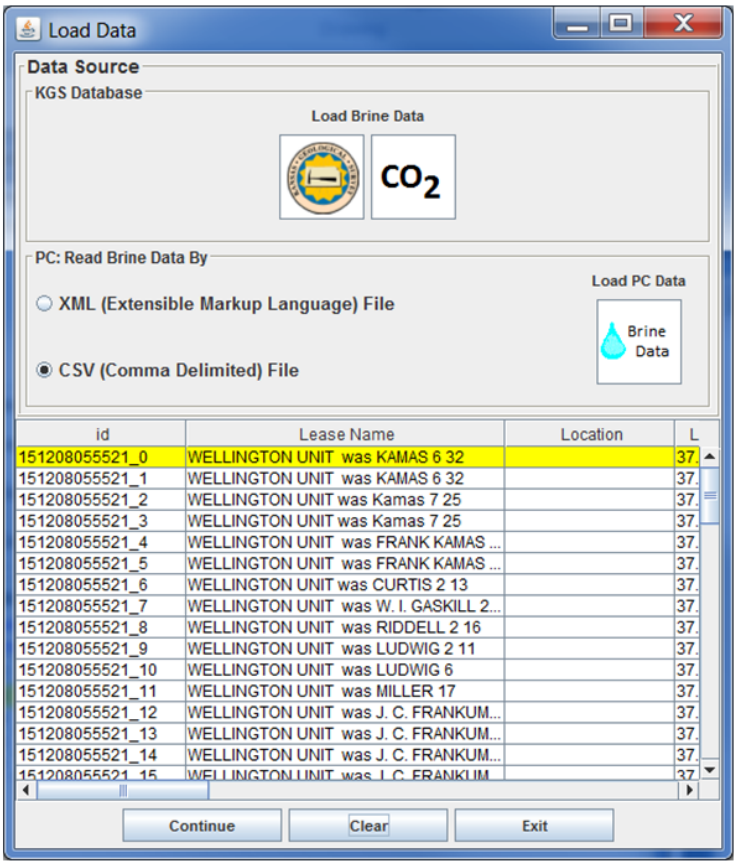
The data displayed is in a CSV format, but it has HTML code embedded, which can be trimmed easily.

KGS (Database) Panel
- KGS Icon
This button allows the user to search the KGS Brine Data Database Table for Brine Data. The Kansas Brine Data Records date back to 1940's and 1950's.
- CO2 Icon
This button allows the user to search the CO_2 Brine Data Database Table for Brine Data. This data supports the CO_2 Sequestration Project.

PC: Read Brine Data By Panel
This panel allows the user read in brine data by 2 file types
1. Comma Separated Values (CSV) ASCII File
2. Extensible Markup Language (XML) ASCII File

Brine Data Loaded Table
This identifies the records that have been downloaded to the web app for processing.

Load Data Dialog Buttons
Continue – Transfers the Brine Data in the table to the Brine Data Dialog.
Clear – Clears the Brine Data Loaded Table.
Exit – Exit Dialog.



Data Source Panel

The Data Source Panel provides two methods of importing data into the Brine Data & Data Entry Web App. The Kansas Geological Survey (KGS) Database and the user's PC. There are 2 icon buttons in the KGS Database panel. The KGS icon button assists the user in locating a set of brine data for selected counties in Kansas. The data are based on archived materials from the Kansas Geological Survey, with measured well data from the 1940's to 1950's. The CO2 icon button allows the user to download the brine data from the CO2 Project Brine Database table by dates measured, analyzed and reported. The "Load PC Data" icon button along with the 2 radio buttons assists the user to load Brine data by 3 possible ASCII File methods,

1. Comma Separated Values (CSV).
2. Extensible Markup Language (XML) Files.

The CSV (Comma Separated Values) radio button under the "PC: Read Brine Data By" panel are expecting a general type of data presentation. Although the order of the specific data columns is not important, the "Mnemonics" of the data column is. The CSV Search Dialog will use the first two lines of the CSV file to automatically match the file column data mnemonics with the web app curve mnemonics and the units of the brine data, but if the program does not recognize the file data mnemonic then it will leave it blank and expect the user to match the file data mnemonic to the web app curve mnemonics, this will be explained later.

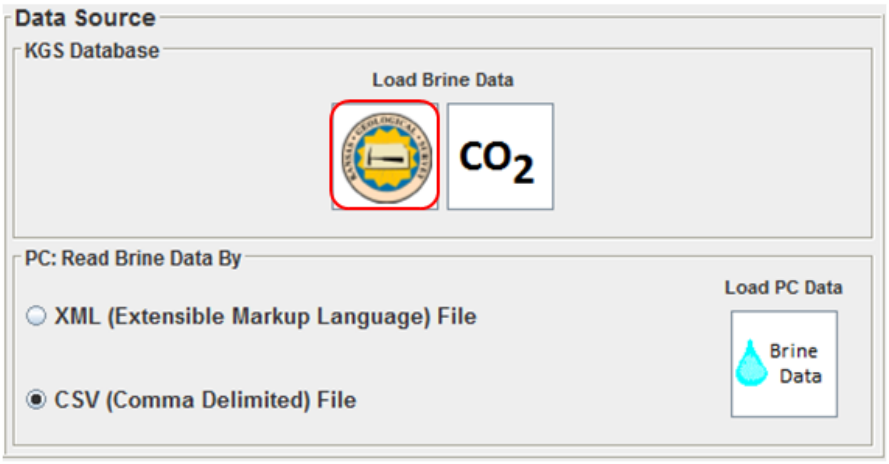
The Extensible Markup Language (XML) radio button under the "PC: Read Brine Data By" panel are expecting a specific Document Type Definition (DTD) to read the file. The DTD is used in retrieve both the data coming from the Kansas Geological Survey Database or as the output from the Brine Data & Data Entry Java Web App. The DTD will be presented later.

Data Loaded Panel

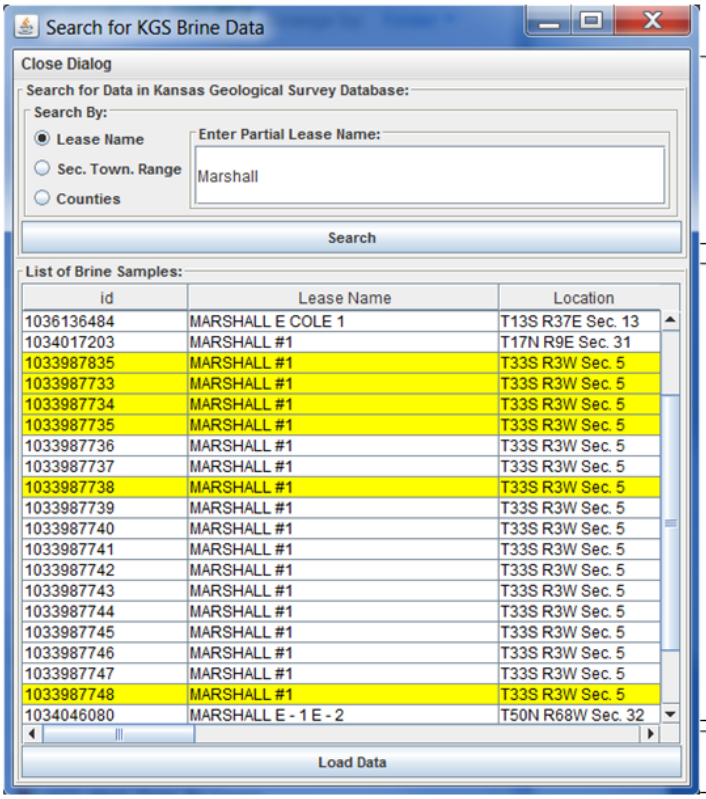
The Brine Data Loaded Panel provides a visual feedback that the brine data was loaded, by the individual samples listed in the "Brine Data Loaded" table. When the user selects the "Continue" button the data is transferred to the Brine Data dialog, where the Principal Components Process can be performed on the data.

KGS (Database) - Importing Brine Data – KGS Icon button

The Kansas Geological Survey (KGS) has a good collection of brine data stored in the ORACLE Database. In this example the user will download the well data available from the KGS Brine Database. The ORACLE Database is accessed by making Stored Procedure PL/SQL calls to the ORACLE Database from which an Extensible Markup Language (XML) data stream is created containing the well & brine data that is passed back to the web app making the request.



Left Click on the KGS Icon Button in the Data Source Panel of the Load Data Dialog.



Search for Brine Data in KGS Database
Search By:
- **Lease Name** – The user can search for well data by lease partial phrase, i.e. "Marshall", which will look for all wells with the phrase "Marshall" in the lease name.
- **Section Township Range** – Search for a list of Wells by a specific area.
- **Counties** – Search for a list of Brine Data within counties available in Brine Database Table.

List of Brine Data for wells that match the search criteria

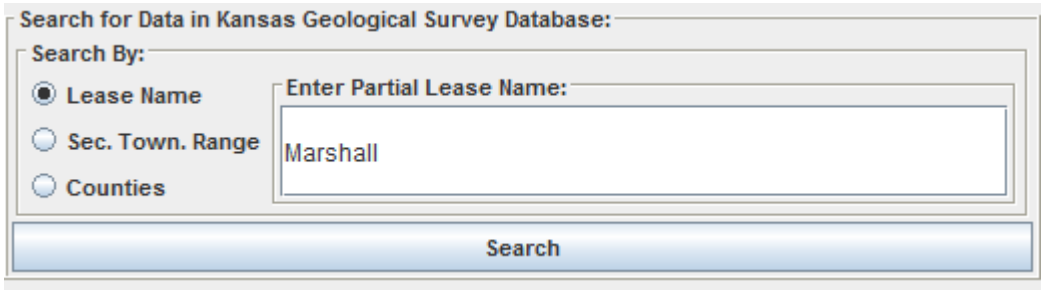
Note: the "List of Brine Samples" Table is set up to make multiple selections of data using the "Ctrl" Key on the keyboard with left click of mouse. Sell the highlighted brine samples for the MARSHALL #1 Well.

Load Data Button – transfers the selected brine data to the calling web app.

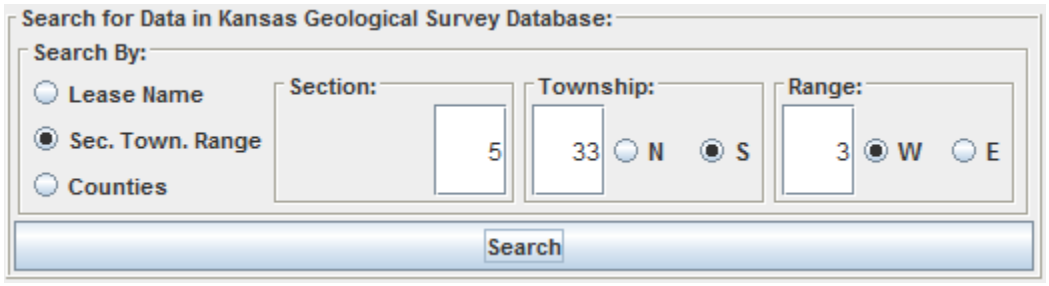
This will display the "Search for KGS Brine Data" Dialog, see above image. This dialog allows the user to search the KGS database for brine data. In this example, the well of interest will be the Marshall #1 this well contains all the brine samples that can be retrieved from the KGS Database.

As the Summary image suggests there are 3 methods for searching for the well data within this dialog,

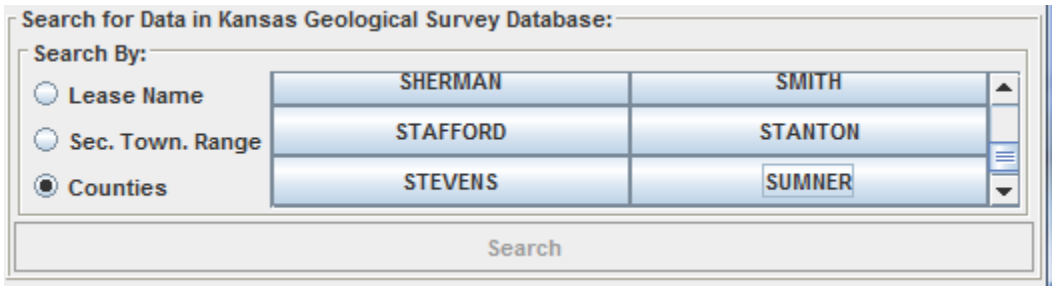
- By Partial Lease Name – The stored procedure used to retrieve the list of brine samples from the KGS Database allows the user to enter a partial phrase, in this example Marshall. The program places a '%' in front and back of the phrase and sends the request to the Database, i.e. "%Marshall%".



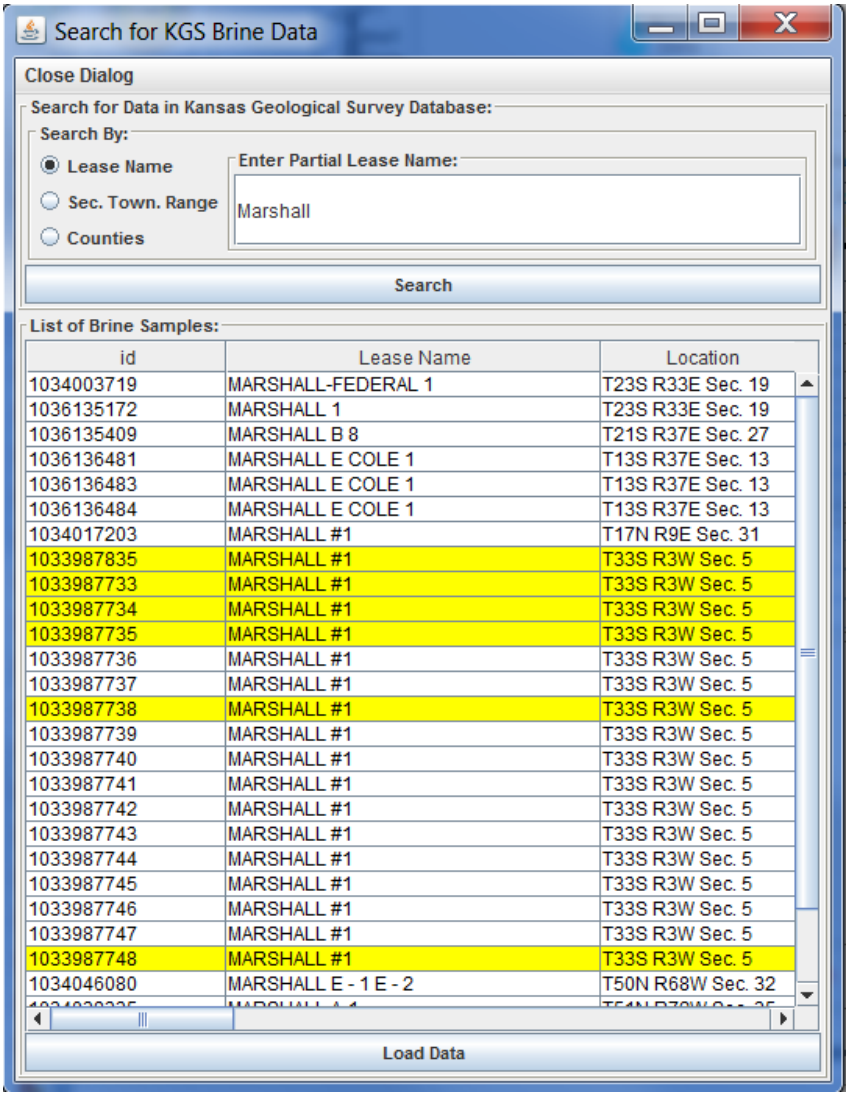
- By Township Range Section – This search is for brine samples in Kansas by, e.g. to look for the Marshall #1 brine samples, enter Section as 5, Township as 33 set the S (South) Radio button and Range as 3 set the W (West) Radio button.



- By County – This panel allows the user to search for brine samples by counties with brine data in the database table, e.g. select the SUMNER County Button.



The user only needs to enter the above data and select the "Search" Button to display the list of brine data samples in the Kansas Database that match the search criteria. In the image below the Lease Name "Marshall" was entered to search for all brine samples for wells in Kansas with the Phrase Marshall in it. The user searches through the list until they find the well of interest. In this example 6 brine samples are highlighted for the Marshall #1 well.

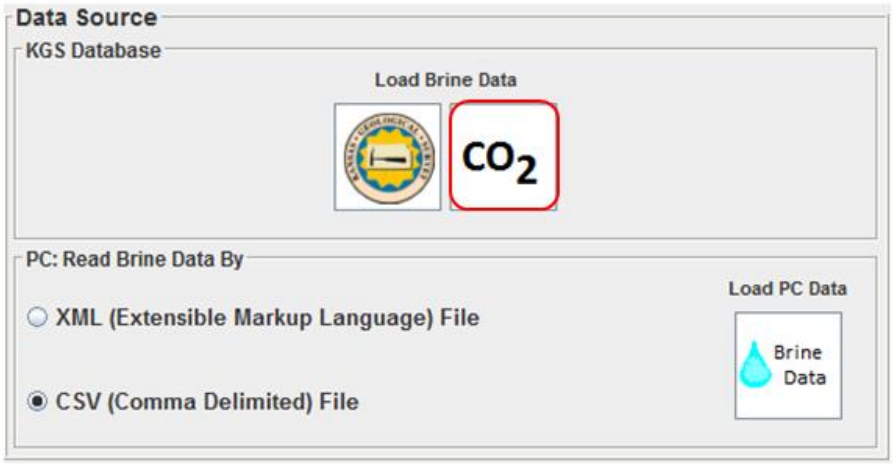


To download the brine data select the "Load Data" Button.

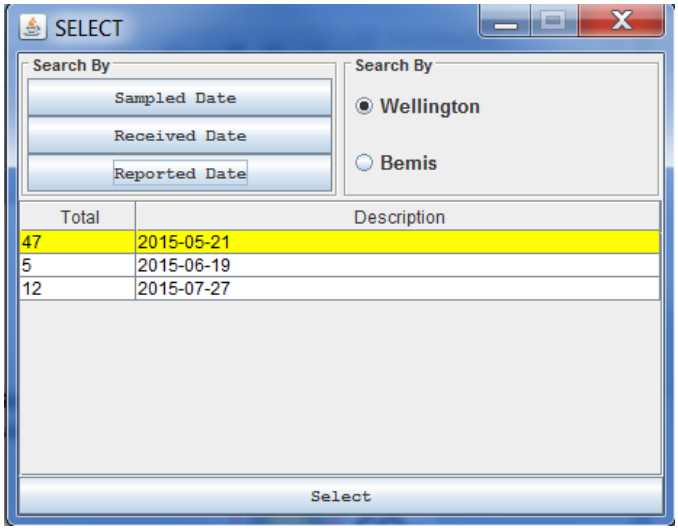
Note: The user needs to hit the "Ctrl" Key on the Keyboard at the same time as they left click with the mouse to select the brine samples for the Marshall #1. In this case there are a number of overlapping samples so only the above samples were selected for viewing. The Brine Data database table is not connected to the Well Headers Table in the Database. For most part the brine data database table holds data from the 1940's and the 1950's. The user will need to search the KGS Master List of Oil and Gas Wells in Kansas web page (http://www.kgs.ku.edu/Magellan/Qualified/index.html). The brine data samples belong to the Marshall 1 (15-191-00003) Township 33S, Range 3W and Section 5, Sumner County, Kansas.

KGS (Database) - Importing Brine Data – CO_2 Icon button

The CO_2 Icon button allows the user to download the well data available from the DOE CO2 Brine Database. The ORACLE Database is accessed by making Stored Procedure PL/SQL calls to the ORACLE Database from which an Extensible Markup Language (XML) data stream is created containing the well & brine data that is passed back to the web app making the request.



Left Click on the CO_2 Icon Button in the Data Source Panel of the Load Data Dialog to display the search dialog. There is only one search engine with this dialog the Search By "Dates".



Selecting any of the "Search By" buttons will automatically search for data in the Brine Data Database Table based on the type of search. The following buttons will retrieve the available brine data by XML - Extensible Markup Language data streams that are parsed. The XML calls are listed as follows:

Buttons	ORACLE PL/SQL call to retrieve the number of wells and available dates
Sampled Date	http://chasm.kgs.ku.edu/ords/iqstrat.co2_grid_brine_data_pkg.getDateListXML?iDate=0
Received Date	http://chasm.kgs.ku.edu/ords/iqstrat.co2_grid_brine_data_pkg.getDateListXML?iDate=1
Reported Date	http://chasm.kgs.ku.edu/ords/iqstrat.co2_grid_brine_data_pkg.getDateListXML?iDate=2

The Search By "Dates" returns the actual date entered for the brine data group and the total number of wells that have brine data with that date, i.e., select the "Reported Date" Button and the following list will be displayed.

Total	Description
47	2015-05-21
5	2015-06-19
12	2015-07-27

At the time of this document there are only 3 possible well groups, "2015-05-21", 2015-06-19" and "2015-07-27". The "2015-05-27" brine data well group has a total of 47 wells out of a possible 52 wells with brine data sampled on this date. The user only needs to highlight the 1st row in the list and click on the "Select" button at the bottom of the panel. This action will automatically retrieve the date as the search criteria and make an ORACLE PL/SQL call,

http://chasm.kgs.ku.edu/ords/iqstrat.co2_grid_brine_data_pkg.getDateXML?iDate=2&sTime=2015-05-21&field=Wellington

This call will return a XML – Extensible Markup Language data stream with a list of wells and the brine data of each well in the Reported Date Well Brine Data Group.

Importing PC Data - Download Well Data to PC

Download either the ASCII Text Files directly or the Zip files extracting the contents into a directory. The problem with the ASCII Text Files being downloaded directly from a web page is that the web page will alter the contents so it does not retain the basic structure and add HTML text to the file. The preferred method if you have Zip or WinZip is to download the zip files to your PC and extract.

Well Data:

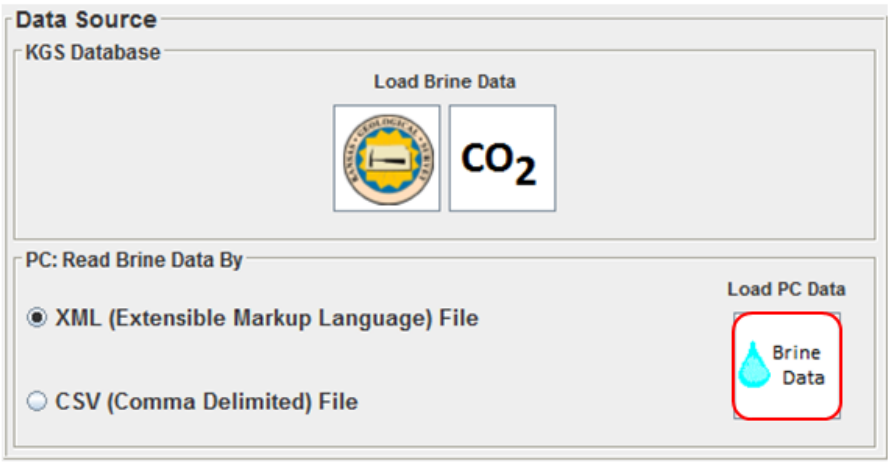
CSV File contains the all the brine data in the DOE CO_2 Brine Database Table on the date 12 October 2015.
XML File contains the brine data in the DOE CO_2 Brine Database Table for the Reported Date 21 May 2015.

Type	ASCII Text Files
CSV	http://www.kgs.ku.edu/PRS/Ozark/Software/PC/DOE_CO2_Wells_2015_10_12.csv
XML	http://www.kgs.ku.edu/PRS/Ozark/Software/PC/DOE_CO2_Wells_2015_05_21.xml

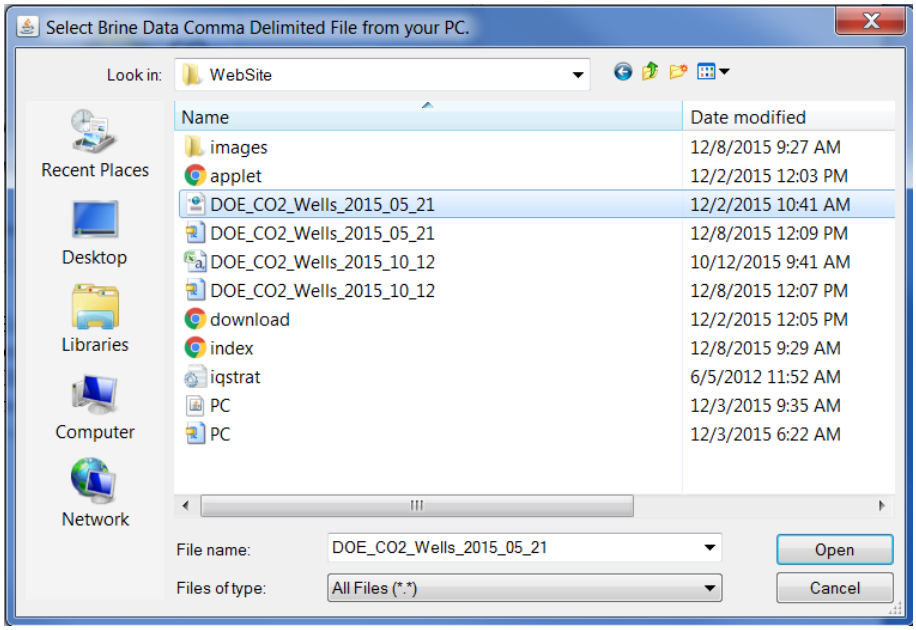
Type	Zip Files
CSV	http://www.kgs.ku.edu/PRS/Ozark/Software/PC/DOE_CO2_Wells_2015_10_12.zip
XML	http://www.kgs.ku.edu/PRS/Ozark/Software/PC/DOE_CO2_Wells_2015_05_21.zip

Importing PC Data – Brine XML (Extensible Markup Language) ASCII File.

This web app allows the user to save and read Brine Data as Extensible Markup Language (XML) file. The data that is retrieved from the Kansas Geological Survey database is retrieved as a XML data stream that is parsed and loaded into the Brine Plot & Data Entry web app. This program allows the user to save the data as a XML file, which uses the same Document Type Definition (DTD) to format the data.



Select the "XML (Extensible Markup Language) ASCII File" radio button and then left click on the "Brine Data" Icon Button in the Data Source Panel of the Load Data Dialog. This will display the "Select Brine Data Comma Delimited File from your PC" Dialog. This dialog allows the user to search their PC for the file of interest. In this example it is the Brine XML file DOE_CO2_Wells_2015_05_21.xml, highlighted below.



Brine Data Extensible Markup Language (XML) Document Type Definition (DTD).

The Brine Data DTD defines the contents of the XML File.
The DTD for the Brine Data is as follows,

```
<?xml version="1.0"?>
<!DOCTYPE fluid_data [
<!ELEMENT fluid_data (columns*,
data*)+>
<!ELEMENT columns (column*)>
<!ATTLIST columns records CDATA
#REQUIRED>
<!ELEMENT column EMPTY>
<!ATTLIST column mnemonic CDATA
#REQUIRED
          name    CDATA #REQUIRED
          unit    CDATA #REQUIRED
          type    CDATA #REQUIRED>
<!ELEMENT data (row*)>
<!ATTLIST data records CDATA
#REQUIRED>
<!ELEMENT row EMPTY>
<!ATTLIST row  KEY    CDATA #IMPLIED
```

Well Header Information →

```
API    CDATA #IMPLIED
NAME   CDATA #IMPLIED
FIELD  CDATA #IMPLIED
LOC    CDATA #IMPLIED
COUNTY CDATA #IMPLIED
STATE  CDATA #IMPLIED
LAT    CDATA #IMPLIED
LONG   CDATA #IMPLIED
KB     CDATA #IMPLIED
GL     CDATA #IMPLIED
DF     CDATA #IMPLIED
TGT    CDATA #IMPLIED
SRC    CDATA #IMPLIED
DATE   CDATA #IMPLIED
```

Other Measured Data →

```
FORM   CDATA #IMPLIED
AGE    CDATA #IMPLIED
TOP    CDATA #IMPLIED
BASE   CDATA #IMPLIED
SPGR   CDATA #IMPLIED
SIGMA  CDATA #IMPLIED
PH     CDATA #IMPLIED
DEG    CDATA #IMPLIED
OHM    CDATA #IMPLIED
OHM75  CDATA #IMPLIED
OHME   CDATA #IMPLIED
```

Cations

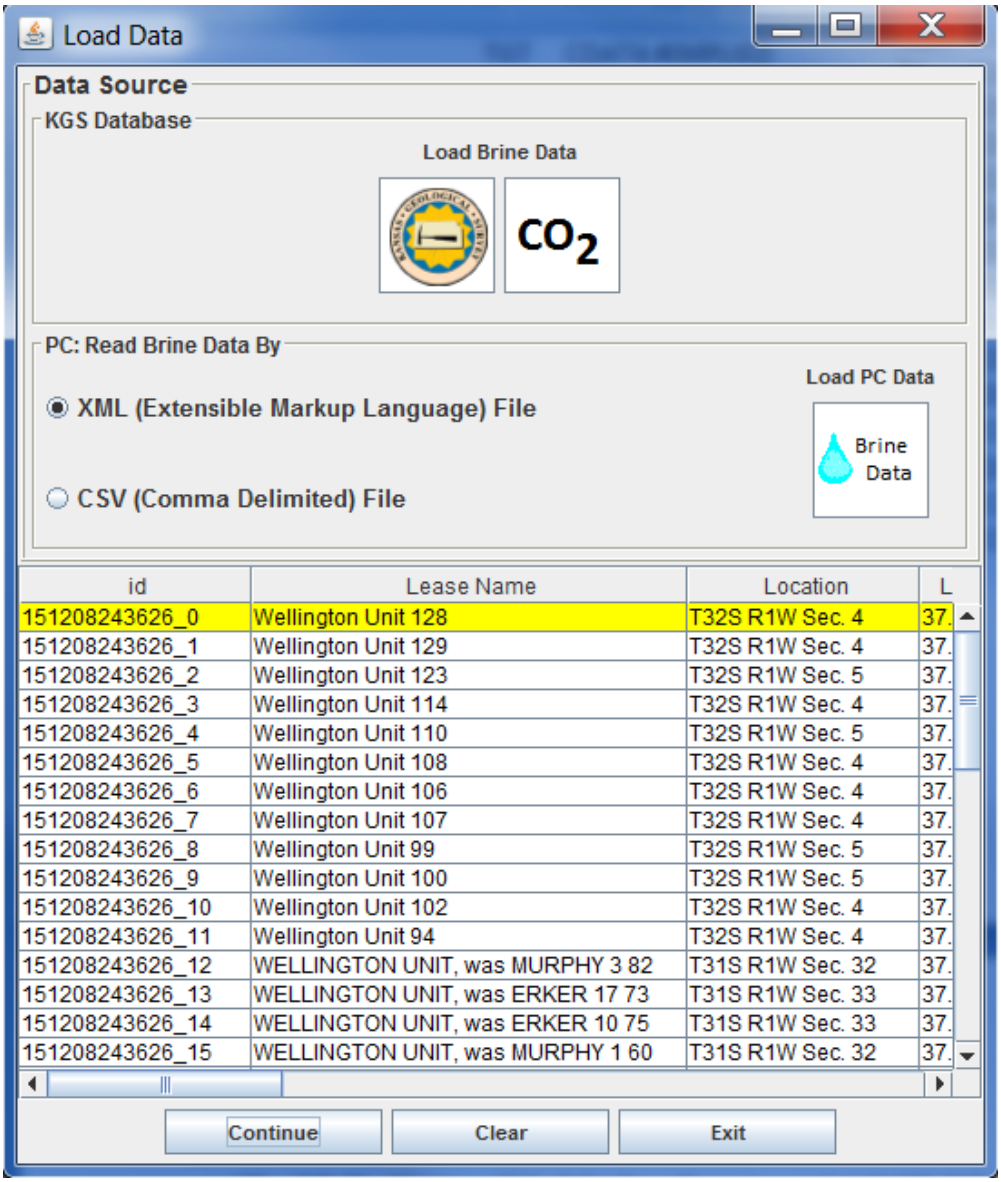
```
Li     CDATA #IMPLIED
Na     CDATA #IMPLIED
K      CDATA #IMPLIED
Rb     CDATA #IMPLIED
Cs     CDATA #IMPLIED
Na_K   CDATA #IMPLIED
Be     CDATA #IMPLIED
Mg     CDATA #IMPLIED
Ca     CDATA #IMPLIED
Sr     CDATA #IMPLIED
Ba     CDATA #IMPLIED
CrII   CDATA #IMPLIED
CrIII  CDATA #IMPLIED
MnII   CDATA #IMPLIED
MnIII  CDATA #IMPLIED
FeII   CDATA #IMPLIED
FeIII  CDATA #IMPLIED
CoII   CDATA #IMPLIED
CoIII  CDATA #IMPLIED
NiII   CDATA #IMPLIED
NiIII  CDATA #IMPLIED
Cu     CDATA #IMPLIED
CuII   CDATA #IMPLIED
Ag     CDATA #IMPLIED
Au     CDATA #IMPLIED
AuIII  CDATA #IMPLIED
Zn     CDATA #IMPLIED
Cd     CDATA #IMPLIED
Hg     CDATA #IMPLIED
HgII   CDATA #IMPLIED
Al     CDATA #IMPLIED
SbIII  CDATA #IMPLIED
SbV    CDATA #IMPLIED
BiIII  CDATA #IMPLIED
BiV    CDATA #IMPLIED
SnII   CDATA #IMPLIED
SnIV   CDATA #IMPLIED
PbII   CDATA #IMPLIED
PbIV   CDATA #IMPLIED
NH4    CDATA #IMPLIED
```

Anions

```
F      CDATA #IMPLIED
Cl     CDATA #IMPLIED
Br     CDATA #IMPLIED
I      CDATA #IMPLIED
OH     CDATA #IMPLIED
BO3    CDATA #IMPLIED
CO3    CDATA #IMPLIED
HCO3   CDATA #IMPLIED
ClO    CDATA #IMPLIED
ClO2   CDATA #IMPLIED
ClO3   CDATA #IMPLIED
ClO4   CDATA #IMPLIED
CN     CDATA #IMPLIED
NCO    CDATA #IMPLIED
OCN    CDATA #IMPLIED
SCN    CDATA #IMPLIED
N      CDATA #IMPLIED
N3     CDATA #IMPLIED
NO2    CDATA #IMPLIED
NO3    CDATA #IMPLIED
CrO4   CDATA #IMPLIED
Cr2O7  CDATA #IMPLIED
MnO4   CDATA #IMPLIED
P      CDATA #IMPLIED
PO4    CDATA #IMPLIED
HPO4   CDATA #IMPLIED
H2PO4  CDATA #IMPLIED
As     CDATA #IMPLIED
Se     CDATA #IMPLIED
S      CDATA #IMPLIED
HS     CDATA #IMPLIED
SO3    CDATA #IMPLIED
HSO3   CDATA #IMPLIED
S2O3   CDATA #IMPLIED
SO4    CDATA #IMPLIED
HSO4   CDATA #IMPLIED

SOLID  CDATA #IMPLIED
TDS    CDATA #IMPLIED>]>
```

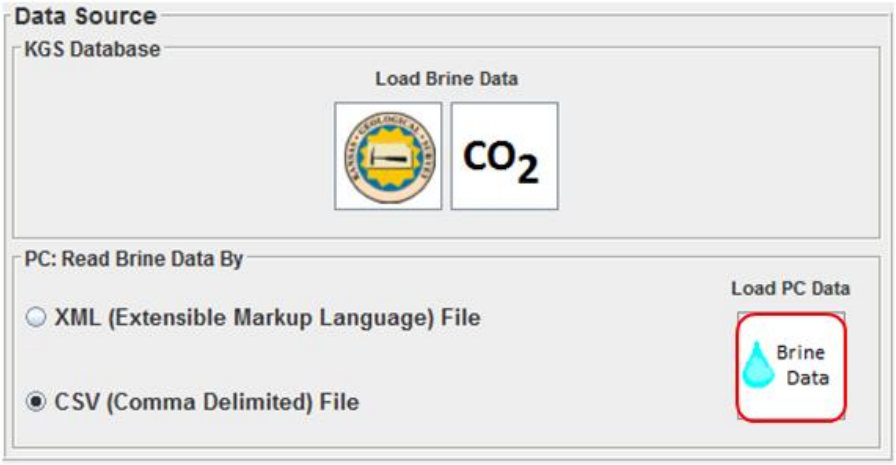
The XML (Extensible Markup Language) ASCII File Read & Parse routines expect the brine data to fit the above DTD (Document Type Definition), otherwise the data will not parse correctly. Select the Open button to load the brine data directly to the "Brine Data Loaded" table.



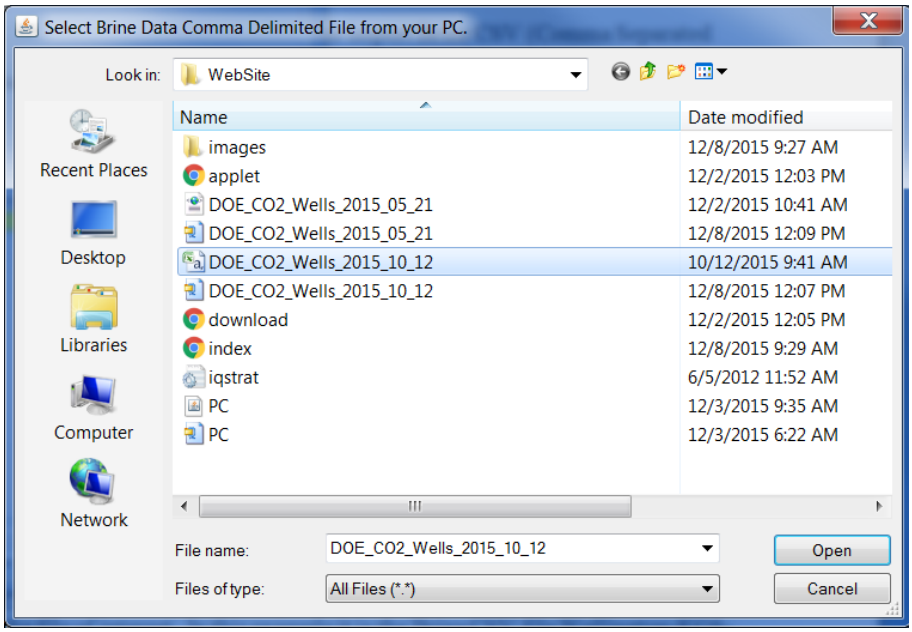
The user only needs to click on the "Continue" button to send the brine data to the "Brine Data" dialog.

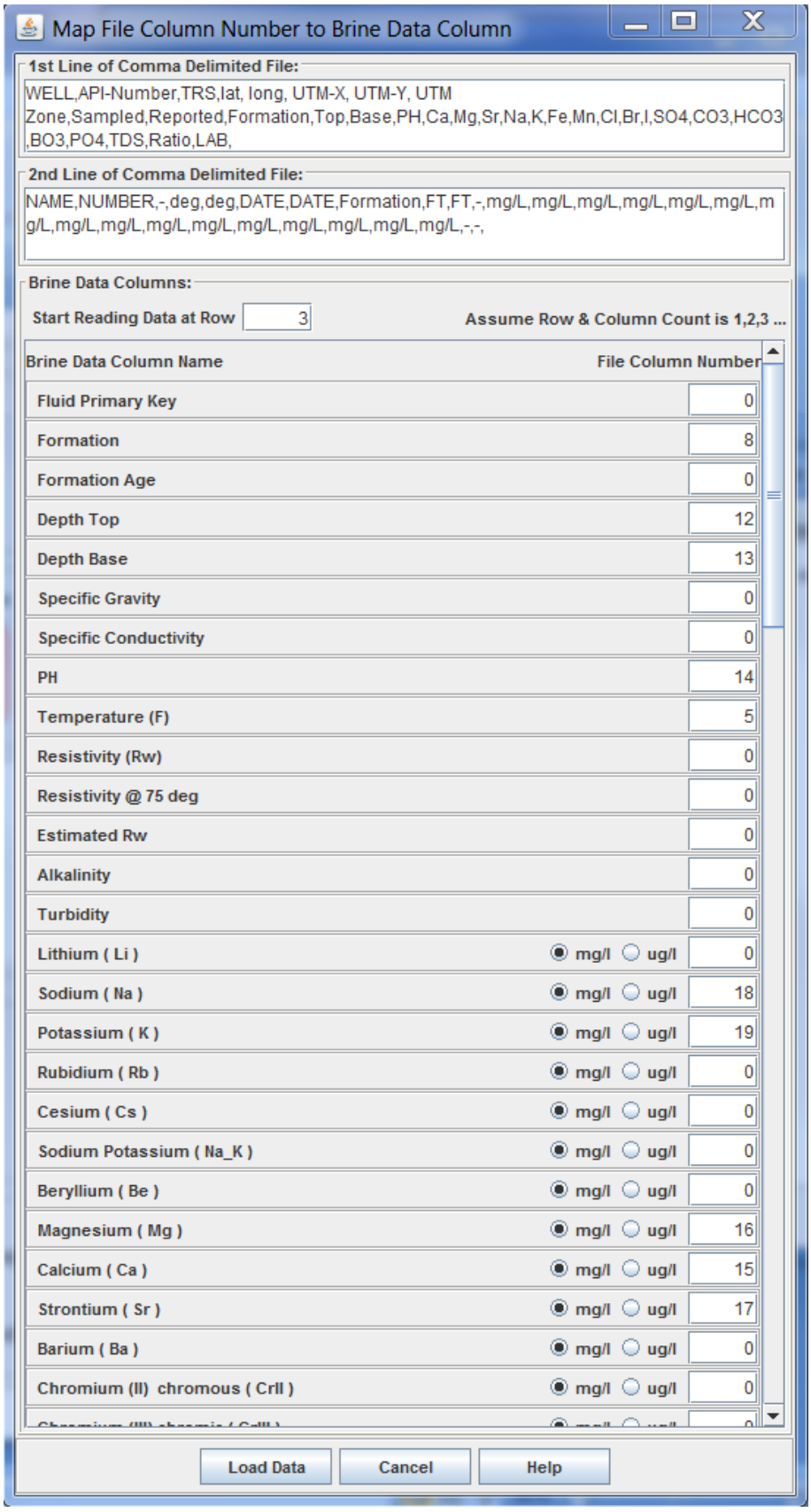
Importing PC Data – Brine CSV (Comma Separated Values) ASCII File.

Most of the web apps will use the same input dialogs to import Brine CSV (Comma Separated Values) file. The Load Data Dialog is basically the same for most of the Web Apps, except they only load a subset of the total data types. In this example a Brine CSV file is being imported into the web app.



Select the "CSV (Comma Delimited) ASCII File" radio button and then left click on the "Brine Data" Icon Button in the Data Source Panel of the Load Data Dialog. This will display the "Select Brine Data Comma Delimited File from your PC" Dialog. This dialog allows the user to search their PC for the file of interest. In this example it is the Brine CSV file DOE_CO2_Wells_2015_10_12.csv, highlighted below. Select the Open button to display the "Select Brine Data Comma Delimited File from your PC" Dialog.





The "Map File Column Number to Brine Data Column" Dialog allows the user to map the file columns number to the web app brine data structure. In this example the file has the file data columns in line one of the Brine Data CSV File and line two of the Brine Data CSV File has the data units. In this case the chosen file columns match the Brine Mnemonics for the brine data structure for most part. The File Column Number is automatically assigned to the Brine Data Column Names. The user only needs to select the "Load Data" Button to parse the Brine Data into the web app. This dialog has the data units as radio buttons to represent mg/l (milligrams/liter) and ug/l (micrograms/liter). The dialog will convert all data to mg/l.

Brine Data CSV (Comma Separated Values) File Structure.

The Brine Data CSV example has two introduction lines, the first line is the file data columns and the second line is the column units for the brine data, illustrated below,

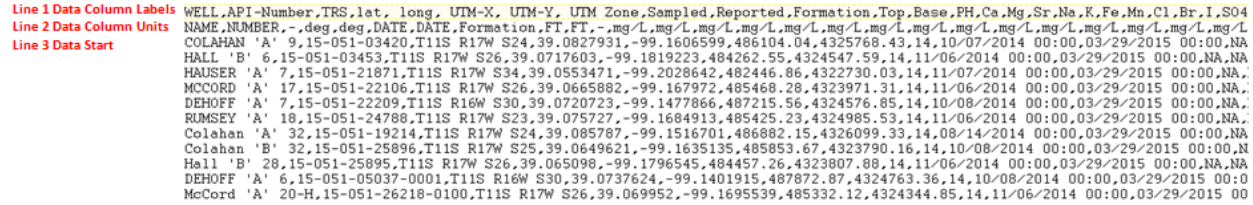


Figure: Partial Contents of Brine.csv File.

The "Map File Column Number to Brine Data Column" Dialog allows the user to map the data in the Brine Data CSV File to the web app data structure variables. The program first reads the first and second line of the CSV File looking for the data column headers. The lines are each parsed to single out the data column headers and to match those headers to the brine data structure. The program then assigns the column number to the Brine Data Column Name starting at column 1,2,3, … if the file column name used matches the expected brine column name. Next the program then searches both lines for the units and automatically sets the radio button to ug/l if it sees ug/l text for the column otherwise it assumes mg/l. The Column Names matrix used to parse the file column variables are listed below,

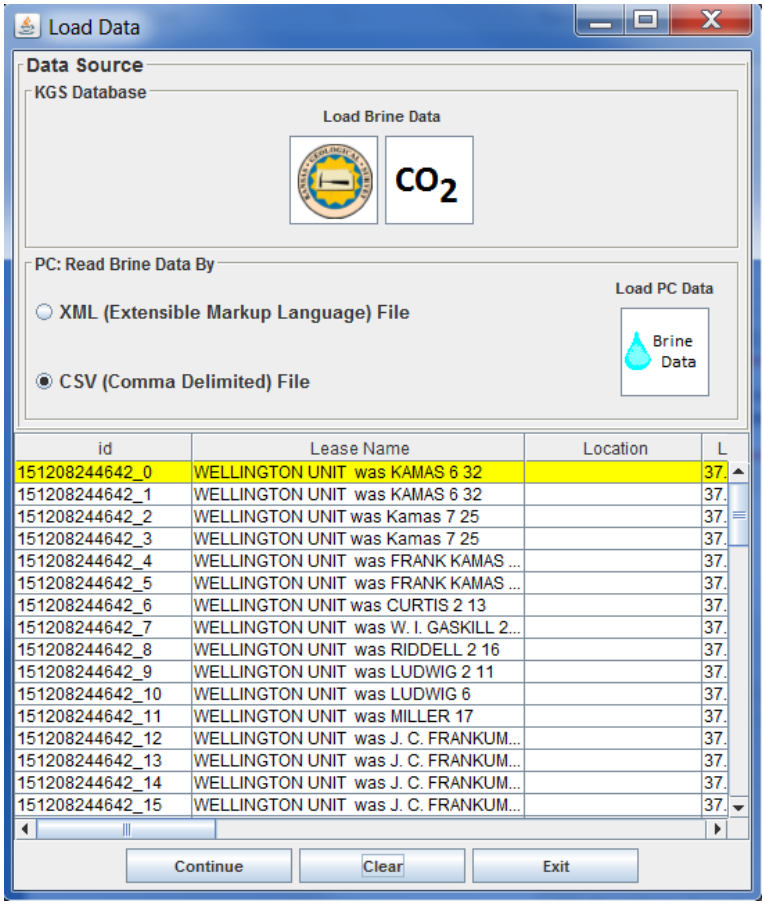
Common Anions			
Formula	**Chemical Name**	**Formula**	**Chemical Name**
F	Fluoride	NO2	Nitrite
Cl	Chloride	NO3	Nitrate
Br	Bromide	CrO4	Chromate
I	Iodine	Cr2O7	Dichromate
OH	Hydroxide	MnO4	Permanganate
BO3	Borate	P	Phosphide
CO3	Carbonate	PO4	Phosphate
HCO3	Bicarbonate	HPO4	Monohydrogen Phosphate
ClO	Hypochlorite	H2PO4	Dihydrogen Phosphate
ClO2	Chlorite	As	Arsenide
ClO3	Chlorate	Se	Selenide
ClO4	Per chlorate	S	Sulfide
CN	Cyanide	HS	Hydrogen Sulfide
NCO	Cyanate	SO3	Sulphite
OCN	Isocyanate	HSO3	Hydrogen Sulphite
SCN	Thicyanite	S2O3	Thiosulphate
N	Nitride	SO4	Sulfate
N3	Azide	HSO4	Bisulfate

Common Cations					
Formula	**Chemical Name I**	**Chemical Name II**	**Formula**	**Chemical Name I**	**Chemical Name II**
Alkali Metal			**IB**		
Li	Lithium		Cu	Copper(I)	cuprous
Na	Sodium		CuII	Copper(II)	cupric
K	Potassium		Ag	Silver	
Rb	Rubidium		Au	Gold	aurous
Cs	Cesium		AuIII	Gold(III)	auric
Na_K	Sodium Potassium		**IIB**		
Alkali Earth Metal			Zn	Zinc	
Be	Beryllium		Cd	Cadmium	
Mg	Magnesium		Hg	Mercury(I)	mercurous
Ca	Calcium		HgII	Mercury(II)	mercuric
Sr	Strontium		**IIIA**		
Ba	Barium		Al	Aluminum	
VIB			**IVA**		
CrII	Chromium(II)	chromous	SnII	Tin(II)	stannous
CrIII	Chromium(III)	chromic	SnIV	Tin(IV)	stannic
VIIB			PbII	Lead(II)	plumbous
MnII	Manganese(II)	manganous	PbIV	Lead(IV)	plumbic
MnIII	Manganese(III)	manganic	**VA**		
VIIIB			SbIII	Antimony(III)	antimonous
FeII	Iron(II)	ferrous	SbV	Antimony(V)	antimonic
FeIII	Iron(III)	ferric	BiIII	Bismuth(III)	bismuthous
CoII	Cobalt(II)	cobaltous	BiV	Bismuth(V)	bismuthic
CoIII	Cobalt(III)	cobaltic	**Other**		
NiII	Nickel(II)	nickelous	NH4	Ammonium	
NiIII	Nickel(III)	nickelic			

Other Variables			
Mnemonic	**Description**	**Mnemonic**	**Description**
FORM	Formation	**Other Measured Well Data**	
AGE	Formation Age	SPGR	Specific Gravity
Depth Range of Sample		SIGMA	Specific Conductivity
TOP	Depth Top	PH	PH
BASE	Depth Base	DEG	Temperature (F)
		OHM	Resistivity (Rw)
		OHM75	Resistivity at 75 deg
		OHME	Estimated Rw

Other Variables II			
Mnemonic	**Description**	**Mnemonic**	**Description**
Well ID		**Other Well Info**	
NAME	Well Name	FIELD	Field
API	API-Number	**Depth Information**	
Location		KB	Kelly Bushing
COUNTY	County	GL	Ground Level
STATE	State	DF	Derrick Floor
LOC	Location	TGT	TGT
LAT	Latitude	SRC	source
LONG	Longitude		

When the user selects the "Load Data" Button on the "Map File Column Number to Brine Data Column" Dialog the data is parsed into the Brine Plot & Data Entry web app, where the contents of the Brine Data CSV file name is loaded into the "List of Brine Samples" table.

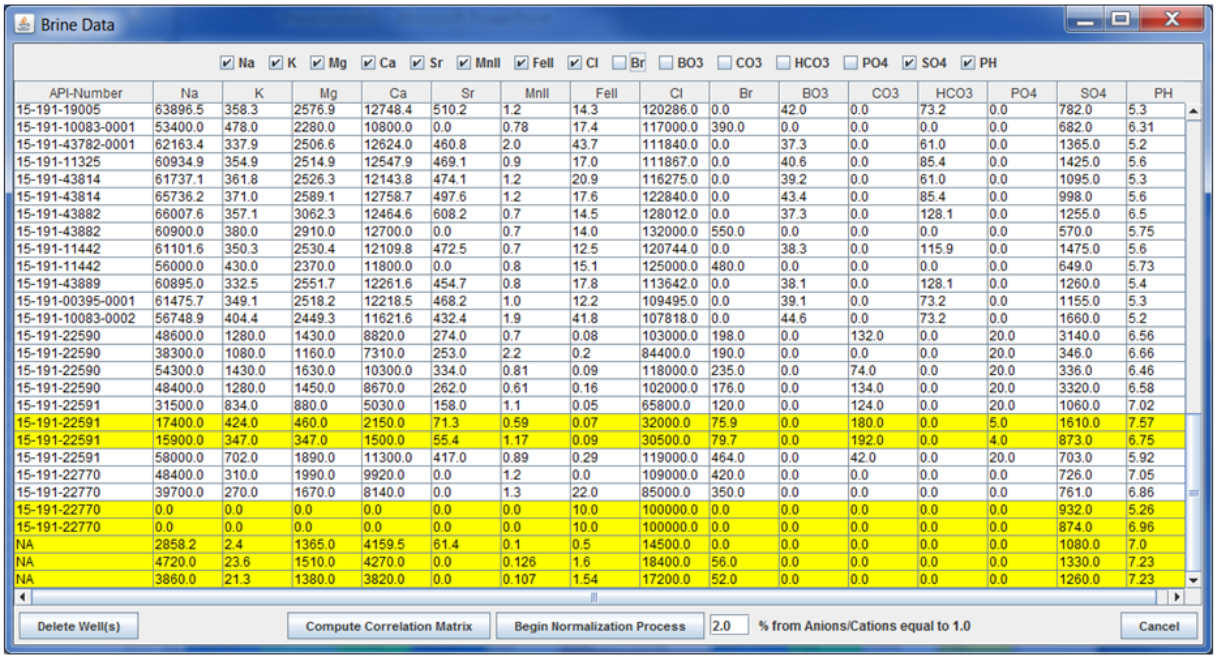


The user only needs to click on the "Continue" button to send the brine data to the "Brine Data" dialog.

Brine Data Dialog

The Brine Data Dialog allows the user to remove unwanted wells with incomplete brine data measurements or data that are outliers that will alias the results of the Principal Components Analysis. The Principal Component Java Functions will not compute the eigenvalues or eigenvector if the column has only zeros. The program will send a warning to the user which columns have zeros and disable functionality of the dialog. To avoid this, the user has the option of deselecting the checkboxes for brine data with excessive zeros before continuing to the next level.

Check boxes at top allow the user to deselect columns with large number of zeros. The Principal Components Matrix functions will not work with a zero column.



API-Number	Na	K	Mg	Ca	Sr	MnII	FeII	Cl	Br	BO3	CO3	HCO3	PO4	SO4	PH
15-191-19005	63896.5	358.3	2576.9	12748.4	510.2	1.2	14.3	120286.0	0.0	42.0	0.0	73.2	0.0	782.0	5.3
15-191-10083-0001	53400.0	478.0	2280.0	10800.0	0.0	0.78	17.4	117000.0	390.0	0.0	0.0	0.0	0.0	682.0	6.31
15-191-43782-0001	62163.4	337.9	2506.6	12624.0	460.8	2.0	43.7	111840.0	0.0	37.3	0.0	61.0	0.0	1365.0	5.2
15-191-11325	60934.9	354.9	2514.9	12547.9	469.1	0.9	17.0	111867.0	0.0	40.6	0.0	85.4	0.0	1425.0	5.6
15-191-43814	61737.1	361.8	2526.3	12143.8	474.1	1.2	20.9	116275.0	0.0	39.2	0.0	61.0	0.0	1095.0	5.3
15-191-43814	65736.2	371.0	2589.1	12758.7	497.6	1.2	17.6	122840.0	0.0	43.4	0.0	85.4	0.0	998.0	5.6
15-191-43882	66007.6	357.1	3062.3	12464.6	608.2	0.7	14.5	128012.0	0.0	37.3	0.0	128.1	0.0	1255.0	6.5
15-191-43882	60900.0	380.0	2910.0	12700.0	0.0	0.7	14.0	132000.0	550.0	0.0	0.0	0.0	0.0	570.0	5.75
15-191-11442	61101.6	350.3	2530.4	12109.8	472.5	0.7	12.5	120744.0	0.0	38.3	0.0	115.9	0.0	1475.0	5.6
15-191-11442	56000.0	430.0	2370.0	11800.0	0.0	0.8	15.1	125000.0	480.0	0.0	0.0	0.0	0.0	649.0	5.73
15-191-43889	60895.0	332.5	2551.7	12261.6	454.7	0.8	17.8	113642.0	0.0	38.1	0.0	128.1	0.0	1260.0	5.4
15-191-00395-0001	61475.7	349.1	2518.2	12218.5	468.2	1.0	12.2	109495.0	0.0	39.1	0.0	73.2	0.0	1155.0	5.3
15-191-10083-0002	56748.9	404.4	2449.3	11621.6	432.4	1.9	41.8	107818.0	0.0	44.6	0.0	73.2	0.0	1660.0	5.2
15-191-22590	48600.0	1280.0	1430.0	8820.0	274.0	0.7	0.08	103000.0	198.0	0.0	132.0	0.0	20.0	3140.0	6.56
15-191-22590	38300.0	1080.0	1160.0	7310.0	253.0	2.2	0.2	84400.0	190.0	0.0	0.0	0.0	20.0	346.0	6.66
15-191-22590	54300.0	1430.0	1630.0	10300.0	334.0	0.81	0.09	118000.0	235.0	0.0	74.0	0.0	20.0	336.0	6.46
15-191-22590	48400.0	1280.0	1450.0	8670.0	262.0	0.61	0.16	102000.0	176.0	0.0	134.0	0.0	20.0	3320.0	6.58
15-191-22591	31500.0	834.0	880.0	5030.0	158.0	1.1	0.05	65800.0	120.0	0.0	124.0	0.0	20.0	1060.0	7.02
15-191-22591	17400.0	424.0	460.0	2150.0	71.3	0.59	0.07	32000.0	75.9	0.0	180.0	0.0	5.0	1610.0	7.57
15-191-22591	15900.0	347.0	347.0	1500.0	55.4	1.17	0.09	30500.0	79.7	0.0	192.0	0.0	4.0	873.0	6.75
15-191-22591	58000.0	702.0	1890.0	11300.0	417.0	0.89	0.29	119000.0	464.0	0.0	42.0	0.0	20.0	703.0	5.92
15-191-22770	48400.0	310.0	1990.0	9920.0	0.0	1.2	0.0	109000.0	420.0	0.0	0.0	0.0	0.0	726.0	7.05
15-191-22770	39700.0	270.0	1670.0	8140.0	0.0	1.3	22.0	85000.0	350.0	0.0	0.0	0.0	0.0	761.0	6.86
15-191-22770	0.0	0.0	0.0	0.0	0.0	0.0	10.0	100000.0	0.0	0.0	0.0	0.0	0.0	932.0	5.26
15-191-22770	0.0	0.0	0.0	0.0	0.0	0.0	10.0	100000.0	0.0	0.0	0.0	0.0	0.0	874.0	6.96
NA	2858.2	2.4	1365.0	4159.5	61.4	0.1	0.5	14500.0	0.0	0.0	0.0	0.0	0.0	1080.0	7.0
NA	4720.0	23.6	1510.0	4270.0	0.0	0.126	1.6	18400.0	56.0	0.0	0.0	0.0	0.0	1330.0	7.23
NA	3860.0	21.3	1380.0	3820.0	0.0	0.107	1.54	17200.0	52.0	0.0	0.0	0.0	0.0	1260.0	7.23

"Delete Well(s)" button allows the user to highlight problem wells and remove them from list before processing.
"Compute Correlation Matrix" button performs basic Principal Components and allows the user to display & plot data.
"Begin Normalization Process" button with the "% from Anions/Cations equal to 1.0" text field allows the user to normalize the brine data set to a "Good" brine data set that falls between 1.0 +/- X%, where the user defines the limit of the "Good" Brine data.
"Cancel" button closes this dialog and all dialogs that are opened by this dialog.

The Principal Component Analysis is automatic when the "Compute Correlation Matrix" or "Begin Normalization Process" buttons are selected. The dialogs that are displayed will have button panels at the top of the dialog that will allow the user to display the correlation matrix table, eigenvector & eigenvalue table, Anions/Cations Ratio Plot and the Principal Components Scores Plot. The user can save the brine data either as an Extensible Markup Language (XML), Comma Separated Values (CSV) or save the displayed dialogs and plots as Portable Network Graphics (PNG) images with the option of creating a Portable Document Format (PDF) of each plot.

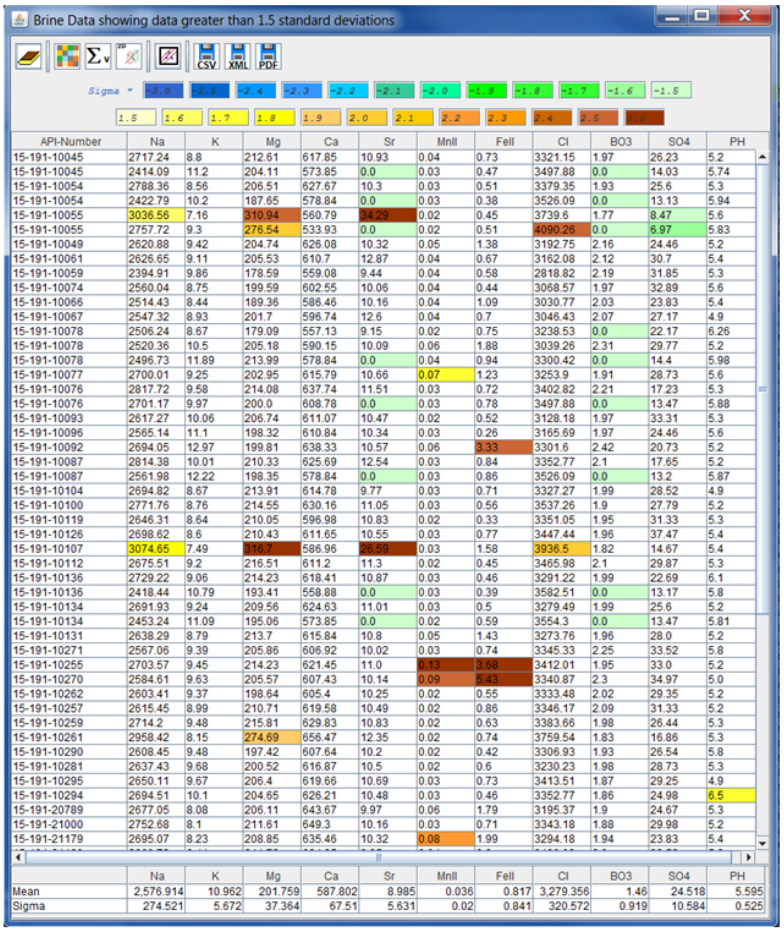
Compute Correlation Matrix Button

Buttons to display dialogs & plots and to save the information generated.

Color Legend for brine data cells that are colored.

Brine Data imported in meq/l units with table cells colored if the data falls outside 1.5 standard deviations.

Table showing the Mean and Standard Deviation of the wells that are displayed.



Close this dialog and all dialogs opened by this dialog.

Display the Covariance Matrix Table.

Display the Eigenvector Matrix & Eigenvalues Tables.

Display the Principal Components Scores Plot.

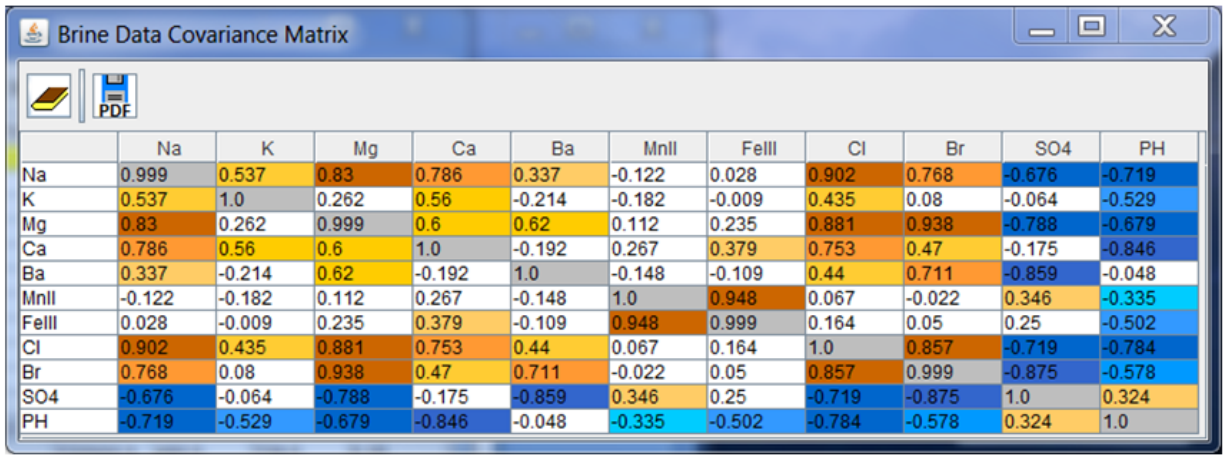
Display the Brine Data Anions/Cations Ratio Plot.

Save Brine Data Displayed as a Comma Separated Values (CSV) ASCII File.

Save Brine Data Displayed as a Extensible Markup Language (XML) ASCII File.

Save dialog or plot as a Portable Network Graphics (PNG) file with the option of creating a Portable Document Format (PDF) file.

Display the Covariance Matrix Table Dialog.



Brine Data Covariance Matrix

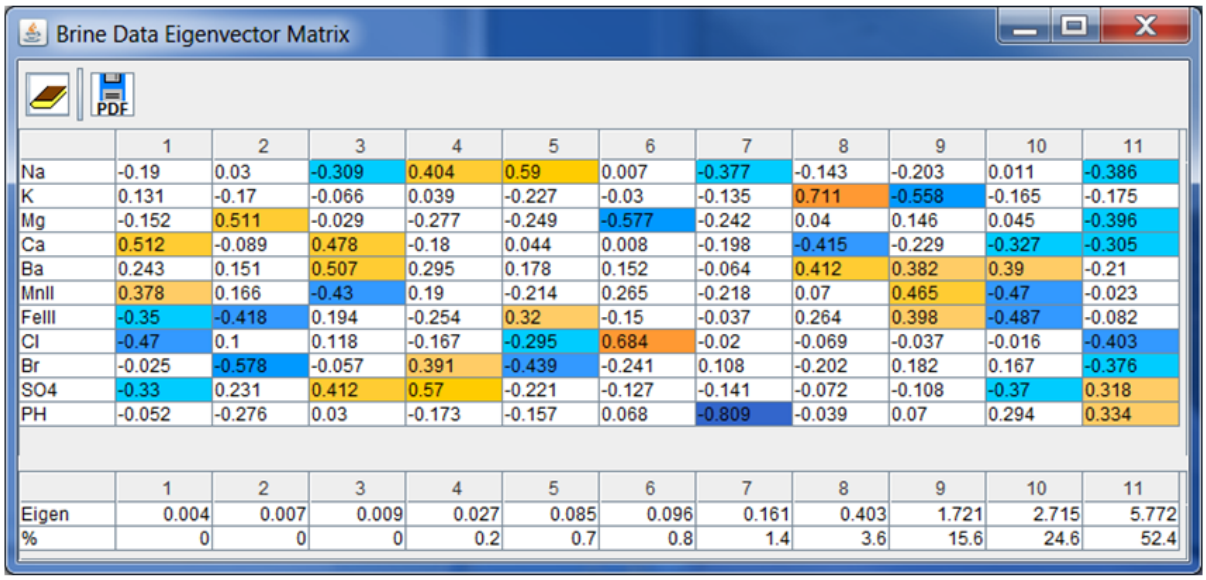
	Na	K	Mg	Ca	Ba	MnII	FeIII	Cl	Br	SO4	PH
Na	0.999	0.537	0.83	0.786	0.337	-0.122	0.028	0.902	0.768	-0.676	-0.719
K	0.537	1.0	0.262	0.56	-0.214	-0.182	-0.009	0.435	0.08	-0.064	-0.529
Mg	0.83	0.262	0.999	0.6	0.62	0.112	0.235	0.881	0.938	-0.788	-0.679
Ca	0.786	0.56	0.6	1.0	-0.192	0.267	0.379	0.753	0.47	-0.175	-0.846
Ba	0.337	-0.214	0.62	-0.192	1.0	-0.148	-0.109	0.44	0.711	-0.859	-0.048
MnII	-0.122	-0.182	0.112	0.267	-0.148	1.0	0.948	0.067	-0.022	0.346	-0.335
FeIII	0.028	-0.009	0.235	0.379	-0.109	0.948	0.999	0.164	0.05	0.25	-0.502
Cl	0.902	0.435	0.881	0.753	0.44	0.067	0.164	1.0	0.857	-0.719	-0.784
Br	0.768	0.08	0.938	0.47	0.711	-0.022	0.05	0.857	0.999	-0.875	-0.578
SO4	-0.676	-0.064	-0.788	-0.175	-0.859	0.346	0.25	-0.719	-0.875	1.0	0.324
PH	-0.719	-0.529	-0.679	-0.846	-0.048	-0.335	-0.502	-0.784	-0.578	0.324	1.0

Covariance Matrix Table Dialog Buttons

Close this dialog.

Save covariance matrix table as a Portable Network Graphics (PNG) file with the option of creating a Portable Document Format (PDF) file.

Display the Eigenvector Matrix & Eigenvalues Table Dialog.



Brine Data Eigenvector Matrix

	1	2	3	4	5	6	7	8	9	10	11
Na	-0.19	0.03	-0.309	0.404	0.59	0.007	-0.377	-0.143	-0.203	0.011	-0.386
K	0.131	-0.17	-0.066	0.039	-0.227	-0.03	-0.135	0.711	-0.558	-0.165	-0.175
Mg	-0.152	0.511	-0.029	-0.277	-0.249	-0.577	-0.242	0.04	0.146	0.045	-0.396
Ca	0.512	-0.089	0.478	-0.18	0.044	0.008	-0.198	-0.415	-0.229	-0.327	-0.305
Ba	0.243	0.151	0.507	0.295	0.178	0.152	-0.064	0.412	0.382	0.39	-0.21
MnII	0.378	0.166	-0.43	0.19	-0.214	0.265	-0.218	0.07	0.465	-0.47	-0.023
FeIII	-0.35	-0.418	0.194	-0.254	0.32	-0.15	-0.037	0.264	0.398	-0.487	-0.082
Cl	-0.47	0.1	0.118	-0.167	-0.295	0.684	-0.02	-0.069	-0.037	-0.016	-0.403
Br	-0.025	-0.578	-0.057	0.391	-0.439	-0.241	0.108	-0.202	0.182	0.167	-0.376
SO4	-0.33	0.231	0.412	0.57	-0.221	-0.127	-0.141	-0.072	-0.108	-0.37	0.318
PH	-0.052	-0.276	0.03	-0.173	-0.157	0.068	-0.809	-0.039	0.07	0.294	0.334

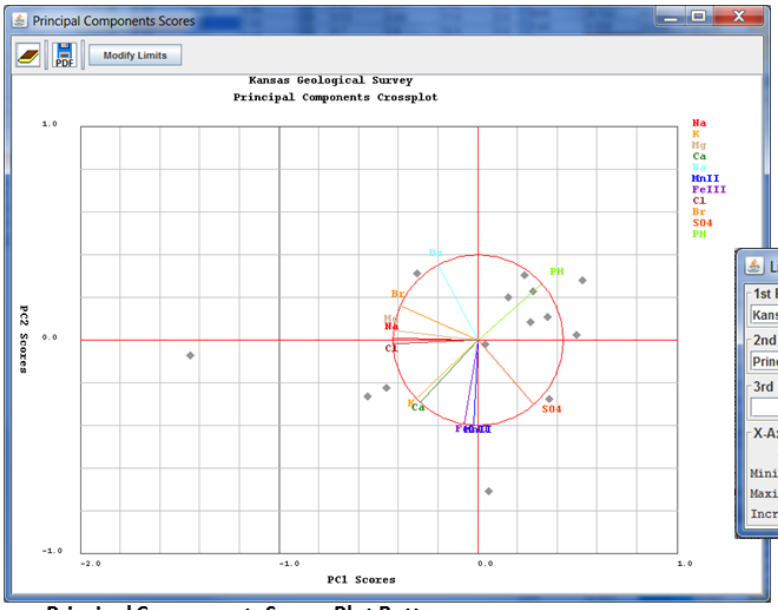
	1	2	3	4	5	6	7	8	9	10	11
Eigen	0.004	0.007	0.009	0.027	0.085	0.096	0.161	0.403	1.721	2.715	5.772
%	0	0	0	0.2	0.7	0.8	1.4	3.6	15.6	24.6	52.4

Eigenvector Matrix & Eigenvalues Table Dialog Buttons

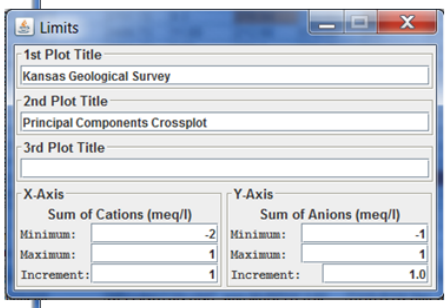
Close this dialog.

Save eigenvector matrix & eigenvalues table panel as a Portable Network Graphics (PNG) file with the option of creating a Portable Document Format (PDF) file.

Display the Principal Components Scores Plot.



Modify Limits button allows the user to change the titles and the X & Y Axis limits.

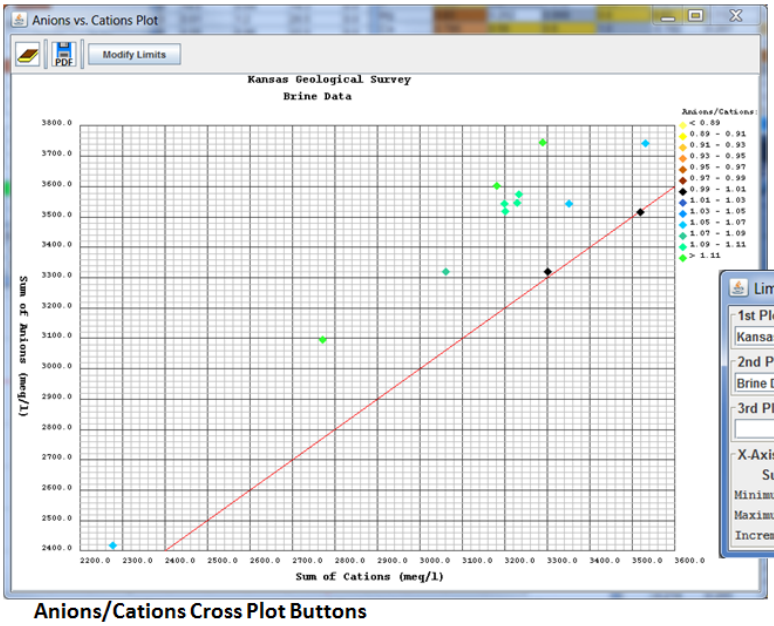


Principal Components Scores Plot Buttons

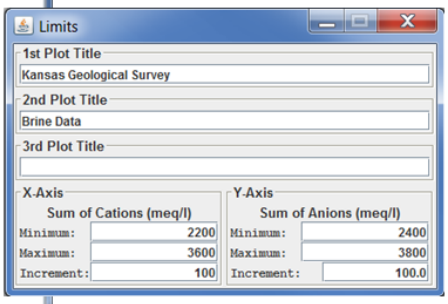
Close this dialog.

Save principal components scores plot as a Portable Network Graphics (PNG) file with the option of creating a Portable Document Format (PDF) file.

Display the Anions/Cations Cross Plot.



Modify Limits button allows the user to change the titles and the X & Y Axis limits.



Anions/Cations Cross Plot Buttons

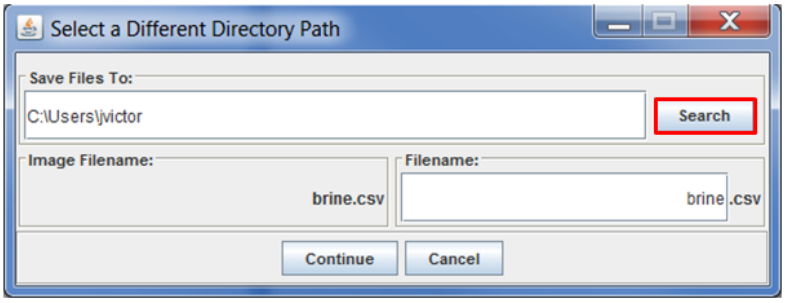
Close this dialog.

Save anions/cations cross plot as a Portable Network Graphics (PNG) file with the option of creating a Portable Document Format (PDF) file.

Save Brine Data as a Comma Separated Values (CSV) ASCII File

Click on the CSV Icon Button 

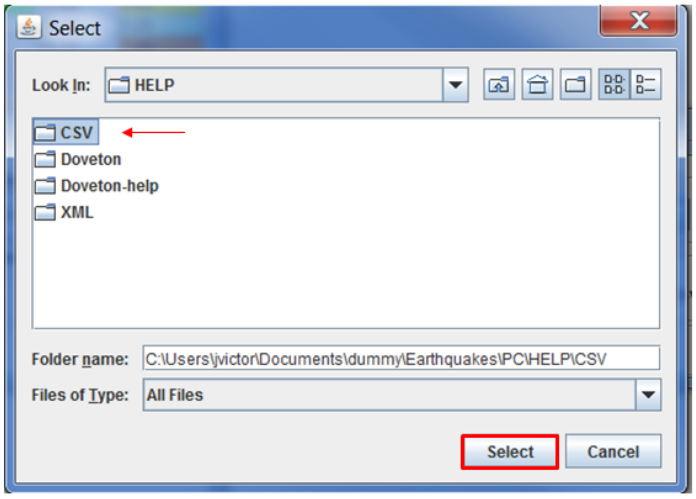
at the top of the "Brine Principal Components" dialog to open the "Select a Different Directory Path" Dialog.

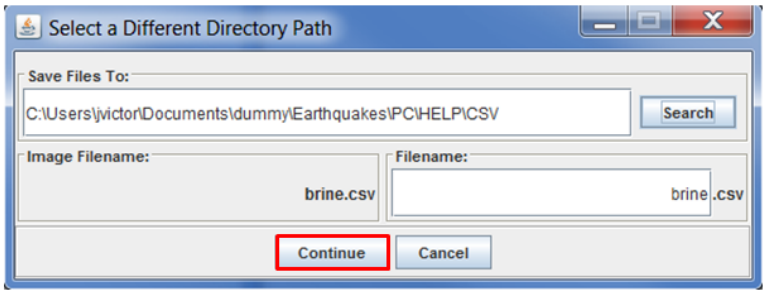


Select the "Search" Button in the "Select a Different Directory Path" Dialog to search your PC for the correct directory path.

Highlight the Directory you wish to place the CSV File.

Select the "Select" Button.

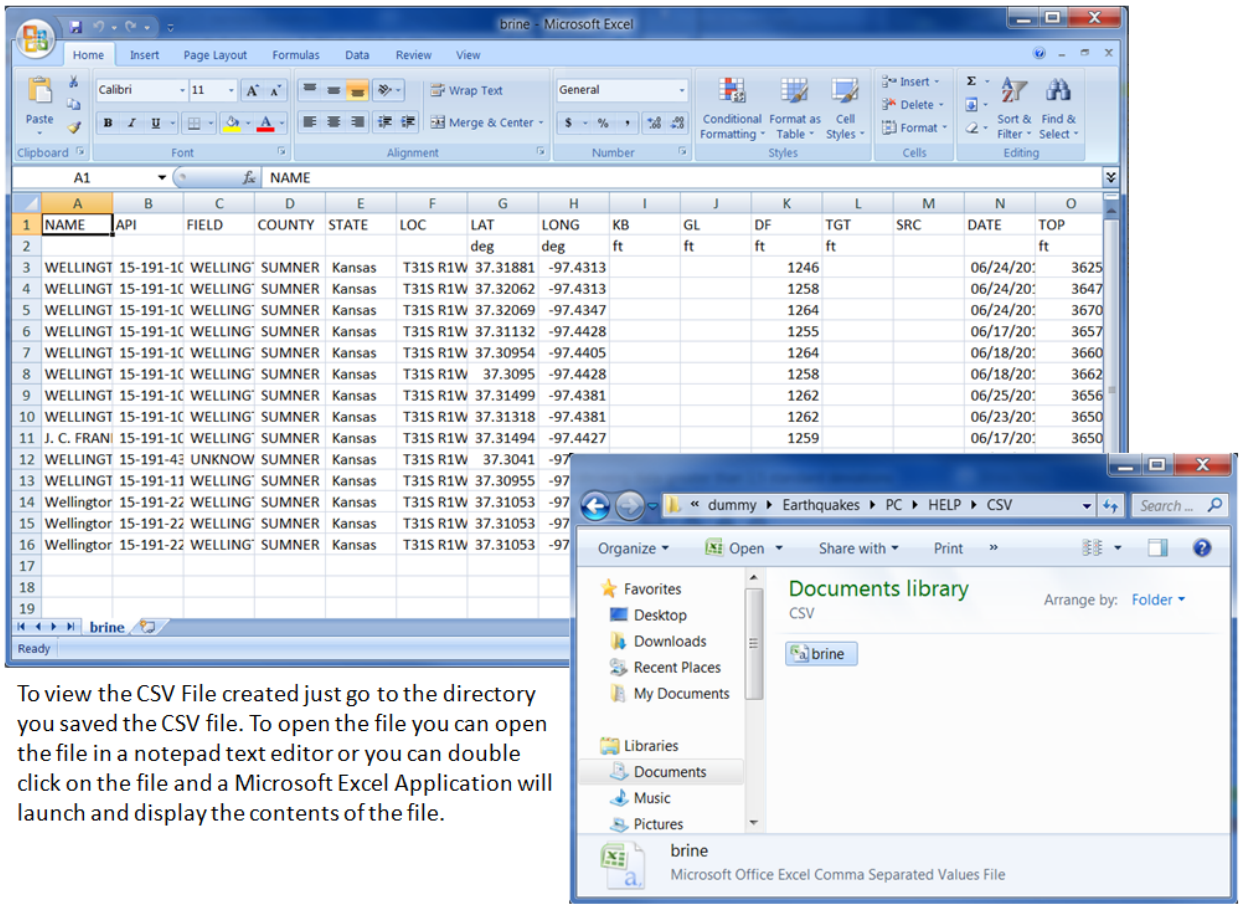




The Directory path is transferred to the "Save Files To:" text field.

"brine" is the default filename, you can alter the name to any name you wish. The "File save as:" text field will show what the file name will be saved as.

Select the "Continue" Button to save file.

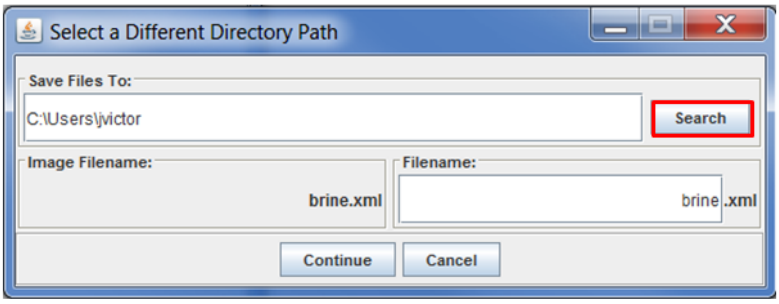


To view the CSV File created just go to the directory you saved the CSV file. To open the file you can open the file in a notepad text editor or you can double click on the file and a Microsoft Excel Application will launch and display the contents of the file.

Save Brine Data as an Extensible Markup Language (XML) ASCII File

Click on the XML Icon Button 

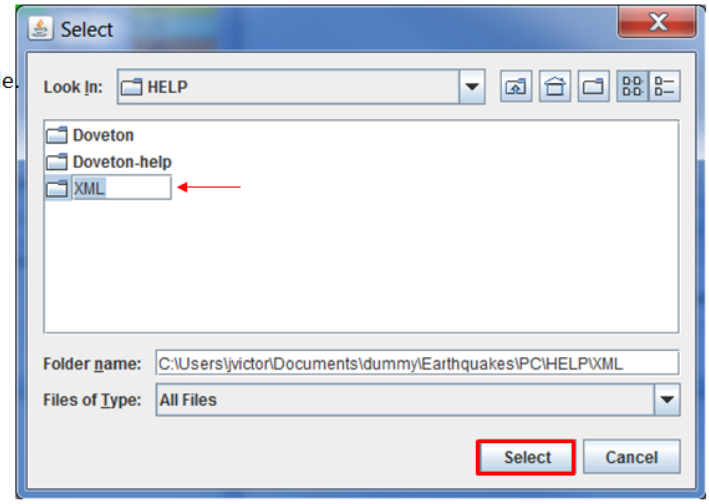
at the top of the "Brine Principal Components" dialog to open the "Select a Different Directory Path" Dialog.

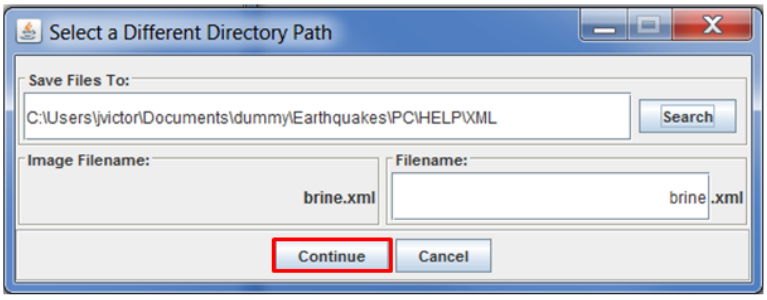


Select the "Search" Button in the "Select a Different Directory Path" Dialog to search your PC for the correct directory path.

Highlight the Directory you wish to place the XML File.

Select the "Select" Button.

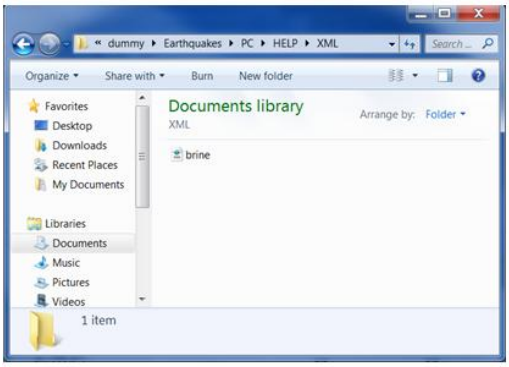




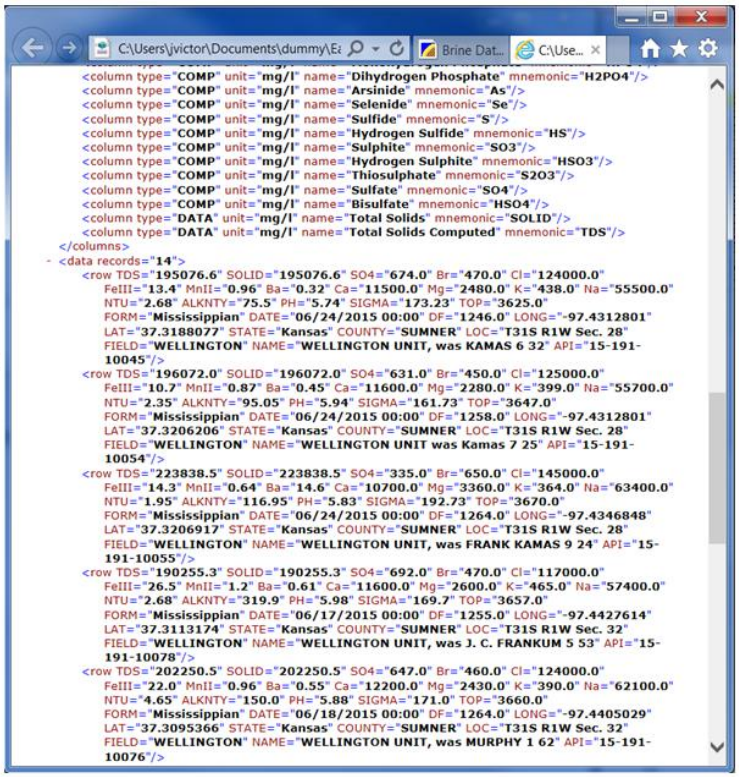
The Directory path is transferred to the "Save Files To:" text field.

"brine" is the default filename, you can alter the name to any name you wish. The "File save as:" text field will show what the file name will be saved as.

Select the "Continue" Button to save file.

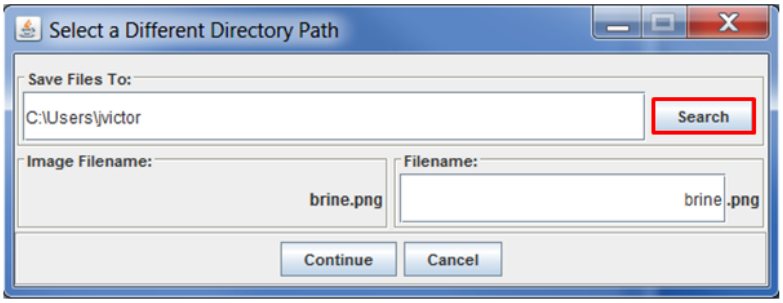


To view the XML File created just go to the directory you saved the XML file and double click and a web page will display the brine data XML File.



Save Brine Principal Components Panel as a Portable Network Graphics (PNG) Image File

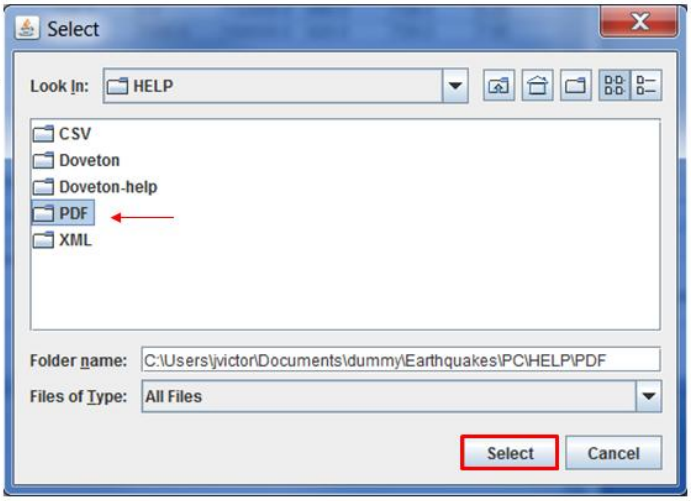
Click on the PDF Icon Button  at the top of the "Brine Principal Components" Dialog to open the "Select a Different Directory Path" Dialog.

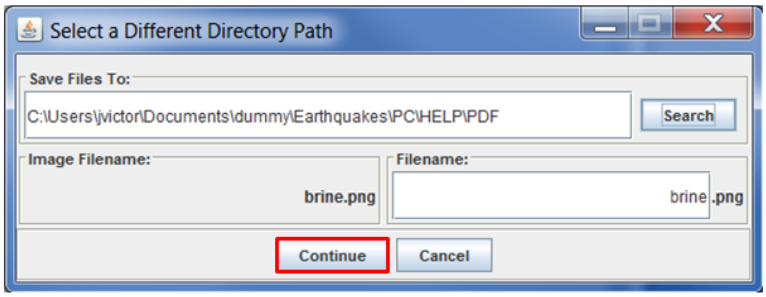


Select the "Search" Button in the "Select a Different Directory Path" Dialog to search your PC for the correct directory path.

Highlight the Directory you wish to place the PNG File.

Select the "Select" Button.



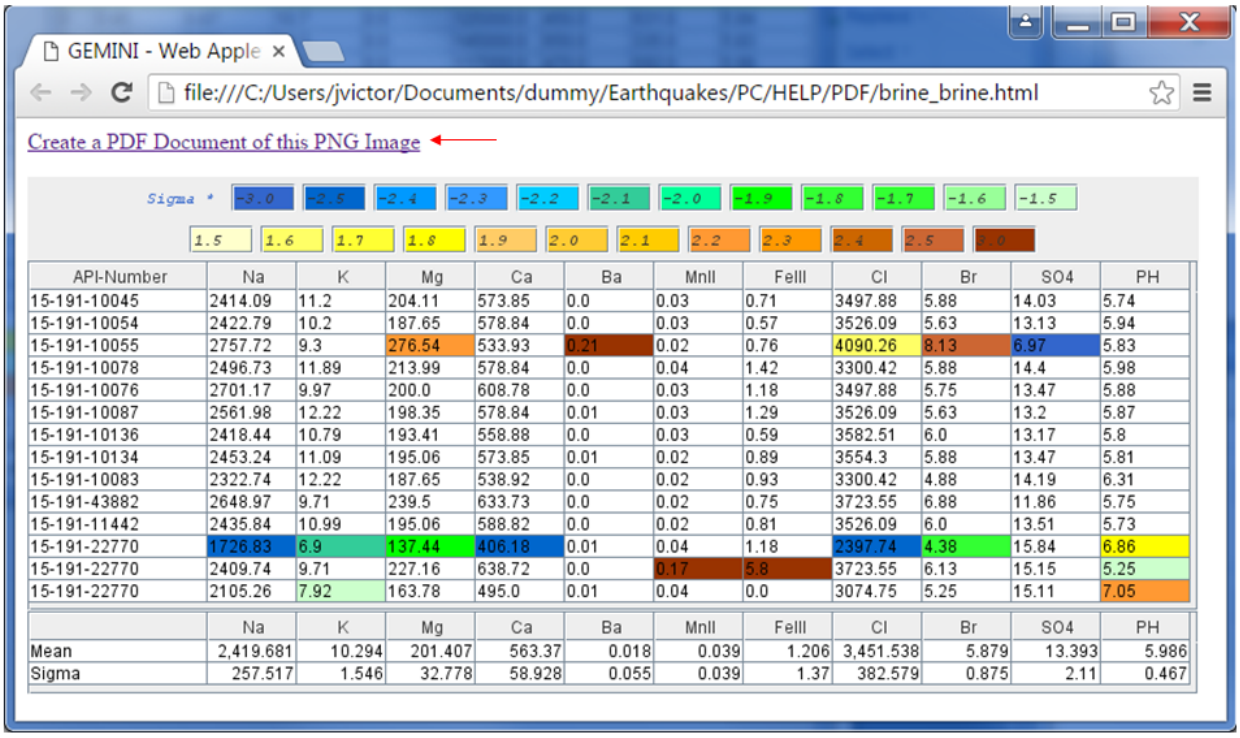


The Directory path is transferred to the "Save Files To:" text field.

"brine" is the default filename, you can alter the name to any name you wish. The "File save as:" text field will show what the file name will be saved as.

Select the "Continue" Button to save file.

The PNG Image File is created along with a HTML file to display the PNG image. At the top of the HTML File is a link that allows the user to create a PDF document of the PNG Image File.



API-Number	Na	K	Mg	Ca	Ba	MnII	FeIII	Cl	Br	SO4	PH
15-191-10045	2414.09	11.2	204.11	573.85	0.0	0.03	0.71	3497.88	5.88	14.03	5.74
15-191-10054	2422.79	10.2	187.65	578.84	0.0	0.03	0.57	3526.09	5.63	13.13	5.94
15-191-10055	2757.72	9.3	276.54	533.93	0.21	0.02	0.76	4090.26	8.13	6.97	5.83
15-191-10078	2496.73	11.89	213.99	578.84	0.0	0.04	1.42	3300.42	5.88	14.4	5.98
15-191-10076	2701.17	9.97	200.0	608.78	0.0	0.03	1.18	3497.88	5.75	13.47	5.88
15-191-10087	2561.98	12.22	198.35	578.84	0.01	0.03	1.29	3526.09	5.63	13.2	5.87
15-191-10136	2418.44	10.79	193.41	558.88	0.0	0.03	0.59	3582.51	6.0	13.17	5.8
15-191-10134	2453.24	11.09	195.06	573.85	0.01	0.02	0.89	3554.3	5.88	13.47	5.81
15-191-10083	2322.74	12.22	187.65	538.92	0.0	0.02	0.93	3300.42	4.88	14.19	6.31
15-191-43882	2648.97	9.71	239.5	633.73	0.0	0.02	0.75	3723.55	6.88	11.86	5.75
15-191-11442	2435.84	10.99	195.06	588.82	0.0	0.02	0.81	3526.09	6.0	13.51	5.73
15-191-22770	1726.83	6.9	137.44	406.18	0.01	0.04	1.18	2397.74	4.38	15.84	6.86
15-191-22770	2409.74	9.71	227.16	638.72	0.0	0.17	5.8	3723.55	6.13	15.15	5.25
15-191-22770	2105.26	7.92	163.78	495.0	0.01	0.04	0.0	3074.75	5.25	15.11	7.05

	Na	K	Mg	Ca	Ba	MnII	FeIII	Cl	Br	SO4	PH
Mean	2,419.681	10.294	201.407	563.37	0.018	0.039	1.206	3,451.538	5.879	13.393	5.986
Sigma	257.517	1.546	32.778	58.928	0.055	0.039	1.37	382.579	0.875	2.11	0.467

If the Covariance Matrix Dialog, Principal Components Scores Plot, etc. are displayed then the PNG button automatically retrieves the image from those dialogs and creates a PNG image of each and displays it at the same time the Brine Principal Components PNG Image is displayed.

It the default name “brine” for the Brine Principal Components PNG Image is used then the each of the other images will append a distinct phrase to distinguish it from the main dialog PNG Image plot, i.e.

- Covariance Matrix Panel PNG File will have the name brine_cov.png
- Eigenvectors & eigenvalues Panel PNG File will have the name brine_eign.png
- Principal Components Scores Plot PNG File will have the name brine_Xplot.png
- Anions/Cations Plot PNG File will have the name brine_plot.png

Brine Data - Principal Components Analysis

The original Brine data set are converted from mg/l units to meq/l units.

Sigma * -3.0 -2.5 -2.4 -2.3 -2.2 -2.1 -2.0 -1.9 -1.8 -1.7 -1.6 -1.5

1.5 1.6 1.7 1.8 1.9 2.0 2.1 2.2 2.3 2.4 2.5 3.0

	API-Number	Na	K	Mg	Ca	Ba	MnII	FeIII	Cl	Br	SO4	PH
i = 1	15-191-10045	2414.09	11.2	204.11	573.85	0.0	0.03	0.71	3497.88	5.88	14.03	5.74
2	15-191-10054	2422.79	10.2	187.65	578.84	0.0	0.03	0.57	3526.09	5.63	13.13	5.94
3	15-191-10055	2757.72	9.3	276.54	533.93	0.21	0.02	0.76	4090.26	8.13	6.97	5.83
	15-191-10078	2496.73	11.89	213.99	578.84	0.0	0.04	1.42	3300.42	5.88	14.4	5.98
	15-191-10076	2701.17	9.97	200.0	608.78	0.0	0.03	1.18	3497.88	5.75	13.47	5.88
	15-191-10087	2561.98	12.22	198.35	578.84	0.01	0.03	1.29	3526.09	5.63	13.2	5.87
.	15-191-10136	2418.44	10.79	193.41	558.88	0.0	0.03	0.59	3582.51	6.0	13.17	5.8
.	15-191-10134	2453.24	11.09	195.06	573.85	0.01	0.02	0.89	3554.3	5.88	13.47	5.81
.	15-191-10083	2322.74	12.22	187.65	538.92	0.0	0.02	0.93	3300.42	4.88	14.19	6.31
	15-191-43882	2648.97	9.71	239.5	633.73	0.0	0.02	0.75	3723.55	6.88	11.86	5.75
	15-191-11442	2435.84	10.99	195.06	588.82	0.0	0.02	0.81	3526.09	6.0	13.51	5.73
	15-191-22770	1726.83	6.9	137.44	406.18	0.01	0.04	1.18	2397.74	4.38	15.84	6.86
	15-191-22770	2409.74	9.71	227.16	638.72	0.0	0.17	5.8	3723.55	6.13	15.15	5.25
N	15-191-22770	2105.26	7.92	163.78	495.0	0.01	0.04	0.0	3074.75	5.25	15.11	7.05

	Na	K	Mg	Ca	Ba	MnII	FeIII	Cl	Br	SO4	PH
Mean	2,419.681	10.294	201.407	563.37	0.018	0.039	1.206	3,451.538	5.879	13.393	5.986
Sigma	257.517	1.546	32.778	58.928	0.055	0.039	1.37	382.579	0.875	2.11	0.467

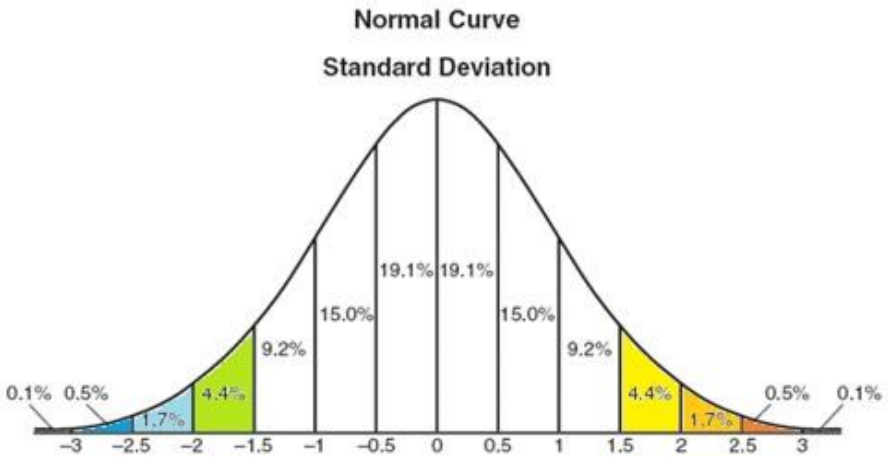
k = 1 2 3 . . . M

Mean $\overline{X}_k$ is the average value of each column k

$$\overline{X}_k = \frac{\sum_{i=1}^{N} X_i}{N}$$

Sigma (Standard Deviation) σ_k is a measure of how spread out the k^{th} data column is.

$$\sigma_k = \left[\frac{\sum_{i=1}^{N} (X_{ik} - \overline{X}_k)^2}{(N-1)}\right]^{1/2}$$



The brine data cells are colored to illustrate how spread out the data is with respect to the standard deviation, i.e. green and blues from -1.5σ to less than -3σ and yellows and oranges from 1.5σ to above 3σ.

	Na	K	Mg	Ca	Ba	MnII	FeIII	Cl	Br	SO4	PH
i = 1	2414.09	11.2	204.11	573.85	0.0	0.03	0.71	3497.88	5.88	14.03	5.74
2	2422.79	10.2	187.65	578.84	0.0	0.03	0.57	3526.09	5.63	13.13	5.94
3	2757.72	9.3	276.54	533.93	0.21	0.02	0.76	4090.26	8.13	6.97	5.83
	2496.73	11.89	213.99	578.84	0.0	0.04	1.42	3300.42	5.88	14.4	5.98
	2701.17	9.97	200.0	608.78	0.0	0.03	1.18	3497.88	5.75	13.47	5.88
	2561.98	12.22	198.35	578.84	0.01	0.03	1.29	3526.09	5.63	13.2	5.87
.	2418.44	10.79	193.41	558.88	0.0	0.03	0.59	3582.51	6.0	13.17	5.8
.	2453.24	11.09	195.06	573.85	0.01	0.02	0.89	3554.3	5.88	13.47	5.81
.	2322.74	12.22	187.65	538.92	0.0	0.02	0.93	3300.42	4.88	14.19	6.31
	2648.97	9.71	239.5	633.73	0.0	0.02	0.75	3723.55	6.88	11.86	5.75
	2435.84	10.99	195.06	588.82	0.0	0.02	0.81	3526.09	6.0	13.51	5.73
	1726.83	6.9	137.44	406.18	0.01	0.04	1.18	2397.74	4.38	15.84	6.86
	2409.74	9.71	227.16	638.72	0.0	0.17	5.8	3723.55	6.13	15.15	5.25
N	2105.26	7.92	163.78	495.0	0.01	0.04	0.0	3074.75	5.25	15.11	7.05
	k = 1	2	3			...					M

Normalize each column to its standard deviation. Unless the data is normalized, a variable with a large variance will dominate, $x_{ik} = X_{ik}/\sigma_k$, where i is the row, k is column.

Covariance Matrix

y	Na	K	Mg	Ca	Ba	MnII	FeIII	Cl	Br	SO4	PH
Na	0.999	0.537	0.83	0.786	0.337	-0.122	0.028	0.902	0.768	-0.676	-0.719
K	0.537	1.0	0.262	0.56	-0.214	-0.182	-0.009	0.435	0.08	-0.064	-0.529
Mg	0.83	0.262	0.999	0.6	0.62	0.112	0.235	0.881	0.938	-0.788	-0.679
Ca	0.786	0.56	0.6	1.0	-0.192	0.267	0.379	0.753	0.47	-0.175	-0.846
Ba	0.337	-0.214	0.62	-0.192	1.0	-0.148	-0.109	0.44	0.711	-0.859	-0.048
MnII	-0.122	-0.182	0.112	0.267	-0.148	1.0	0.948	0.067	-0.022	0.346	-0.335
FeIII	0.028	-0.009	0.235	0.379	-0.109	0.948	0.999	0.164	0.05	0.25	-0.502
Cl	0.902	0.435	0.881	0.753	0.44	0.067	0.164	1.0	0.857	-0.719	-0.784
Br	0.768	0.08	0.938	0.47	0.711	-0.022	0.05	0.857	0.999	-0.875	-0.578
SO4	-0.676	-0.064	-0.788	-0.175	-0.859	0.346	0.25	-0.719	-0.875	1.0	0.324
PH	-0.719	-0.529	-0.679	-0.846	-0.048	-0.335	-0.502	-0.784	-0.578	0.324	1.0
	X →										

The web app performs all the processing in the background. The process begins by constructing the Covariance matrix for the brine data set. Covariance [cov(x,y)] is a measure how much each data column vary from the mean with respect to each other.

$$\text{cov}(x,y) = \frac{\sum_{i=1}^{N} (x_i - \bar{x})(y_i - \bar{y})}{(N-1)}$$

where x is the mean of brine data column k divided by σ_k where x_i is the individual brine data divided by σ_k, subscript i represents the well, subscript k represents the brine data column, e.g. cov (Na, Ca) is sum over the Na (Sodium cation) and Ca (Calcium cation) columns of the normalized data set.

To compute the Eigenvectors and Eigenvalues this web app uses JAMA a Java Matrix Package (http://math.nist.gov/javanumerics/jama/).

"JAMA is a basic linear algebra package for Java. It provides user-level classes for constructing and manipulating real, dense matrices. It is meant to provide sufficient functionality for routine problems, packaged in a way that is natural and understandable to non-experts. It is intended to serve as the standard matrix class for Java."

JAMA Java Functions:
C represents the symbol for the Covariance Matrix
The eigenvalues & eigenvectors JAMA functions are listed as follows

E_v = C.eig(), where the eig() function computes the eigenvalues & eigenvectors of the covariance matrix C.

The eigenvalues can be retrieved as follows, Eigenvalues = E_v.getRealEigenvalues() and the eigenvectors can then be retrieve as follows, Eigenvectors = E_v.getV().

1st two principal component vectors: Pc_2 Pc_1

Eigenvectors

	1	2	3	4	5	6	7	8	9	10	11
Na	-0.19	0.03	-0.309	0.404	0.59	0.007	-0.377	-0.143	-0.203	0.011	-0.386
K	0.131	-0.17	-0.066	0.039	-0.227	-0.03	-0.135	0.711	-0.558	-0.165	-0.175
Mg	-0.152	0.511	-0.029	-0.277	-0.249	-0.577	-0.242	0.04	0.146	0.045	-0.396
Ca	0.512	-0.089	0.478	-0.18	0.044	0.008	-0.198	-0.415	-0.229	-0.327	-0.305
Ba	0.243	0.151	0.507	0.295	0.178	0.152	-0.064	0.412	0.382	0.39	-0.21
MnII	0.378	0.166	-0.43	0.19	-0.214	0.265	-0.218	0.07	0.465	-0.47	-0.023
FeIII	-0.35	-0.418	0.194	-0.254	0.32	-0.15	-0.037	0.264	0.398	-0.487	-0.082
Cl	-0.47	0.1	0.118	-0.167	-0.295	0.684	-0.02	-0.069	-0.037	-0.016	-0.403
Br	-0.025	-0.578	-0.057	0.391	-0.439	-0.241	0.108	-0.202	0.182	0.167	-0.376
SO4	-0.33	0.231	0.412	0.57	-0.221	-0.127	-0.141	-0.072	-0.108	-0.37	0.318
PH	-0.052	-0.276	0.03	-0.173	-0.157	0.068	-0.809	-0.039	0.07	0.294	0.334

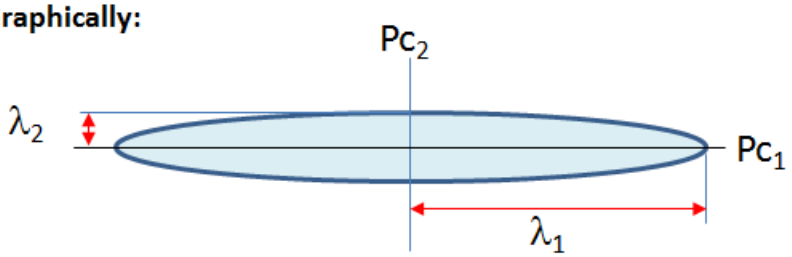
1st two principal component eigenvalues: λ_2 λ_1

Eigenvalues →

	1	2	3	4	5	6	7	8	9	10	11
Eigen	0.004	0.007	0.009	0.027	0.085	0.096	0.161	0.403	1.721	2.715	5.772
%	0	0	0	0.2	0.7	0.8	1.4	3.6	15.6	24.6	52.4

The principal components is less than or equal to the number of original variables. The first principal component Pc_1 has the largest possible variance i.e., it accounts for as much of the variability in the data as possible and the next principal component Pc_2 has the highest variance possible under the constraint that it is orthogonal to the preceding component. The principal components are orthogonal because they are the eigenvectors of the covariance matrix, which is symmetric.

Graphically:



Construct a Feature Vector from the 1st two principal components, e.g. columns 10 and ll.

Feature Vector [V] =

Pc_1	Pc_2	
-0.386	0.011	Na
-0.175	-0.165	K
-0.396	0.045	Mg
-0.305	-0.327	Ca
-0.21	0.39	Ba
-0.023	-0.47	MnII
-0.082	-0.487	FeIII
-0.403	-0.016	Cl
-0.376	0.167	Br
0.318	-0.37	SO4
0.334	0.294	PH

Then construct an Adjusted Data Matrix from the Brine Data Matrix by subtracting the mean of each column and then dividing the standard deviation of the each column.

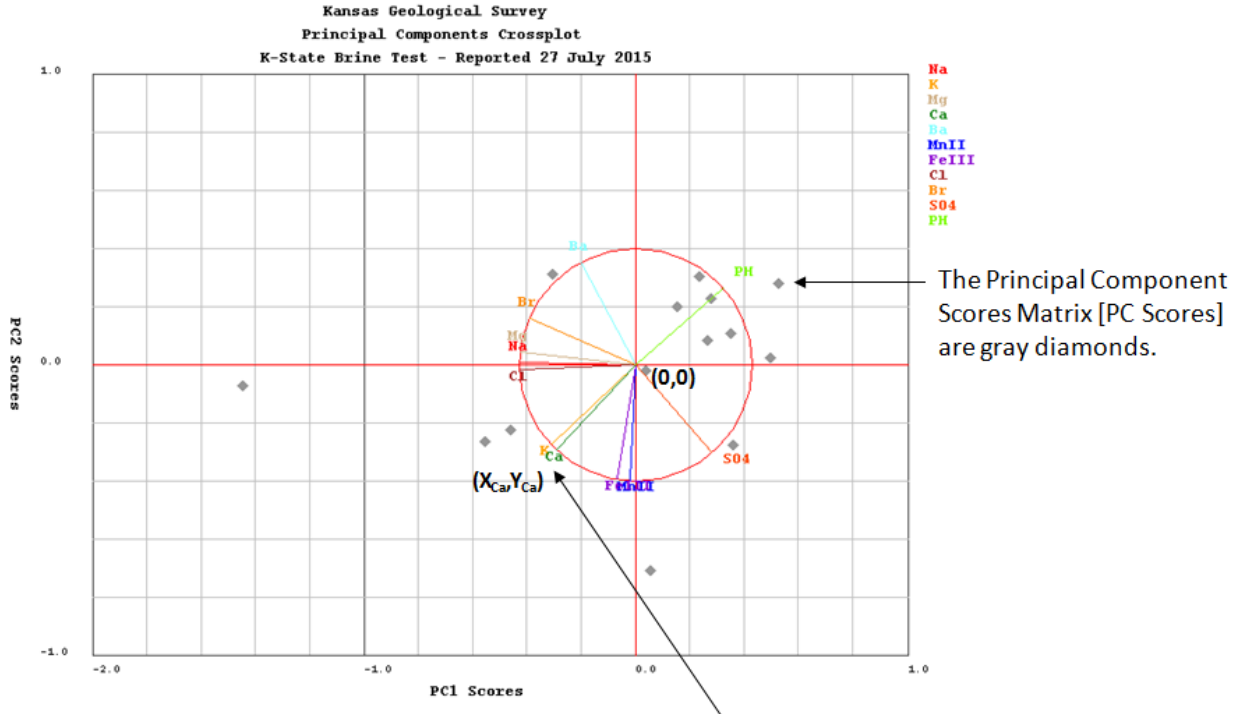
Adjusted Data Matrix [Am] = [$(X_{ik} - \overline{X}_k) / \sigma_k$]

where $\overline{X}_k$ is the mean of brine data column k
X_{ik} is the individual brine data; i=well, k=brine data
σ_k is the standard deviation of the brine data column

Compute the Principal Components Scores [PC Scores] matrix as the Adjusted Data matrix times the Feature Vector.

[PC Scores] = [Am] X [V]

The Principal Components Scores [PC Scores] matrix converts the multi dimensional matrix into a 2 dimensional matrix.



Feature Vector [V] =

Pc_1	Pc_2	
-0.386	0.011	Na
-0.175	-0.165	K
-0.396	0.045	Mg
-0.305	-0.327	Ca
-0.21	0.39	Ba
-0.023	-0.47	MnII
-0.082	-0.487	FeIII
-0.403	-0.016	Cl
-0.376	0.167	Br
0.318	-0.37	SO4
0.334	0.294	PH

The Feature Vector is represented as colored lines around a red unit circle, where each Feature Vector row is normalized to 1, i.e.

$X_k = Pc_{1k} / (Pc_{1k}^2 + Pc_{2k}^2)^{0.5}$
$Y_k = Pc_{2k} / (Pc_{1k}^2 + Pc_{2k}^2)^{0.5}$

where k is the analyte being computed.

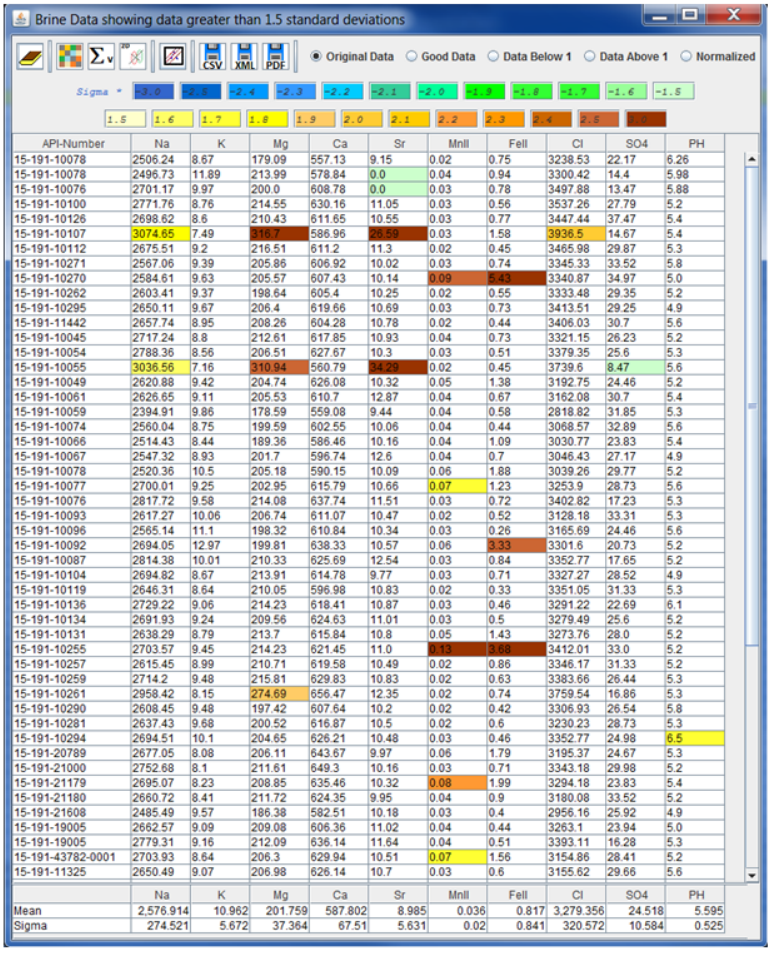
Begin Normalization Process Button

Buttons to display dialogs & plots and to save the information generated.

Color Legend for brine data cells that are colored.

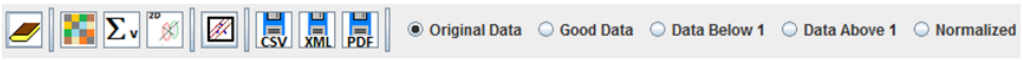
Brine Data imported in meq/l units with table cells colored if the data falls outside 1.5 standard deviations.

Table showing the Mean and Standard Deviation of the wells that are displayed.



API-Number	Na	K	Mg	Ca	Sr	MnII	FeII	Cl	SO4	PH
15-191-10078	2506.24	8.67	179.09	557.13	9.15	0.02	0.75	3238.53	22.17	6.26
15-191-10078	2496.73	11.89	213.99	578.84	0.0	0.04	0.94	3300.42	14.4	5.98
15-191-10076	2701.17	9.97	200.0	608.78	0.0	0.03	0.78	3497.88	13.47	5.88
15-191-10100	2771.76	8.76	214.55	630.16	11.05	0.03	0.56	3537.26	27.79	5.2
15-191-10126	2698.62	8.6	210.43	611.65	10.55	0.03	0.77	3447.44	37.47	5.4
15-191-10107	3074.65	7.49	316.7	586.96	22.59	0.03	1.58	3936.5	14.67	5.4
15-191-10112	2675.51	9.2	216.51	611.2	11.3	0.02	0.45	3465.98	29.87	5.3
15-191-10271	2567.06	9.39	205.86	606.92	10.02	0.03	0.74	3345.33	33.52	5.8
15-191-10270	2584.61	9.63	205.57	607.43	10.14	0.09	5.43	3340.87	34.97	5.0
15-191-10262	2603.41	9.37	198.64	605.4	10.25	0.02	0.55	3333.48	29.35	5.2
15-191-10295	2650.11	9.67	206.4	619.66	10.69	0.03	0.73	3413.51	29.25	4.9
15-191-11442	2657.74	8.95	208.26	604.28	10.78	0.02	0.44	3406.03	30.7	5.6
15-191-10045	2717.24	8.8	212.61	617.85	10.93	0.04	0.73	3321.15	26.23	5.2
15-191-10054	2788.36	8.56	206.51	627.67	10.3	0.03	0.51	3379.35	25.6	5.3
15-191-10055	3036.56	7.16	310.94	560.79	34.29	0.02	0.45	3739.6	8.47	5.6
15-191-10049	2620.88	9.42	204.74	626.08	10.32	0.05	1.38	3192.75	24.46	5.2
15-191-10061	2626.65	9.11	205.53	610.7	12.87	0.04	0.67	3162.08	30.7	5.4
15-191-10059	2394.91	9.86	178.59	559.08	9.44	0.04	0.58	2818.82	31.85	5.3
15-191-10074	2560.04	8.75	199.59	602.55	10.06	0.04	0.44	3068.57	32.89	5.6
15-191-10066	2514.43	8.44	189.36	586.46	10.16	0.04	1.09	3030.77	23.83	5.4
15-191-10067	2547.32	8.93	201.7	596.74	12.6	0.04	0.7	3046.43	27.17	4.9
15-191-10078	2520.36	10.5	205.18	590.15	10.09	0.06	1.88	3039.26	29.77	5.2
15-191-10077	2700.01	9.25	202.95	615.79	10.66	0.07	1.23	3253.9	28.73	5.6
15-191-10076	2817.72	9.58	214.08	637.74	11.51	0.03	0.72	3402.82	17.23	5.3
15-191-10093	2617.27	10.06	206.74	611.07	10.47	0.02	0.52	3128.18	33.31	5.3
15-191-10096	2565.14	11.1	198.32	610.84	10.34	0.03	0.26	3165.69	24.46	5.6
15-191-10092	2694.05	12.97	199.81	638.33	10.57	0.06	3.33	3301.6	20.73	5.2
15-191-10087	2814.38	10.01	210.33	625.69	12.54	0.03	0.84	3352.77	17.65	5.2
15-191-10104	2694.82	8.67	213.91	614.78	9.77	0.03	0.71	3327.27	28.52	4.9
15-191-10119	2646.31	8.64	210.05	596.98	10.83	0.02	0.33	3351.05	31.33	5.3
15-191-10136	2729.22	9.06	214.23	618.41	10.87	0.03	0.46	3291.22	22.69	6.1
15-191-10134	2691.93	9.24	209.56	624.63	11.01	0.03	0.5	3279.49	25.6	5.2
15-191-10131	2638.29	8.79	213.7	615.84	10.8	0.05	1.43	3273.76	28.0	5.2
15-191-10255	2703.57	9.45	214.23	621.45	11.0	0.13	3.68	3412.01	33.0	5.2
15-191-10257	2615.45	8.99	210.71	619.58	10.49	0.02	0.86	3346.17	31.33	5.2
15-191-10259	2714.2	9.48	215.81	629.83	10.83	0.02	0.63	3383.66	26.44	5.3
15-191-10261	2958.42	8.15	274.69	656.47	12.35	0.02	0.74	3759.54	16.86	5.3
15-191-10290	2608.45	9.48	197.42	607.64	10.2	0.02	0.42	3306.93	26.54	5.8
15-191-10281	2637.43	9.68	200.52	616.87	10.5	0.02	0.6	3230.23	28.73	5.3
15-191-10294	2694.51	10.1	204.65	626.21	10.48	0.03	0.46	3352.77	24.98	6.5
15-191-20789	2677.05	8.08	206.11	643.67	9.97	0.06	1.79	3195.37	24.67	5.3
15-191-21000	2752.68	8.1	211.61	649.3	10.16	0.03	0.71	3343.18	29.98	5.2
15-191-21179	2695.07	8.23	208.85	635.46	10.32	0.08	1.99	3294.18	23.83	5.4
15-191-21180	2660.72	8.41	211.72	624.35	9.95	0.04	0.9	3180.08	33.52	5.2
15-191-21608	2485.49	9.57	186.38	582.51	10.18	0.03	0.4	2956.16	25.92	4.9
15-191-19005	2662.57	9.09	209.08	606.36	11.02	0.04	0.44	3263.1	23.94	5.0
15-191-19005	2779.31	9.16	212.09	636.14	11.64	0.04	0.51	3393.11	16.28	5.3
15-191-43782-0001	2703.93	8.64	206.3	629.94	10.51	0.07	1.56	3154.86	28.41	5.2
15-191-11325	2650.49	9.07	206.98	626.14	10.7	0.03	0.6	3155.62	29.66	5.6

	Na	K	Mg	Ca	Sr	MnII	FeII	Cl	SO4	PH
Mean	2,576.914	10.962	201.759	587.802	8.985	0.036	0.817	3,279.356	24.518	5.595
Sigma	274.521	5.672	37.364	67.51	5.631	0.02	0.841	320.572	10.584	0.525



Close this dialog and all dialogs opened by this dialog.

Display the Covariance Matrix Table.

Display the Eigenvector Matrix & Eigenvalues Tables.

Display the Principal Components Scores Plot.

Display the Brine Data Anions/Cations Ratio Plot.

Save Brine Data Displayed as a Comma Separated Values (CSV) ASCII File.

Save Brine Data Displayed as a Extensible Markup Language (XML) ASCII File.

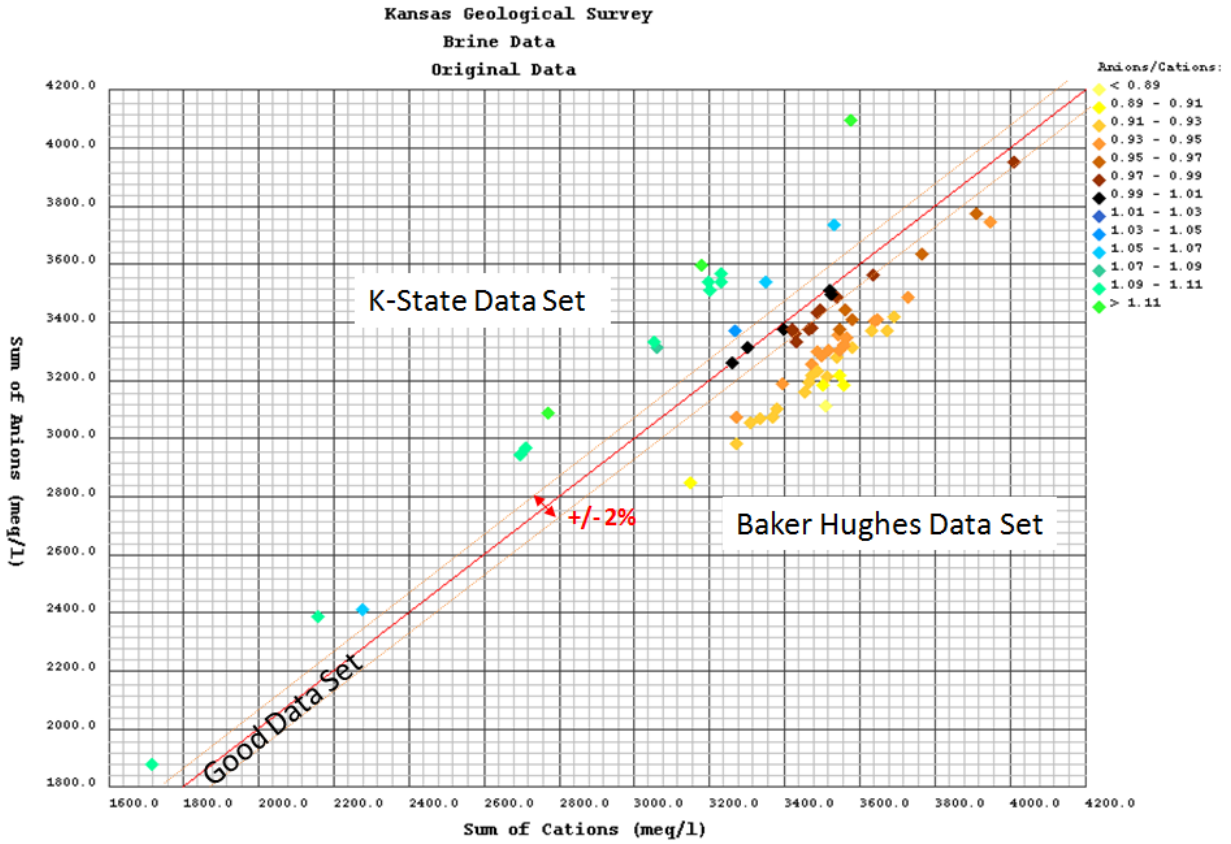
Save dialog or plot as a Portable Network Graphics (PNG) file with the option of creating a Portable Document Format (PDF) file.

Radio Buttons:

- **Original Data** – Displays all the imported brine data ordered by "Good" brine data set, Brine Data Anions/Cations Ratio below 1.0, Brine Data Anions/Cations Ration above 1.0.
- **Good Data** – Displays the "Good" brine data set.
- **Data Below 1** – Displays the Brine Data Anions/Cations Ratio below 1.0.
- **Data Above 1** – Displays the Brine Data Anions/Cations Ration above 1.0.
- **Normalized** – Displays all the brine data normalized to the "Good" brine data set ordered by "Good" brine data set, Brine Data Anions/Cations Ratio below 1.0, Brine Data Anions/Cations Ration above 1.0.

Normalization Brine Data to +/- 2% of the Anions/Cations Ratio of 1.0

The "Begin Normalization Process" Button on the "Brine Data" Dialog allows the user to force the brine data set to a "Corrected" Value. The default "% from Anions/Cations equal to 1.0" text field is 2.0, which implies the "Good" data set will fall between 1.02 and 0.98 inclusive. The web app separates the brine data above 1.02 and labels it as "Data Above 1" and brine data below 0.98 as "Data Below 1". In this specific example the data above 1.0 is K-State measured data and the data below is Baker Hughes measured data. The "Good" data set has at least 2 measurements of K-State in the data set with the rest being from the Baker Hughes data set.



The web app performs all the processing in the background, the user can only change the "% from Anions/Cations equal to 1.0" text field. The process begins by constructing the Covariance matrix for the "Good" data set, since this will be used in correcting the above and below data sets. Covariance [cov(x,y)] matrix is a measure how much each data column vary from the mean with respect to each other.

$$\text{cov}(x,y) = \frac{\sum_{i=1}^{N} (x_i - \bar{x})(y_i - \bar{y})}{(N-1)}$$

where x is the mean of brine data column k divided by σ_k where x_i is the individual brine data divided by σ_k, subscript i represents the well, subscript k represents the brine data column, e.g. cov (Na, Ca) is sum over the Na (Sodium cation) and Ca (Calcium cation) columns of the normalized data set.

Covariance Matrix – Good Data Set

	Na	K	Mg	Ca	Sr	MnII	FeII	Cl	SO4	PH
Na	1.0	-0.672	0.88	0.218	0.754	-0.135	-0.033	0.988	-0.262	-0.327
K	-0.672	1.0	-0.457	-0.065	-0.831	0.253	0.048	-0.584	-0.224	0.216
Mg	0.88	-0.457	1.0	-0.049	0.761	0.001	0.09	0.921	-0.366	-0.208
Ca	0.218	-0.065	-0.049	0.999	0.01	0.093	-0.009	0.165	0.496	-0.729
Sr	0.754	-0.831	0.761	0.01	0.999	-0.077	0.11	0.713	0.128	-0.397
MnII	-0.135	0.253	0.001	0.093	-0.077	0.999	0.958	-0.11	0.186	-0.326
FeII	-0.033	0.048	0.09	-0.009	0.11	0.958	0.999	-0.023	0.191	-0.337
Cl	0.988	-0.584	0.921	0.165	0.713	-0.11	-0.023	1.0	-0.353	-0.265
SO4	-0.262	-0.224	-0.366	0.496	0.128	0.186	0.191	-0.353	1.0	-0.505
PH	-0.327	0.216	-0.208	-0.729	-0.397	-0.326	-0.337	-0.265	-0.505	0.999

y ↓

X →

Covariance Matrix

$$C = \begin{bmatrix} cov(Na, Na) & cov(Na, K) & cov(Na, Mg) & \dots & cov(Na, SO_4) & cov(Na, PH) \\ cov(K, Na) & cov(K, K) & cov(K, Mg) & \dots & cov(K, SO_4) & cov(K, PH) \\ cov(Mg, Na) & cov(Mg, K) & cov(Mg, Mg) & \dots & cov(Mg, SO_4) & cov(Mg, PH) \\ & & \vdots & & & \vdots \\ cov(SO_4, Na) & cov(SO_4, K) & cov(SO_4, Mg) & \dots & cov(SO_4, SO_4) & cov(SO_4, PH) \\ cov(PH, Na) & cov(PH, K) & cov(PH, Mg) & \dots & cov(PH, SO_4) & cov(PH, PH) \end{bmatrix}$$

To compute the Eigenvectors and Eigenvalues this web app uses JAMA a Java Matrix Package (http://math.nist.gov/javanumerics/jama/).

"JAMA is a basic linear algebra package for Java. It provides user-level classes for constructing and manipulating real, dense matrices. It is meant to provide sufficient functionality for routine problems, packaged in a way that is natural and understandable to non-experts. It is intended to serve as the standard matrix class for Java."

JAMA Java Functions:
C represents the symbol for the Covariance Matrix
The eigenvalues & eigenvectors JAMA functions are listed as follows

E_v = C.eig(), where the eig() function computes the eigenvalues & eigenvectors of the covariance matrix C.

The eigenvalues can be retrieved as follows, Eigenvalues = E_v.getRealEigenvalues() and the eigenvectors can then be retrieve as follows, Eigenvectors = E_v.getV().

Eigenvector [V] =

0.511	-0.528	-0.12	0.353	0.033	-0.246	-0.177	0.024	-0.062	-0.47	Na
0.476	0.04	0.088	-0.011	-0.296	0.482	-0.513	0.204	0.006	0.37	K
-0.544	-0.27	0.129	0.04	-0.473	0.343	-0.125	0.241	-0.094	-0.432	Mg
-0.082	-0.103	0.12	-0.495	-0.17	-0.339	-0.502	-0.417	0.376	-0.094	Ca
0.377	0.06	-0.1	-0.606	0.0	0.373	0.381	-0.02	0.047	-0.434	Sr
-0.072	0.049	-0.687	-0.061	-0.14	-0.173	-0.02	0.502	0.459	0.049	MnII
0.095	-0.062	0.671	-0.031	0.13	-0.17	0.163	0.517	0.44	-0.016	FeII
0.101	0.785	0.078	0.183	-0.114	-0.185	-0.237	0.092	-0.093	-0.459	Cl
0.14	0.069	0.049	0.384	-0.553	0.061	0.395	-0.399	0.443	0.05	SO4
0.147	-0.05	0.064	-0.27	-0.549	-0.486	0.225	0.19	-0.482	0.202	PH

Construct an Adjusted Data Matrix from the Brine Data Matrix by subtracting the mean of each column.

$$\text{Adjusted Data Matrix [Am]} = [\ (X_{ik} - \overline{X}_k)\ ]$$

where $\overline{X}_k$ is the mean of brine data column k

X_{ik} is the individual brine data; i=well, k=brine data

Compute the Final Data [F] matrix as the Eigenvector [V] times the transpose of the Adjusted Data $[Am]^T$ matrix,

$$[F] = [V] \text{ X } [Am]^T$$

The Original Data [B] matrix can be found by multiplying the transpose of the Feature Vector $[V]^T$ times the Fine Data [F] matrix plus the Original Mean $[X_o]$ of the "Good" data set,

$$[B] = [V]^T \text{ X } [F] + [X_o].$$

The above equation also works even if a feature vector is constructed from the eigenvectors where not all the eigenvectors are included. If the eigenvector is used on the Adjusted Data Matrix and the Original Mean is added back then the original Brine data matrix should be reproduced. This is the basis of the correction of the above and below data sets.

Good	Na	K	Mg	Ca	Sr	MnII	FeII	Cl	SO4	PH
Mean	2,665.634	9.299	214.667	602.367	10.043	0.033	1.143	3,438.603	26.469	5.493
Sigma	152.374	1.045	33.629	19.478	6.607	0.019	1.383	178.909	8.326	0.416

Below 1	Na	K	Mg	Ca	Sr	MnII	FeII	Cl	SO4	PH
Mean	2,677.727	9.214	211.104	615.492	11.342	0.039	0.918	3,263.849	25.996	5.372
Sigma	122.8	0.936	21.36	20.935	3.693	0.021	0.724	183.52	5.352	0.339

Above 1	Na	K	Mg	Ca	Sr	MnII	FeII	Cl	SO4	PH
Mean	2,259.291	16.556	169.01	507.481	2.278	0.03	0.332	3,206.169	19.403	6.229
Sigma	372.107	9.807	52.16	98.683	3.367	0.015	0.308	565.91	18.376	0.482

The mean values for the Below & Above data sets are compared with the "Good" data set. The means for the Chlorides are lower for the Below & Above data sets. The Above data set is also mixed for the other analytes.

The normalization process assumes that the "Good" Data set is correct and that for some reason the measurements Below and Above the 2% of the Anions/Cations ratio of 1.0 have below average values of Chlorides, because these water samples have a very high concentration of Chlorides which could have saturated the measurements results. This analysis is not suggesting that the data is in error only that the Brine data for Below and Above data sets will be modified to fit the "Good" Data set mean value.

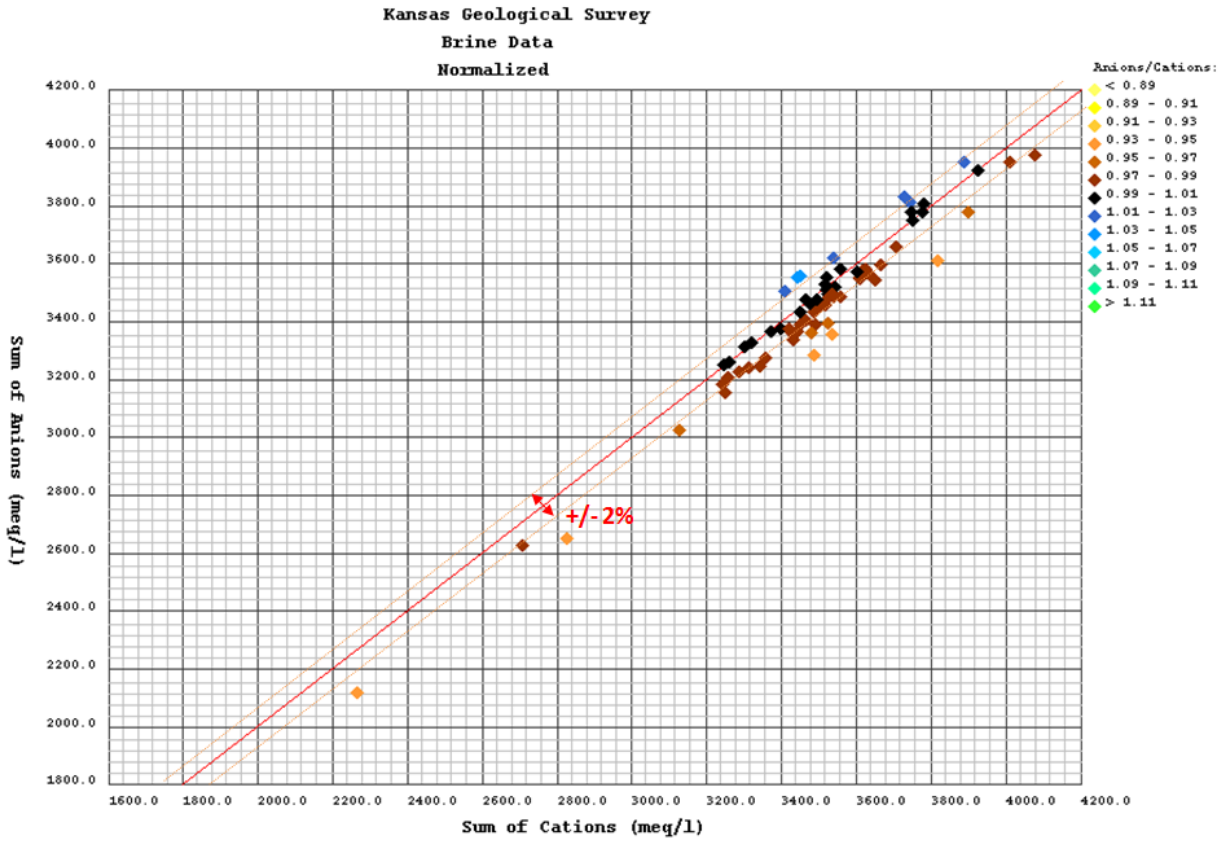
The "Good" Data eigenvectors and Means will be used to correct the Brine data for the Below and Above data sets. In the same manner as the "Good" brine data set, the Adjusted Data Matrix will be constructed for the Below and Above data sets using their respective means. Then the "Good" eigenvectors and "Good" means will be used to compute the "original" data sets as if the

above and below were measured as the original good data, the final equation is used to compute the corrected data sets,

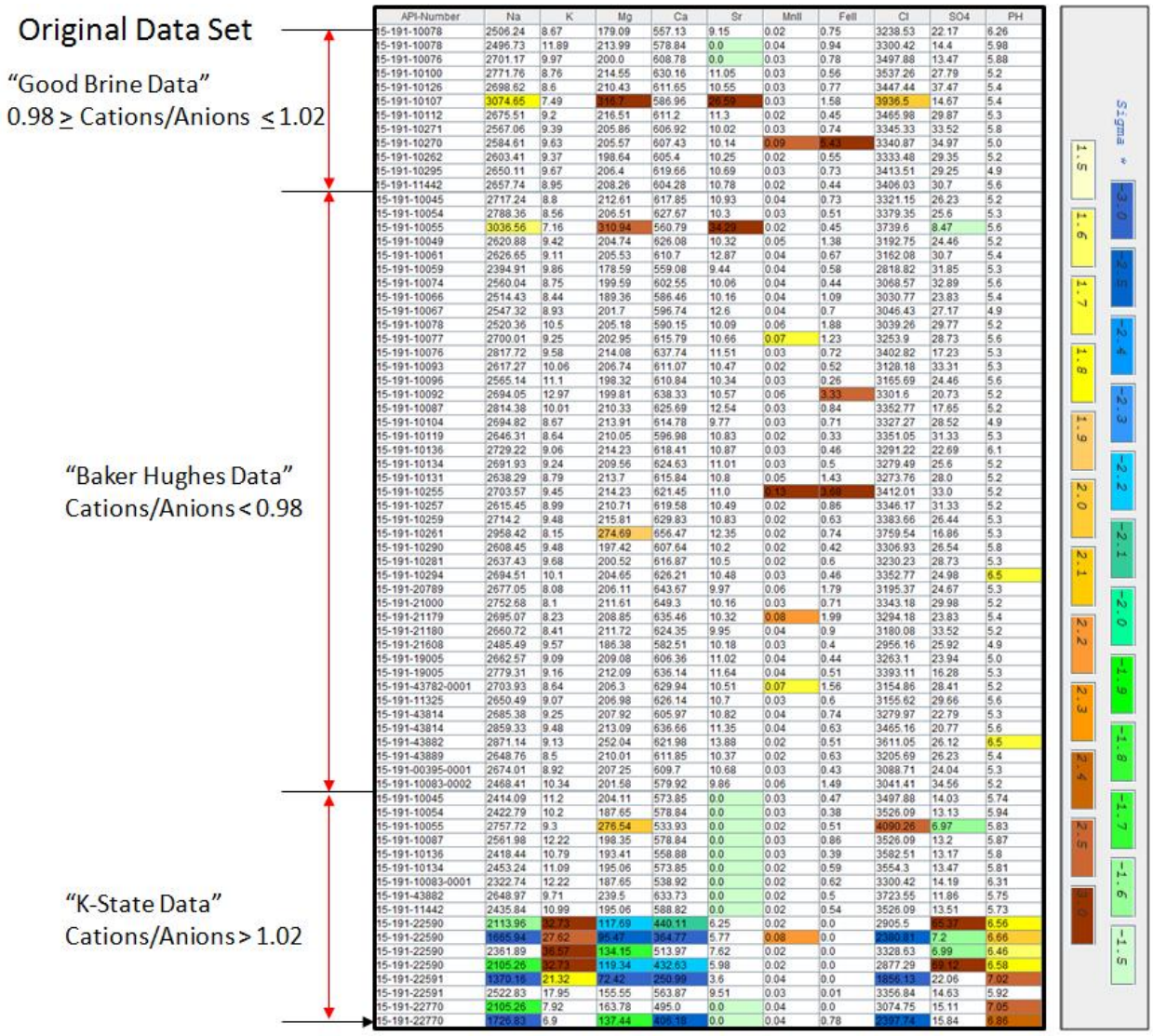
$$[B] = [Vg]^T \text{ X } [\,[Vg] \text{ X } [Am_R]^T\,] + [Xg].$$

where [Vg] is the eigenvector of the "Good" data set
[Xg] is the "Good" mean matrix
$[Am_R]$ is the Adjusted Data Matrix for either the Below or Above data sets.
[B] is the "new Original" data set of the Below or Above Brine data.

Using the above equation on the Above & Below data sets the data is corrected to the 2% range limit as illustrated below,



Comparison of the Original Brine Data with the Normalized Brine Data



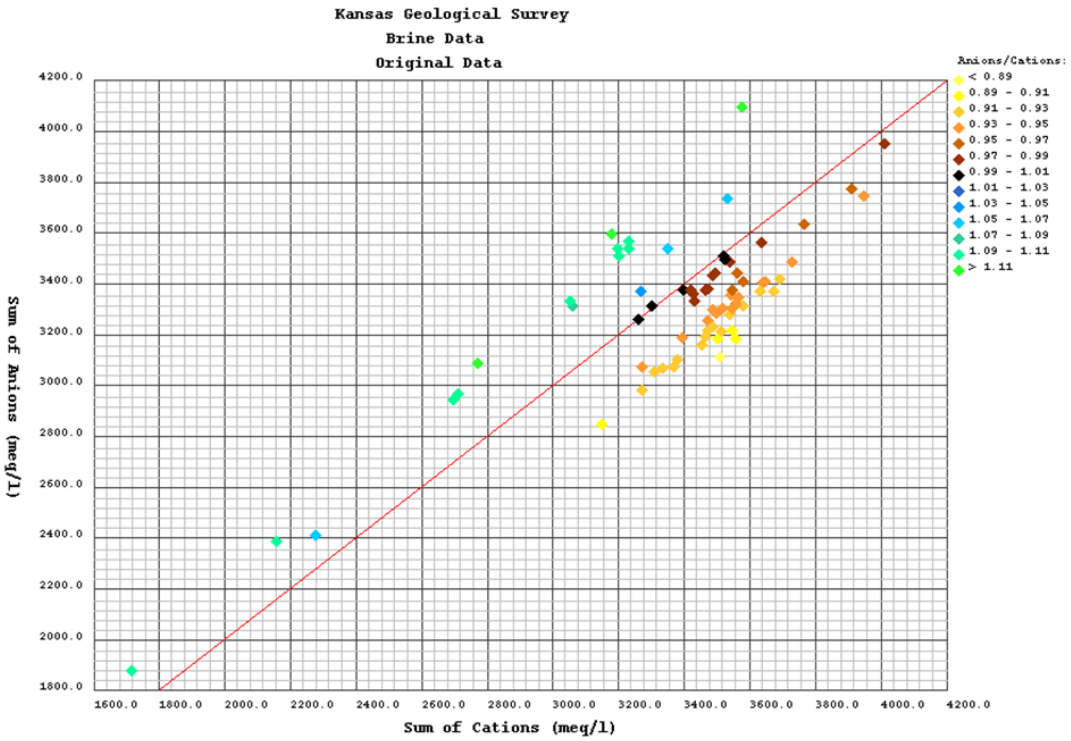
API-Number	Na	K	Mg	Ca	Sr	MnII	FeII	Cl	SO4	PH
15-191-10078	2506.24	8.67	179.09	557.13	9.15	0.02	0.75	3238.53	22.17	6.26
15-191-10078	2496.73	11.89	213.99	578.84	0.0	0.04	0.94	3300.42	14.4	5.98
15-191-10076	2701.17	9.97	200.0	608.78	0.0	0.03	0.78	3497.88	13.47	5.88
15-191-10100	2771.76	8.76	214.55	630.16	11.05	0.03	0.56	3537.26	27.79	5.2
15-191-10126	2698.62	8.6	210.43	611.65	10.55	0.03	0.77	3447.44	37.47	5.4
15-191-10107	3074.65	7.49	246.7	586.96	99.69	0.03	1.58	3936.5	14.67	5.4
15-191-10112	2675.51	9.2	216.51	611.2	11.3	0.02	0.45	3465.98	29.87	5.3
15-191-10271	2567.06	9.39	205.86	606.92	10.02	0.03	0.74	3345.33	33.52	5.8
15-191-10270	2584.61	9.63	205.57	607.43	10.14	0.09	8.43	3340.87	34.97	5.0
15-191-10262	2603.41	9.37	198.64	605.4	10.25	0.02	0.55	3333.48	29.35	5.2
15-191-10295	2650.11	9.67	206.4	619.66	10.69	0.03	0.73	3413.51	29.25	4.9
15-191-11442	2657.74	8.95	208.26	604.28	10.78	0.02	0.44	3406.03	30.7	5.6
15-191-10045	2717.24	8.8	212.61	617.85	10.93	0.04	0.73	3321.15	26.23	5.2
15-191-10054	2788.36	8.56	206.51	627.67	10.3	0.03	0.51	3379.35	25.6	5.3
15-191-10055	3036.56	7.16	310.94	560.79	14.29	0.02	0.45	3739.6	8.47	5.6
15-191-10049	2620.88	9.42	204.74	626.08	10.32	0.05	1.38	3192.75	24.46	5.2
15-191-10061	2626.65	9.11	205.53	610.7	12.87	0.04	0.67	3162.08	30.7	5.4
15-191-10059	2394.91	9.86	178.59	559.08	9.44	0.04	0.58	2818.82	31.85	5.3
15-191-10074	2560.04	8.75	199.59	602.55	10.06	0.04	0.44	3068.57	32.89	5.6
15-191-10066	2514.43	8.44	189.36	586.46	10.16	0.04	1.09	3030.77	23.83	5.4
15-191-10067	2547.32	8.93	201.7	596.74	12.6	0.04	0.7	3046.43	27.17	4.9
15-191-10078	2520.36	10.5	205.18	590.15	10.09	0.06	1.88	3039.26	29.77	5.2
15-191-10077	2700.01	9.25	202.95	615.79	10.66	0.07	1.23	3253.9	28.73	5.6
15-191-10076	2817.72	9.58	214.08	637.74	11.51	0.03	0.72	3402.82	17.23	5.3
15-191-10093	2617.27	10.06	206.74	611.07	10.47	0.02	0.52	3128.18	33.31	5.3
15-191-10096	2565.14	11.1	198.32	610.84	10.34	0.03	0.26	3165.69	24.46	5.6
15-191-10092	2694.05	12.97	199.81	638.33	10.57	0.06	3.33	3301.6	20.73	5.2
15-191-10087	2814.38	10.01	210.33	625.69	12.54	0.03	0.84	3352.77	17.65	5.2
15-191-10104	2694.82	8.67	213.91	614.78	9.77	0.03	0.71	3327.27	28.52	4.9
15-191-10119	2646.31	8.64	210.05	596.98	10.83	0.02	0.33	3351.05	31.33	5.3
15-191-10136	2729.22	9.06	214.23	618.41	10.87	0.03	0.46	3291.22	22.69	6.1
15-191-10134	2691.93	9.24	209.56	624.63	11.01	0.03	0.5	3279.49	25.6	5.2
15-191-10131	2638.29	8.79	213.7	615.84	10.8	0.05	1.43	3273.76	28.0	5.2
15-191-10255	2703.57	9.45	214.23	621.45	11.0	0.13	3.68	3412.01	33.0	5.2
15-191-10257	2615.45	8.99	210.71	619.58	10.49	0.02	0.86	3346.17	31.33	5.2
15-191-10259	2714.2	9.48	215.81	629.83	10.83	0.02	0.63	3383.66	26.44	5.3
15-191-10261	2958.42	8.15	274.69	656.47	12.35	0.02	0.74	3759.54	16.86	5.3
15-191-10290	2608.45	9.48	197.42	607.64	10.2	0.02	0.42	3306.93	26.54	5.8
15-191-10281	2637.43	9.68	200.52	616.87	10.5	0.02	0.6	3230.23	28.73	5.3
15-191-10294	2694.51	10.1	204.65	626.21	10.48	0.03	0.46	3352.77	24.98	6.5
15-191-20789	2677.05	8.08	206.11	643.67	9.97	0.06	1.79	3195.37	24.67	5.3
15-191-21000	2752.68	8.1	211.61	649.3	10.16	0.03	0.71	3343.18	29.98	5.2
15-191-21179	2695.07	8.23	208.85	635.46	10.32	0.08	1.99	3294.18	23.83	5.4
15-191-21180	2660.72	8.41	211.72	624.35	9.95	0.04	0.9	3180.08	33.52	5.2
15-191-21608	2485.49	9.57	186.38	582.51	10.18	0.03	0.4	2956.16	25.92	4.9
15-191-19005	2662.57	9.09	209.08	606.36	11.02	0.04	0.44	3263.1	23.94	5.0
15-191-19005	2779.31	9.16	212.09	636.14	11.64	0.04	0.51	3393.11	16.28	5.3
15-191-43782-0001	2703.93	8.64	206.3	629.94	10.51	0.07	1.56	3154.86	28.41	5.2
15-191-11325	2650.49	9.07	206.98	626.14	10.7	0.03	0.6	3155.62	29.66	5.6
15-191-43814	2685.38	9.25	207.92	605.97	10.82	0.04	0.74	3279.97	22.79	5.3
15-191-43814	2859.33	9.48	213.09	636.66	11.35	0.04	0.63	3465.16	20.77	5.6
15-191-43882	2871.14	9.13	252.04	621.98	13.88	0.02	0.51	3611.05	26.12	6.5
15-191-43889	2648.76	8.5	210.01	611.85	10.37	0.02	0.63	3205.69	26.23	5.4
15-191-00395-0001	2674.01	8.92	207.25	609.7	10.68	0.03	0.43	3088.71	24.04	5.3
15-191-10083-0002	2468.41	10.34	201.58	579.92	9.86	0.06	1.49	3041.41	34.56	5.2
15-191-10045	2414.09	11.2	204.11	573.85	0.0	0.03	0.47	3497.88	14.03	5.74
15-191-10054	2422.79	10.2	187.65	578.84	0.0	0.03	0.38	3526.09	13.13	5.94
15-191-10055	2757.72	9.3	276.54	533.93	0.0	0.02	0.51	4090.26	6.97	5.83
15-191-10087	2561.98	12.22	198.35	578.84	0.0	0.03	0.86	3526.09	13.2	5.87
15-191-10136	2418.44	10.79	193.41	558.88	0.0	0.03	0.39	3582.51	13.17	5.8
15-191-10134	2453.24	11.09	195.06	573.85	0.0	0.02	0.59	3554.3	13.47	5.81
15-191-10083-0001	2322.74	12.22	187.65	538.92	0.0	0.02	0.62	3300.42	14.19	6.31
15-191-43882	2648.97	9.71	239.5	633.73	0.0	0.02	0.5	3723.55	11.86	5.75
15-191-11442	2435.84	10.99	195.06	588.82	0.0	0.02	0.54	3526.09	13.51	5.73
15-191-22590	2113.96	32.73	117.69	440.11	6.25	0.02	0.0	2905.5	25.37	6.56
15-191-22590	1865.94	27.62	95.47	354.77	5.77	0.08	0.0	2380.81	7.2	6.66
15-191-22590	2361.89	36.57	134.15	513.97	7.62	0.02	0.0	3328.63	6.99	6.46
15-191-22590	2105.26	32.73	119.34	432.63	5.98	0.02	0.0	2877.29	58.12	6.58
15-191-22591	1370.16	21.32	72.42	250.99	3.6	0.04	0.0	1858.13	22.06	7.02
15-191-22591	2522.83	17.95	155.55	563.87	9.51	0.03	0.01	3356.84	14.63	5.92
15-191-22770	2105.26	7.92	163.78	495.0	0.0	0.04	0.0	3074.75	15.11	7.05
15-191-22770	1726.83	6.9	137.44	406.18	0.0	0.04	0.78	2397.74	15.84	6.86

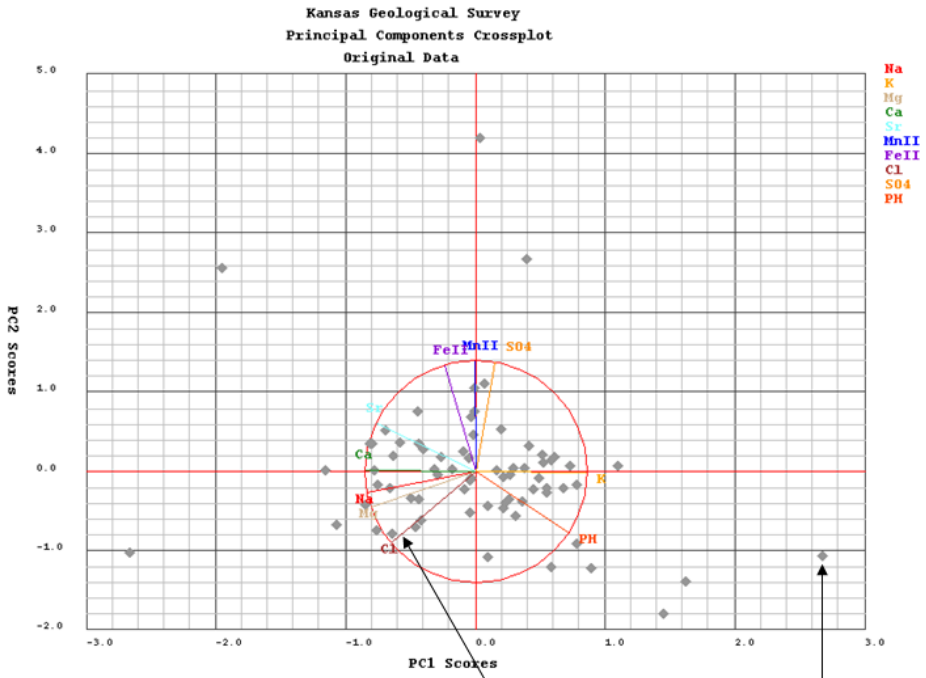
	Na	K	Mg	Ca	Sr	MnII	FeII	Cl	SO4	PH
Mean	2,576.914	10.962	201.759	587.802	8.985	0.036	0.817	3,279.356	24.518	5.595
Sigma	274.521	5.672	37.364	67.51	5.631	0.02	0.841	320.572	10.584	0.525

Covariance Matrix – Original Data Set

	Na	K	Mg	Ca	Sr	MnII	FeII	Cl	SO4	PH
Na	1.0	-0.559	0.875	0.895	0.559	-0.092	0.232	0.796	-0.059	-0.653
K	-0.559	1.0	-0.671	-0.635	-0.222	-0.05	-0.25	-0.368	0.226	0.522
Mg	0.875	-0.671	0.999	0.708	0.508	-0.114	0.227	0.801	-0.233	-0.527
Ca	0.895	-0.635	0.708	0.999	0.335	0.005	0.297	0.661	-0.007	-0.728
Sr	0.559	-0.222	0.508	0.335	1.0	0.053	0.158	0.167	0.174	-0.436
MnII	-0.092	-0.05	-0.114	0.005	0.053	1.0	0.724	-0.253	0.062	-0.175
FeII	0.232	-0.25	0.227	0.297	0.158	0.724	1.0	0.113	0.103	-0.393
Cl	0.796	-0.368	0.801	0.661	0.167	-0.253	0.113	1.0	-0.291	-0.328
SO4	-0.059	0.226	-0.233	-0.007	0.174	0.062	0.103	-0.291	1.0	-0.141
PH	-0.653	0.522	-0.527	-0.728	-0.436	-0.175	-0.393	-0.328	-0.141	1.0

- -0.30 – -0.40
- -0.40 – -0.65
- -0.65 – -0.99
- 1.00
- 0.80 – 0.99
- 0.65 – 0.80
- 0.30 – 0.65





	Pc_1	Pc_2	
Feature Vector [V] =	-0.442	-0.085	Na
	0.333	-0.004	K
	-0.423	-0.145	Mg
	-0.418	0.007	Ca
	-0.248	0.12	Sr
	-0.009	0.634	MnII
	-0.171	0.568	FeII
	-0.35	-0.293	Cl
	0.053	0.302	SO4
	0.349	-0.23	PH

The Principal Component Scores Matrix [PC Scores] are gray diamonds.

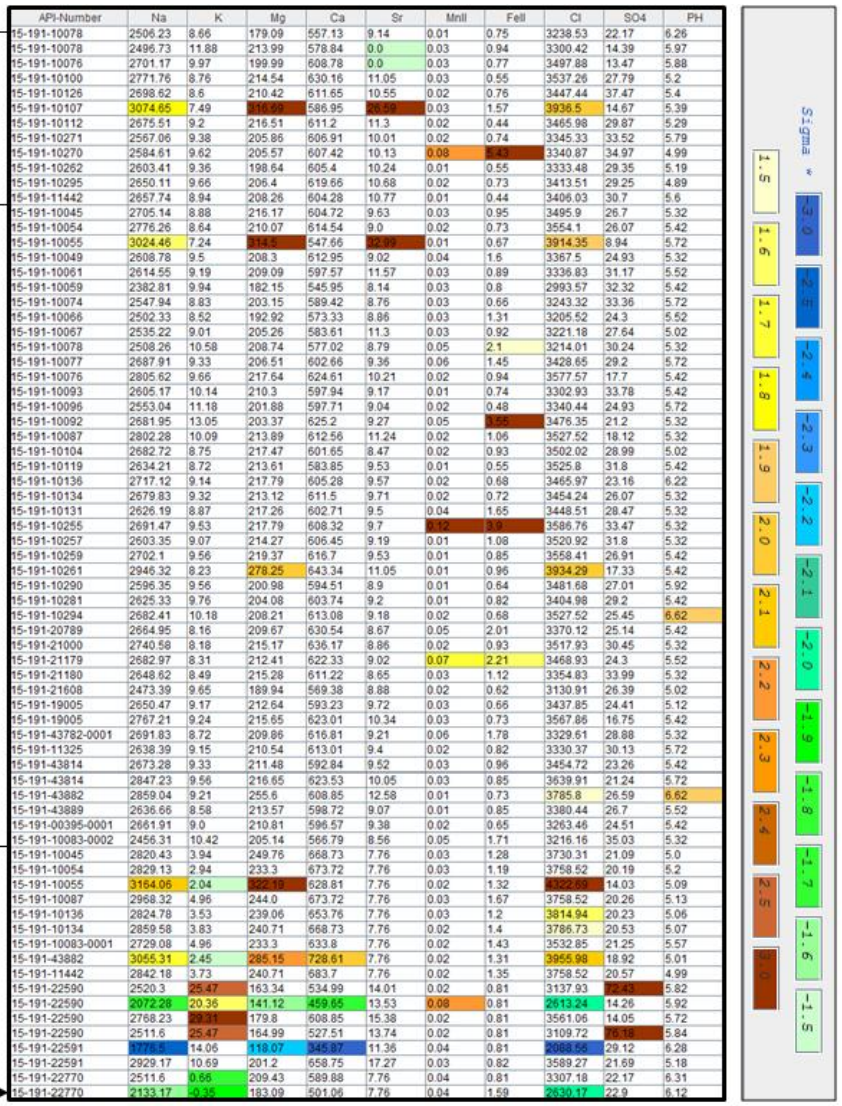
The Feature Vector is represented as colored lines around a red unit circle, where each Feature Vector row is normalized to unit circle.

Normalized Data Set

"Good Brine Data"
0.98 ≥ Cations/Anions ≤ 1.02

"Baker Hughes Data"
Cations/Anions < 0.98

"K-State Data"
Cations/Anions > 1.02



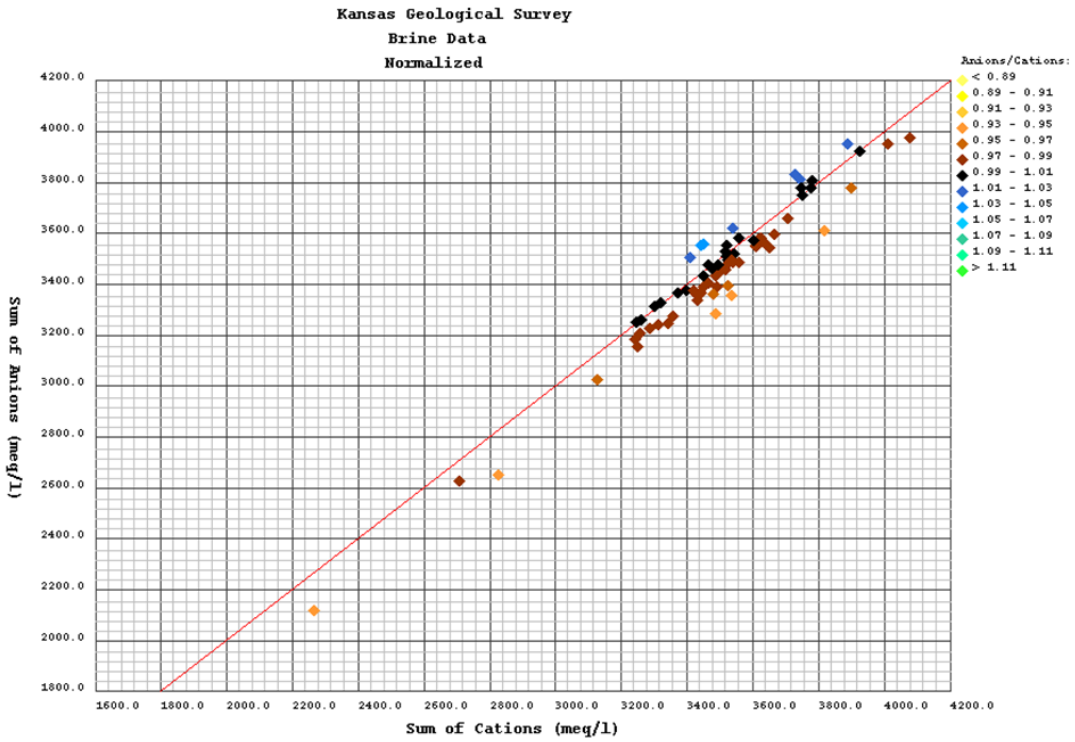
API-Number	Na	K	Mg	Ca	Sr	MnII	FeII	Cl	SO4	PH
15-191-10078	2506.23	8.66	179.09	557.13	9.14	0.01	0.75	3238.53	22.17	6.26
15-191-10078	2496.73	11.88	213.99	578.84	0.0	0.03	0.94	3300.42	14.39	5.97
15-191-10076	2701.17	9.97	199.99	608.78	0.0	0.03	0.77	3497.88	13.47	5.88
15-191-10100	2771.76	8.76	214.54	630.16	11.05	0.03	0.55	3537.26	27.79	5.2
15-191-10126	2698.62	8.6	210.42	611.65	10.55	0.02	0.76	3447.44	37.47	5.4
15-191-10107	3074.65	7.49	418.93	586.95	26.59	0.03	1.57	3936.5	14.67	5.39
15-191-10112	2675.51	9.2	216.51	611.2	11.3	0.02	0.44	3465.98	29.87	5.29
15-191-10271	2567.06	9.38	205.86	606.91	10.01	0.02	0.74	3345.33	33.52	5.79
15-191-10270	2584.61	9.62	205.57	607.42	10.13	0.08	5.43	3340.87	34.97	4.99
15-191-10262	2603.41	9.36	198.64	605.4	10.24	0.01	0.55	3333.48	29.35	5.19
15-191-10295	2650.11	9.66	206.4	619.66	10.68	0.02	0.73	3413.51	29.25	4.89
15-191-11442	2657.74	8.94	208.26	604.28	10.77	0.01	0.44	3406.03	30.7	5.6
15-191-10045	2705.14	8.88	216.17	604.72	9.63	0.03	0.95	3495.9	26.7	5.32
15-191-10054	2776.26	8.64	210.07	614.54	9.0	0.02	0.73	3554.1	26.07	5.42
15-191-10055	3024.46	7.24	314.5	547.66	32.99	0.01	0.67	3914.35	8.94	5.72
15-191-10049	2608.78	9.5	208.3	612.95	9.02	0.04	1.6	3367.5	24.93	5.32
15-191-10061	2614.55	9.19	209.09	597.57	11.57	0.03	0.89	3336.83	31.17	5.52
15-191-10059	2382.81	9.94	182.15	545.95	8.14	0.03	0.8	2993.57	32.32	5.42
15-191-10074	2547.94	8.83	203.15	589.42	8.76	0.03	0.66	3243.32	33.36	5.72
15-191-10066	2502.33	8.52	192.92	573.33	8.86	0.03	1.31	3205.52	24.3	5.52
15-191-10067	2535.22	9.01	205.26	583.61	11.3	0.03	0.92	3221.18	27.64	5.02
15-191-10078	2508.26	10.58	208.74	577.02	8.79	0.05	2.1	3214.01	30.24	5.32
15-191-10077	2687.91	9.33	206.51	602.66	9.36	0.06	1.45	3428.65	29.2	5.72
15-191-10076	2805.62	9.66	217.64	624.61	10.21	0.02	0.94	3577.57	17.7	5.42
15-191-10093	2605.17	10.14	210.3	597.94	9.17	0.01	0.74	3302.93	33.78	5.42
15-191-10096	2553.04	11.18	201.88	597.71	9.04	0.02	0.48	3340.44	24.93	5.72
15-191-10092	2681.95	13.05	203.37	625.2	9.27	0.05	3.55	3476.35	21.2	5.32
15-191-10087	2802.28	10.09	213.89	612.56	11.24	0.02	1.06	3527.52	18.12	5.32
15-191-10104	2682.72	8.75	217.47	601.65	8.47	0.02	0.93	3502.02	28.99	5.02
15-191-10119	2634.21	8.72	213.61	583.85	9.53	0.01	0.55	3525.8	31.8	5.42
15-191-10136	2717.12	9.14	217.79	605.28	9.57	0.02	0.68	3465.97	23.16	6.22
15-191-10134	2679.83	9.32	213.12	611.5	9.71	0.02	0.72	3454.24	26.07	5.32
15-191-10131	2626.19	8.87	217.26	602.71	9.5	0.04	1.65	3448.51	28.47	5.32
15-191-10255	2691.47	9.53	217.79	608.32	9.7	0.12	3.9	3586.76	33.47	5.32
15-191-10257	2603.35	9.07	214.27	606.45	9.19	0.01	1.08	3520.92	31.8	5.32
15-191-10259	2702.1	9.56	219.37	616.7	9.53	0.01	0.85	3558.41	26.91	5.42
15-191-10261	2946.32	8.23	278.25	643.34	11.05	0.01	0.96	3934.29	17.33	5.42
15-191-10290	2596.35	9.56	200.98	594.51	8.9	0.01	0.64	3481.68	27.01	5.92
15-191-10281	2625.33	9.76	204.08	603.74	9.2	0.01	0.82	3404.98	29.2	5.42
15-191-10294	2682.41	10.18	208.21	613.08	9.18	0.02	0.68	3527.52	25.45	6.62
15-191-20789	2664.95	8.16	209.67	630.54	8.67	0.05	2.01	3370.12	25.14	5.42
15-191-21000	2740.58	8.18	215.17	636.17	8.86	0.02	0.93	3517.93	30.45	5.32
15-191-21179	2682.97	8.31	212.41	622.33	9.02	0.07	2.21	3468.93	24.3	5.52
15-191-21180	2648.62	8.49	215.28	611.22	8.65	0.03	1.12	3354.83	33.99	5.32
15-191-21608	2473.39	9.65	189.94	569.38	8.88	0.02	0.62	3130.91	26.39	5.02
15-191-19005	2650.47	9.17	212.64	593.23	9.72	0.03	0.66	3437.85	24.41	5.12
15-191-19005	2767.21	9.24	215.65	623.01	10.34	0.03	0.73	3567.86	16.75	5.42
15-191-43782-0001	2691.83	8.72	209.86	616.81	9.21	0.06	1.78	3329.61	28.88	5.32
15-191-11325	2638.39	9.15	210.54	613.01	9.4	0.02	0.82	3330.37	30.13	5.72
15-191-43814	2673.28	9.33	211.48	592.84	9.52	0.03	0.96	3454.72	23.26	5.42
15-191-43814	2847.23	9.56	216.65	623.53	10.05	0.03	0.85	3639.91	21.24	5.72
15-191-43882	2859.04	9.21	255.6	608.85	12.58	0.01	0.73	3785.8	26.59	6.62
15-191-43889	2636.66	8.58	213.57	598.72	9.07	0.01	0.85	3380.44	26.7	5.52
15-191-00395-0001	2661.91	9.0	210.81	596.57	9.38	0.02	0.65	3263.46	24.51	5.42
15-191-10083-0002	2456.31	10.42	205.14	566.79	8.56	0.05	1.71	3216.16	35.03	5.32
15-191-10045	2820.43	3.94	249.76	668.73	7.76	0.03	1.28	3730.31	21.09	5.0
15-191-10054	2829.13	2.94	233.3	673.72	7.76	0.03	1.19	3758.52	20.19	5.2
15-191-10055	3164.06	2.04	322.19	628.81	7.76	0.02	1.32	4322.69	14.03	5.09
15-191-10087	2968.32	4.96	244.0	673.72	7.76	0.03	1.67	3758.52	20.26	5.13
15-191-10136	2824.78	3.53	239.06	653.76	7.76	0.03	1.2	3814.94	20.23	5.06
15-191-10134	2859.58	3.83	240.71	668.73	7.76	0.02	1.4	3786.73	20.53	5.07
15-191-10083-0001	2729.08	4.96	233.3	633.8	7.76	0.02	1.43	3532.85	21.25	5.57
15-191-43882	3055.31	2.45	285.15	728.61	7.76	0.02	1.31	3955.98	18.92	5.01
15-191-11442	2842.18	3.73	240.71	683.7	7.76	0.02	1.35	3758.52	20.57	4.99
15-191-22590	2520.3	25.47	163.34	534.99	14.01	0.02	0.81	3137.93	72.43	5.82
15-191-22590	2072.28	20.36	141.12	459.65	13.53	0.08	0.81	2613.24	14.26	5.92
15-191-22590	2768.23	29.31	179.8	608.85	15.38	0.02	0.81	3561.06	14.05	5.72
15-191-22590	2511.6	25.47	164.99	527.51	13.74	0.02	0.81	3109.72	76.18	5.84
15-191-22591	1776.5	14.06	118.07	345.87	11.36	0.04	0.81	2088.58	29.12	6.28
15-191-22591	2929.17	10.69	201.2	658.75	17.27	0.03	0.82	3589.27	21.69	5.18
15-191-22770	2511.6	0.66	209.43	589.88	7.76	0.04	0.81	3307.18	22.17	6.31
15-191-22770	2133.17	-0.35	183.09	501.06	7.76	0.04	1.59	2630.17	22.9	6.12

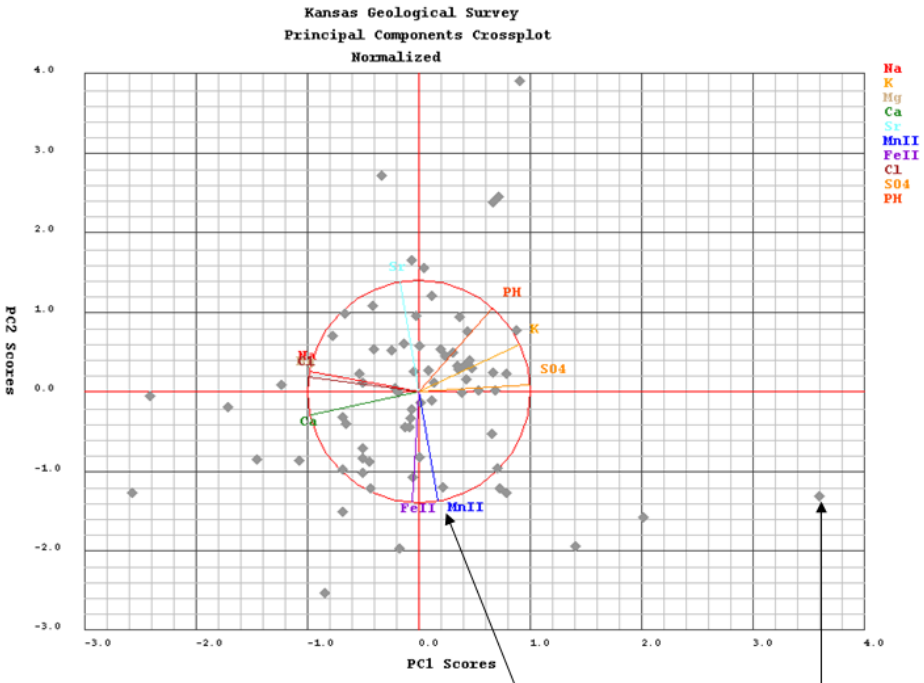
	Na	K	Mg	Ca	Sr	MnII	FeII	Cl	SO4	PH
Mean	2,665.629	9.295	214.663	602.363	10.04	0.029	1.139	3,438.599	26.466	5.491
Sigma	209.095	4.729	32.53	50.126	4.169	0.019	0.792	311.532	10.187	0.384

Covariance Matrix – Normalized Data Set

	Na	K	Mg	Ca	Sr	MnII	FeII	Cl	SO4	PH
Na	1.0	-0.317	0.841	0.818	0.224	-0.255	0.034	0.969	-0.319	-0.383
K	-0.317	1.0	-0.551	-0.431	0.236	0.051	-0.092	-0.368	0.468	0.243
Mg	0.841	-0.551	0.999	0.594	0.285	-0.207	0.08	0.865	-0.437	-0.311
Ca	0.818	-0.431	0.594	1.0	-0.208	-0.156	0.128	0.818	-0.261	-0.499
Sr	0.224	0.236	0.285	-0.208	1.0	-0.081	-0.069	0.137	-0.006	0.04
MnII	-0.255	0.051	-0.207	-0.156	-0.081	1.0	0.729	-0.247	0.004	-0.073
FeII	0.034	-0.092	0.08	0.128	-0.069	0.729	0.999	0.057	0.016	-0.266
Cl	0.969	-0.368	0.865	0.818	0.137	-0.247	0.057	1.0	-0.351	-0.363
SO4	-0.319	0.468	-0.437	-0.261	-0.006	0.004	0.016	-0.351	0.999	0.057
PH	-0.383	0.243	-0.311	-0.499	0.04	-0.073	-0.266	-0.363	0.057	0.999

- -0.30 – -0.40
- -0.40 – -0.65
- -0.65 – -0.99
- 1.00
- 0.80 – 0.99
- 0.65 – 0.80
- 0.30 – 0.65





	Pc_1	Pc_2	
Feature Vector [V] =	-0.456	0.084	Na
	0.283	0.134	K
	-0.439	0.057	Mg
	-0.416	-0.091	Ca
	-0.042	0.235	Sr
	0.112	-0.632	MnII
	-0.041	-0.654	FeII
	-0.461	0.062	Cl
	0.236	0.015	SO4
	0.241	0.274	PH

The Principal Component Scores Matrix [PC Scores] are gray diamonds.

The Feature Vector is represented as colored lines around a red unit circle, where each Feature Vector row is normalized to unit circle.