

Implementation Of A Workflow For Streaming Sensor Data For A Large-Scale Hydrologic Monitoring Network



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4-1-2014

Support:
EPS 1208732



Challenges to Managing Sensor Data

- Volume of data
- Data heterogeneity
- Multiple watersheds
- Multiple institutions
- Multiple personnel
- Scale
- Data quality assurance and quality control
- Standardize data editing
- Synchronize timing, data access, equipment tracking

Rain, Snow, and Climate



Sapflux



Soil water and chemistry



Water quality



Water quantity



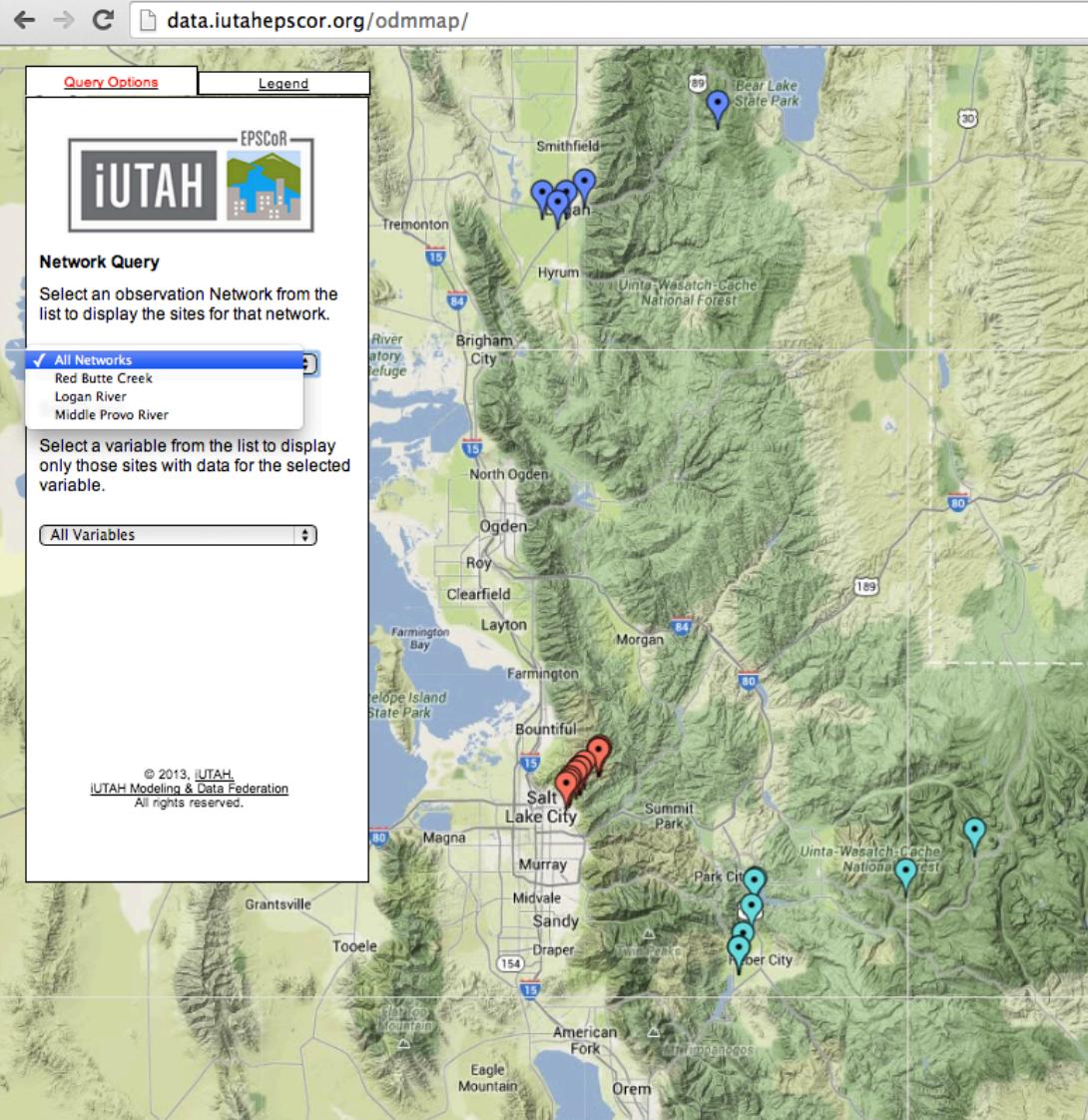
Groundwater



Mobile Platforms



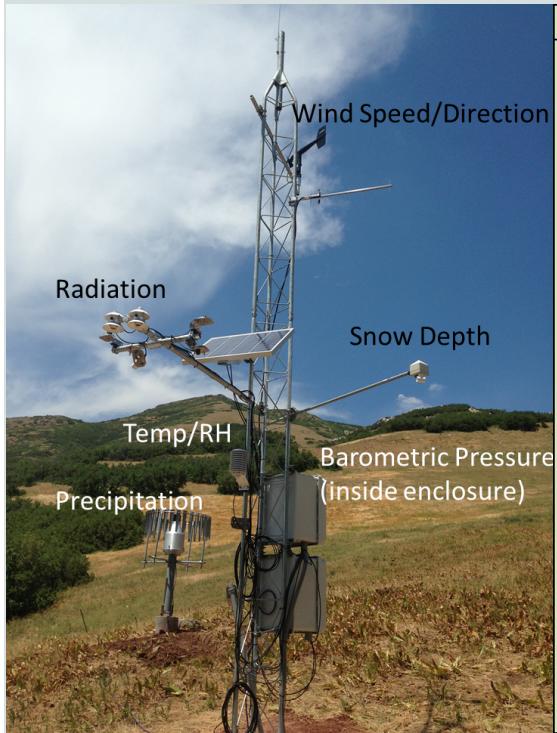
Gradients Along Mountain To Urban Transitions (GAMUT) Network



- Ecohydrologic observatory deployed in 3 watersheds: Logan River, Red Butte Creek, Provo River
- Watersheds with similar water source (high elevation snow) but different land use transitions
- Measures aspects of water inputs and outputs and water quality over mountain-to-urban gradient
- Mix of aquatic and terrestrial *in situ* and re-locatable sensors

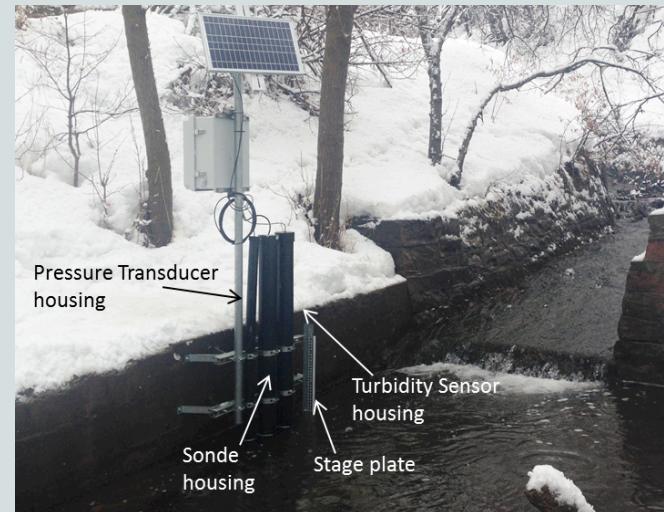
Gradients Along Mountain to Urban Transitions (GAMUT) Network

Climate/Terrestrial Sites



Manufacturer	Instrument	Variables Measured
Campbell	HC2S3	Air Temperature and Relative Humidity
Apogee	ST110	Air Temperature
Campbell	CS106	Barometric Pressure
RM Young	5303	Wind Speed/Direction
Geonor	TB-200	Precipitation
Judd	Depth Sensor	Snow Depth
Hukseflux	NR01	Incoming and Outgoing Shortwave and Longwave Radiation
Apogee	SP-230	Incoming Shortwave Radiation
Apogee	SQ-110	Incoming and Outgoing Photosynthetically Active Radiation
Apogee	SI-111	Surface Temperature
Acclima	ACC-SEN-SDI	Soil Moisture, Temperature, and Conductivity at 5 cm, 10 cm, 20 cm, 50 cm, 100 cm below ground
Campbell	CS210	Enclosure Humidity
Campbell	18166	Enclosure open door sensor

Aquatic Sites

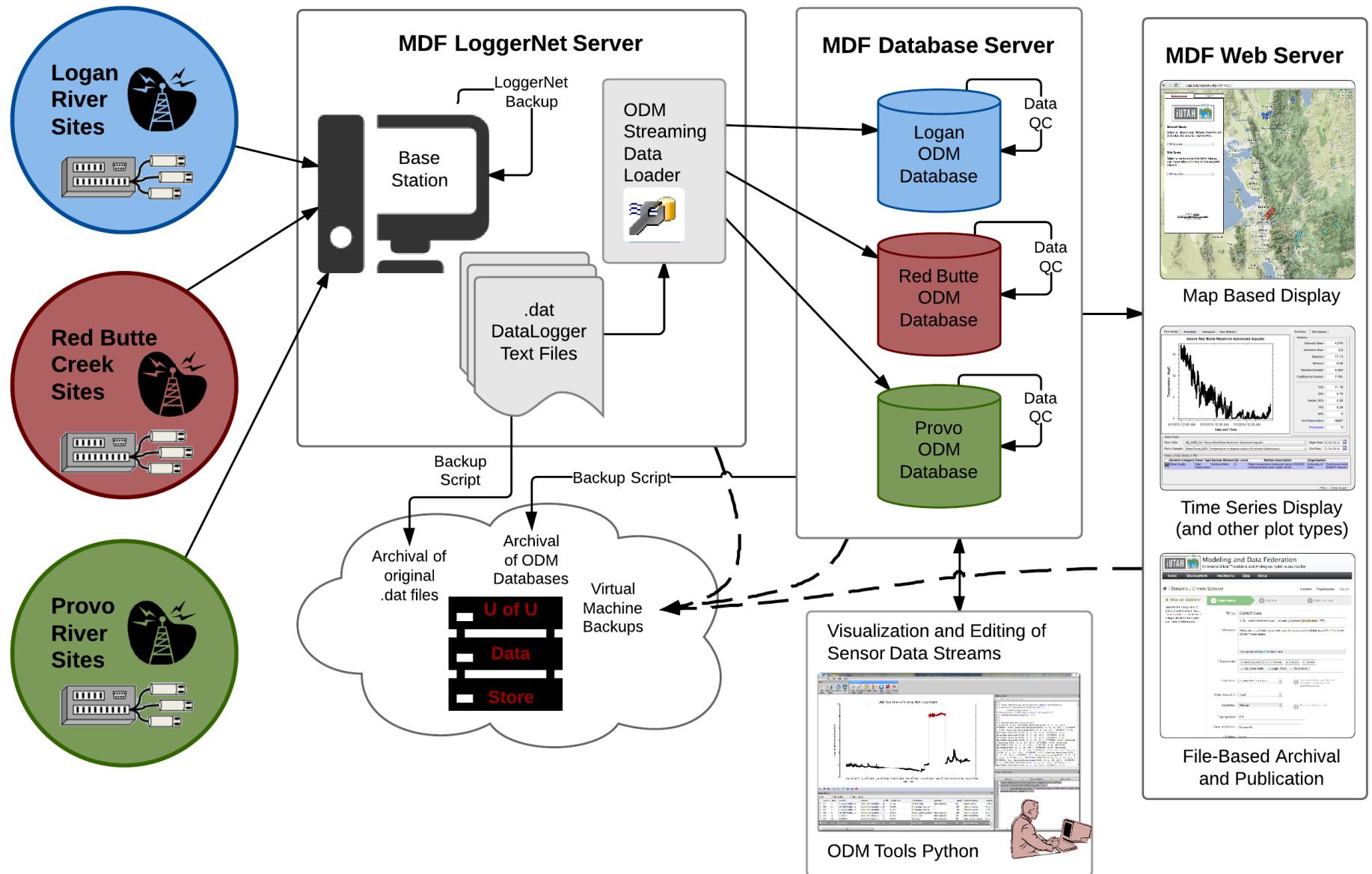


Manufacturer	Instrument	Variables Measured
YSI	599100-01	Dissolved Oxygen
YSI	599870-01	Specific Conductivity and Water Temperature
YSI	599795-02	pH
YSI	599101-01	Fluorescent Dissolved Organic Matter (fDOM)
YSI	599102-01	Blue Green Algae and Chlorophyll <i>a</i>
Campbell	CS451	Water Depth and Water Temperature
FTS	DTS-12	Turbidity and Water Temperature

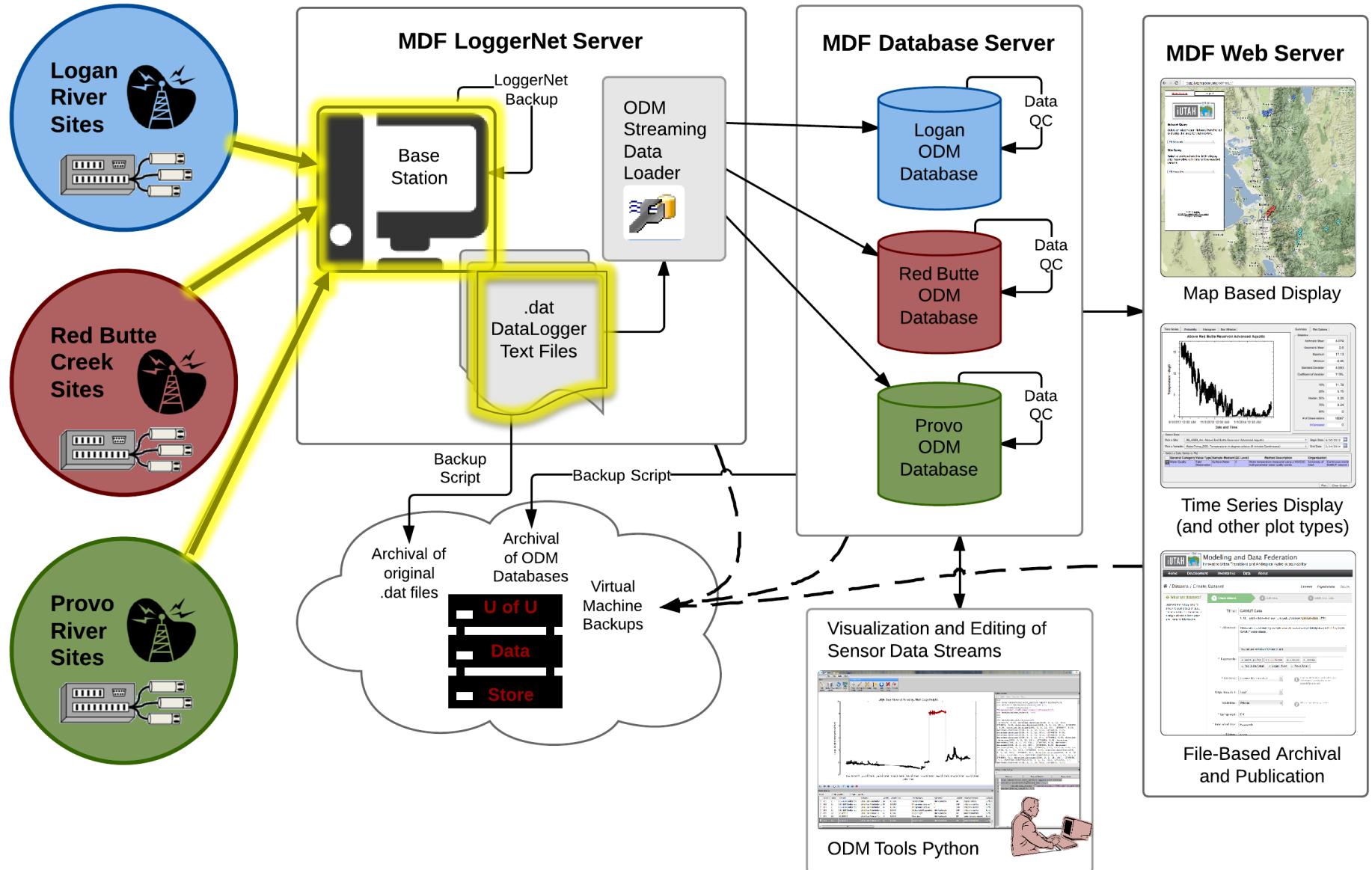
Gradients Along Mountain to Urban Transitions (GAMUT) Network



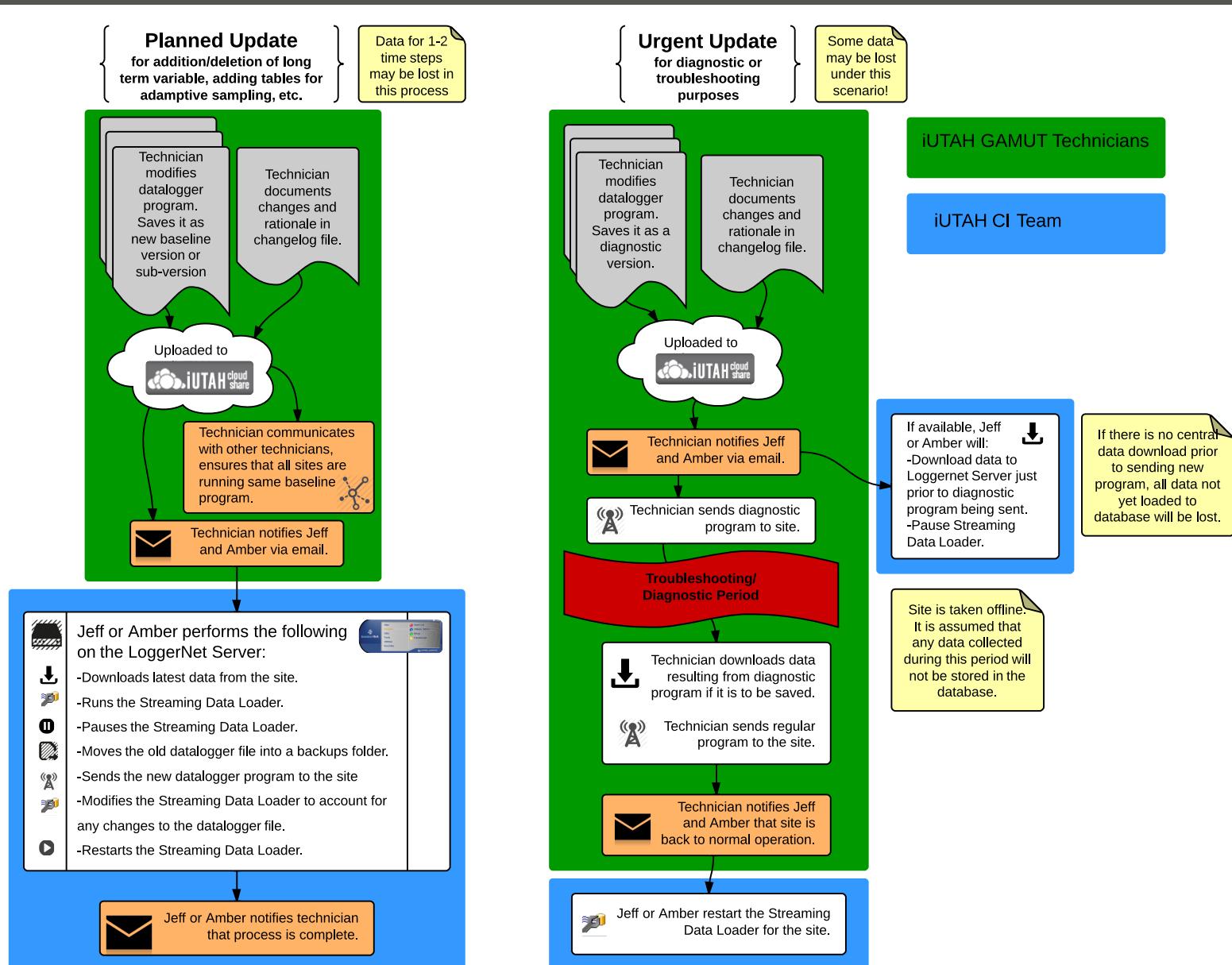
GAMUT Data Workflow



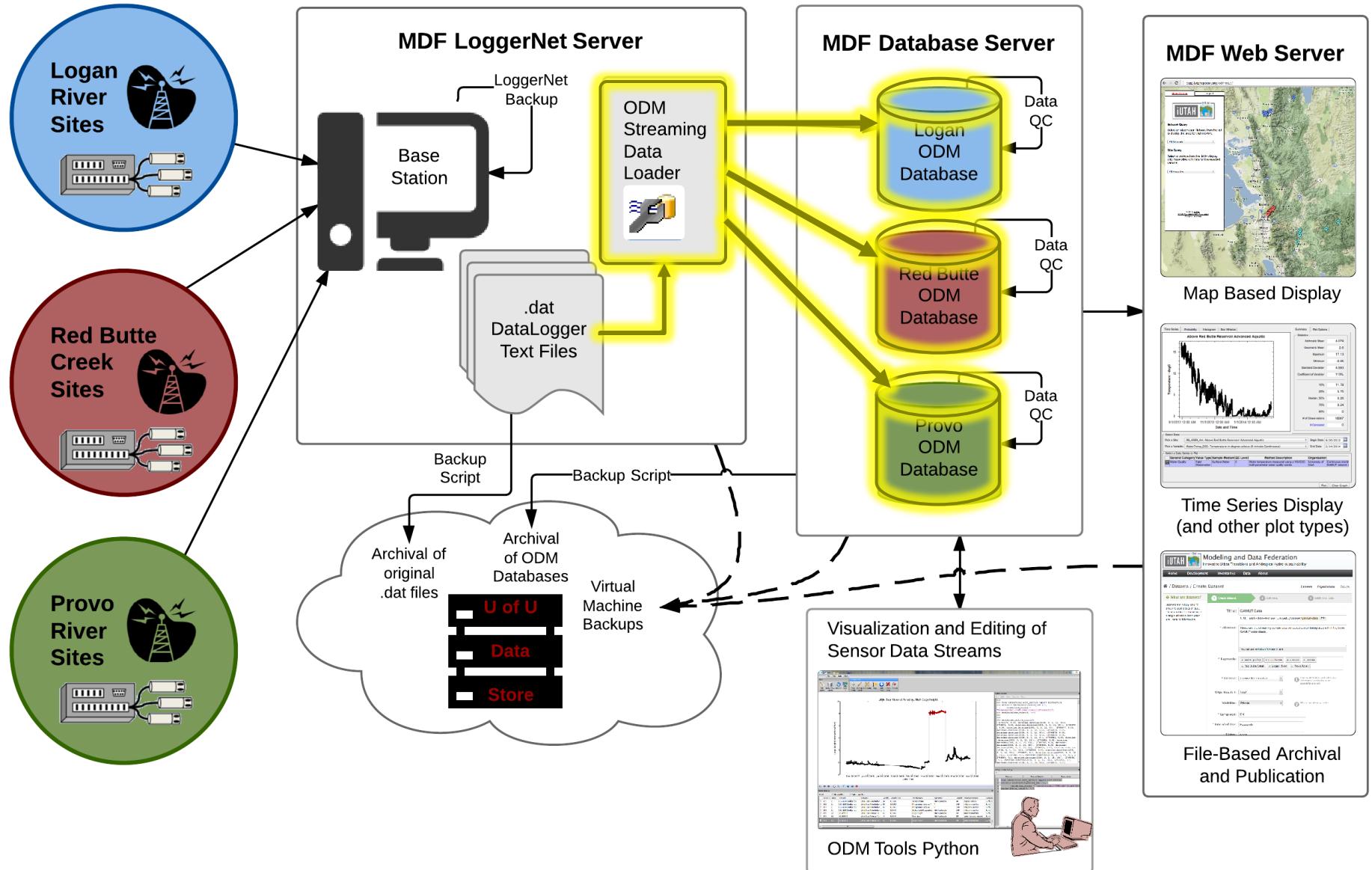
Sensor Data Acquisition



Datalogger Program Updates



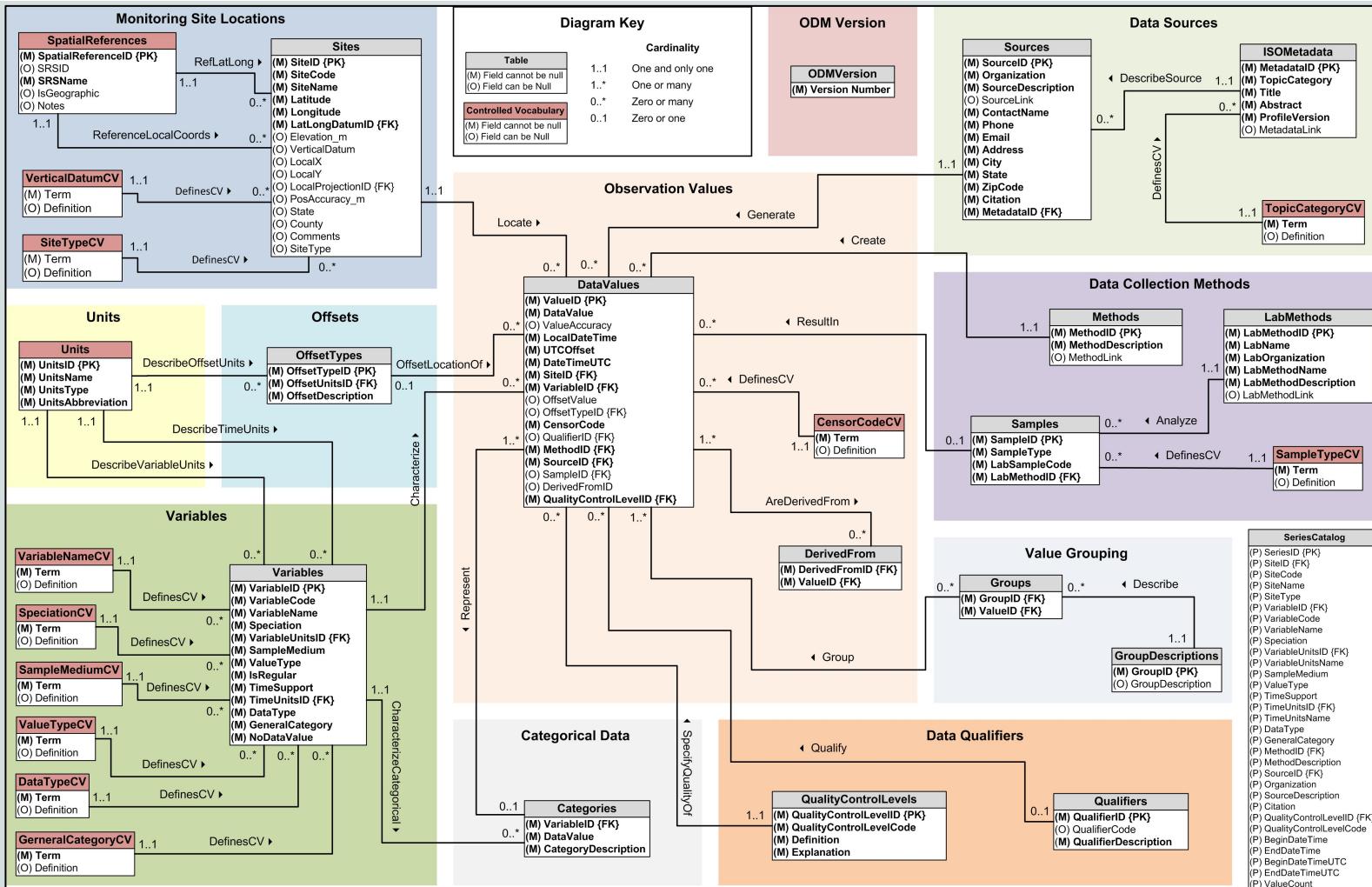
Data Loading and Storage



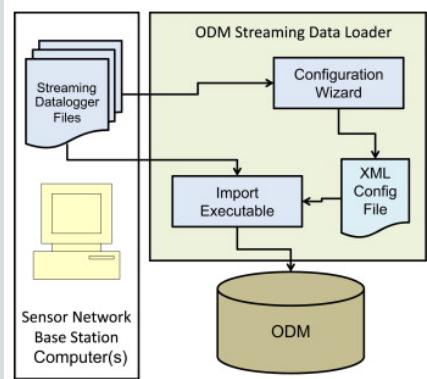
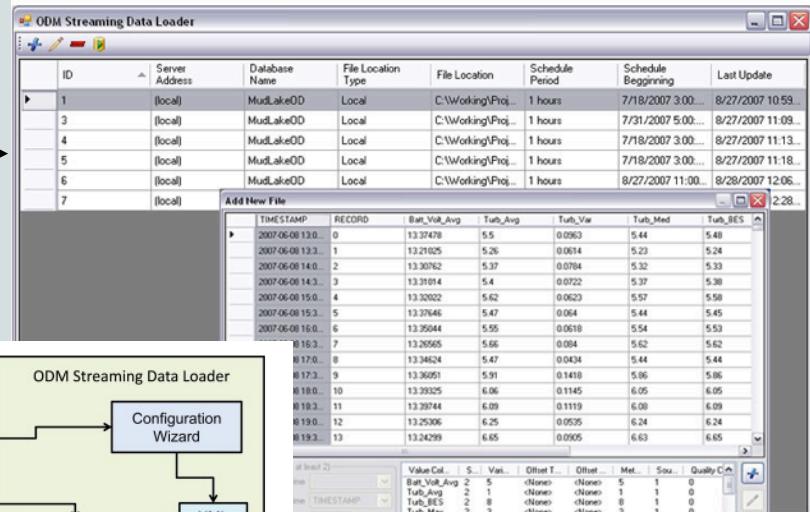
Data Loading and Storage



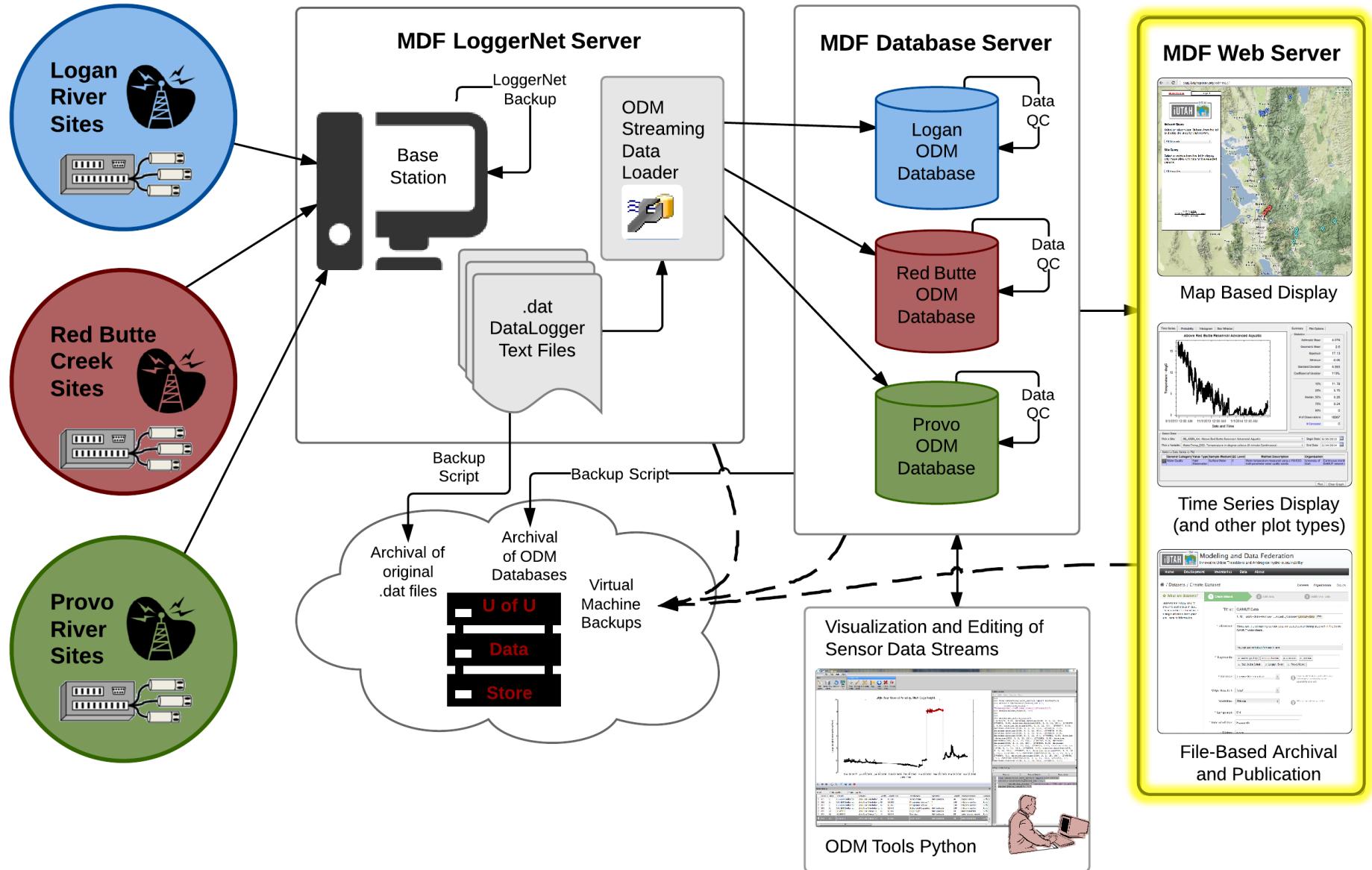
CUAHSI
HIS



Data Loading and Storage



Web-Based Data Access



Web-based Data Access



CUAHSI
HIS
Sharing hydrologic data

iUTAH EPSCoR Modeling and Data Federation
Innovative Urban Transitions and Aridregion Hydro-sustainability

Home Development Inventories Data About

Red Butte Creek

Red Butte Creek watershed is 18.8 km² with elevations between 1500 and 2400 m. Average annual streamflow ranges from 0.058 m³/s to 0.416 m³/s. Red Butte Creek originates in the mountains west of Salt Lake City, and Red Butte Canyon is a Research Natural Area managed by the U.S. Forest Service. Red Butte Reservoir, initially built to supply water to Fort Douglas, is currently used as a habitat for June sucker fish that are transported to other watersheds in the Wasatch Front. After exiting the canyon, the creek makes a rapid transition to built-out, urbanized land use through the University of Utah campus and into Salt Lake City before discharging to the Jordan River.

Monitoring Sites: Click on a site code to visualize and download data
The data presented here is provisional and subject to revision

Site Code	Site Name
RB_KF_BA	Knollton Fork Aquatic
RB_KF_C	Knollton Fork Climate
RB_ARBR_AA	Red Butte Creek Above Red
RB_ARBL_C	Red Butte Creek Above Red
RB_RB_C_A	Red Butte Creek Gate Basic
RB_CC_BA	Red Butte Creek at Cotton's
RB_GIRF_C	Green Infrastructure Climate
RB_FD_AA	Red Butte Creek at Foothill Dr
RB_ARBR_USGS	USGS Gage 10172200 above

This project is funded material are those of

View Red Butte Creek

Select sites from a map

Time Series Analyst

Logan River | iUTAH Modeling a... GAMUT Map Server Time Series Analyst

File Graph Data Time Series Probability Histogram Box Whisker

Trial Lake Climate

Temperature - degC

10
0
-10
-20
-30

11/1/2013 12:00 AM 1/1/2014 12:00 AM Date and Time

Summary Plot Options Statistics

Arithmetic Mean -6.672
Geometric Mean 1.078
Maximum 9.01
Minimum -29.34
Standard Deviation 5.942
Coefficient of Variation -89%

10% -13.19
25% -6.612
Median, 50% -1.495
75% -16.2
90% 0.683
of Observations 8929
Censored 0

Pick a Site: PR_TL_C: Trial Lake Climate Begin Date: 10/27/2013 End Date: 1/28/2014

Pick a Variable: AirTemp_Avg: Temperature in degree celsius (15 minute Average)

Select a Data Series to Plot

General Category	Value Type	Sample Medium	QC Level	Method Description	Organization
Climate	Field Observation	Air	0	Air temperature measured using a Campbell Scientific HC2S3 temperature and relative humidity sensor.	Brighton Young University

Plot Clear Grap

Query Options Legend

iUTAH EPSCoR

Network Query

Select an observation Network from the list to display the sites for that network.

All Networks

Site Query

Select a variable from the list to display only those sites with data for the selected variable.

All Variables

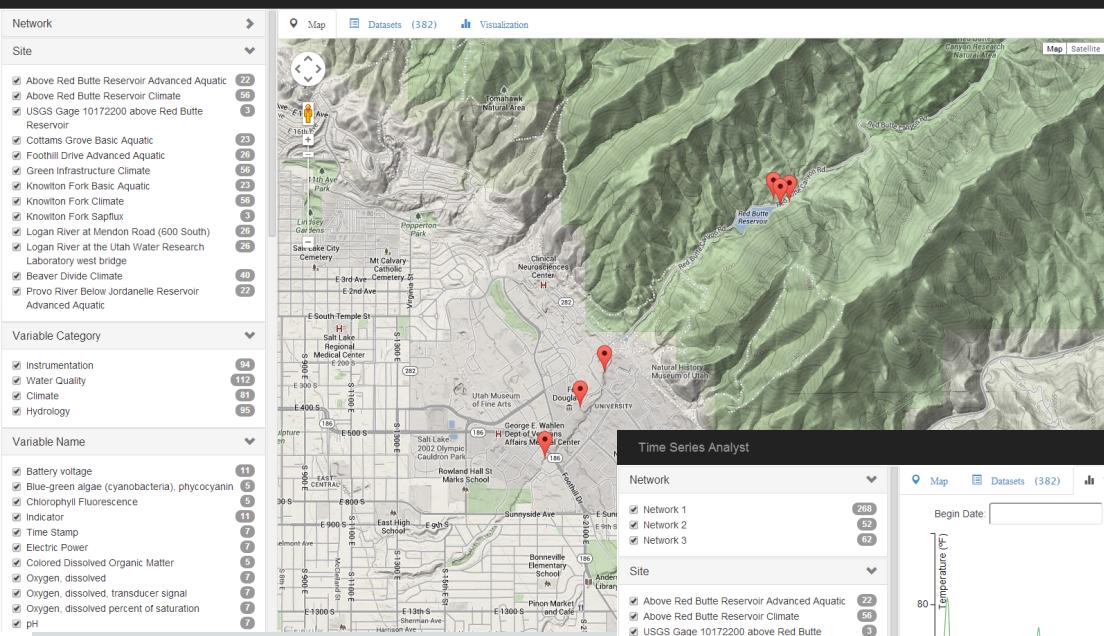
© 2013, iUTAH, All rights reserved.

SiteCode: PR_TL_C
SiteName: Trial Lake Climate
Latitude: 40.678111
Longitude: -104.548339
View and download data

Map data ©2014 Google | Terms of Use Report a map error

Enhanced Web-Based Time Series Data Access and Visualization

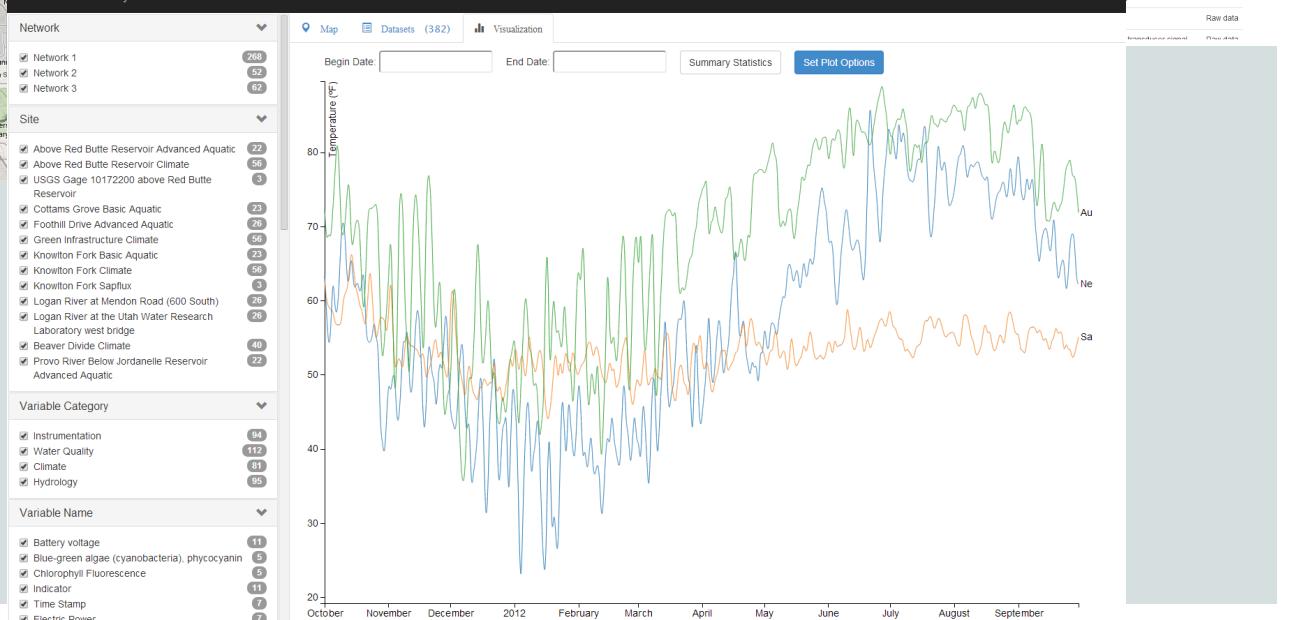
Time Series Analyst



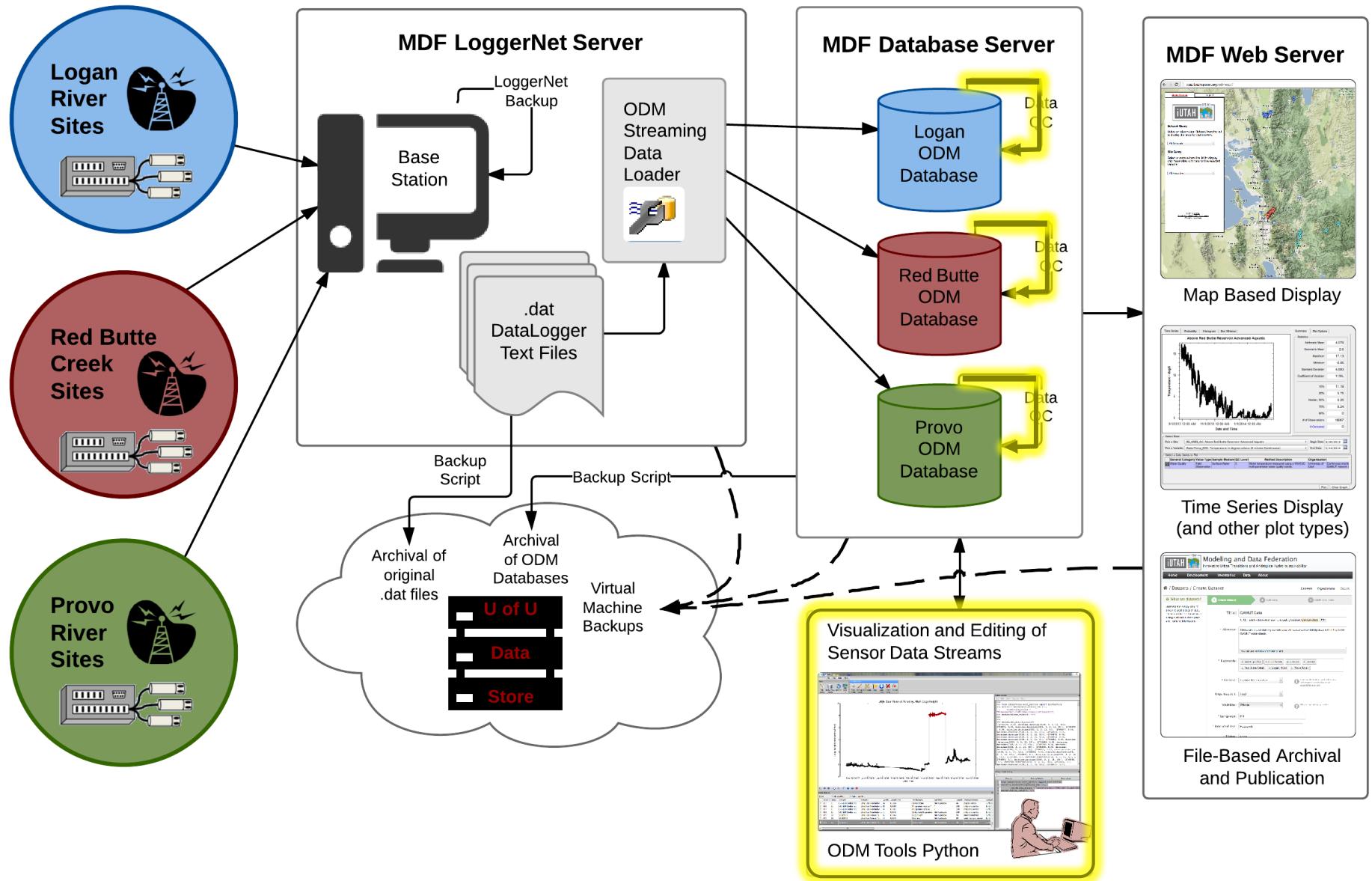
Time Series Analyst

Site Code	Variable	Quality Control Level
RB_ARBR_AA	Oxygen, dissolved	Raw data
RB_ARBR_AA	Oxygen, dissolved, transducer signal	Raw data
RB_CO_BA	Oxygen, dissolved percent of saturation	Raw data
RB_CO_BA	Oxygen, dissolved, transducer signal	Raw data
RB_CO_BA	Oxygen, dissolved percent of saturation	Raw data
RB_FD_AA	Oxygen, dissolved	Raw data
RB_FD_AA	Oxygen, dissolved, transducer signal	Raw data
RB_FD_AA	Oxygen, dissolved percent of saturation	Raw data
RB_KF_BA	Oxygen, dissolved	Raw data
RB_KF_BA	Oxygen, dissolved, transducer signal	Raw data
RB_Mendon_AA	Oxygen, dissolved	Raw data
RB_Mendon_AA	Oxygen, dissolved, transducer signal	Raw data
RB_Mendon_AA	Oxygen, dissolved percent of saturation	Raw data
RL_Waterab_AA	Oxygen, dissolved	Raw data
RL_Waterab_AA	Oxygen, dissolved, transducer signal	Raw data

Time Series Analyst



Sensor Data QAQC



Development of a QAQC Plan

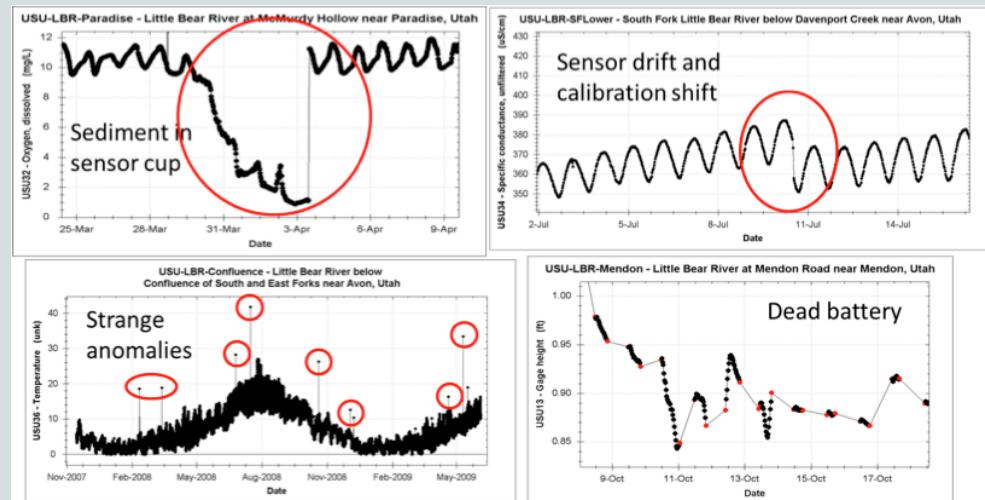
Quality Assurance:

“...protocols developed and adhered to in a way that minimizes inaccuracies in the data produced ... produces high-quality data while minimizing the need for corrective measures to improve data quality.”

- Site Standardization
- Data Curation (Datalogger Programs and Files, Data Averaging, Database Structure, Equipment Management)
- Replicate Sensors
- Factory Maintenance
- Field Maintenance Schedule and Procedures
- Field Calibration Schedule and Procedures
- Manual Data Monitoring
- Automated Data Monitoring and Alerts
- Recording Events

Quality Control: “occurs after the data are generated and tests whether they meet the necessary requirements for quality outlined by the end users.”

- Data Qualifiers and Flagging
- ODM Tools Python (data management software)
- Quality Control Levels
- Data Processing Steps

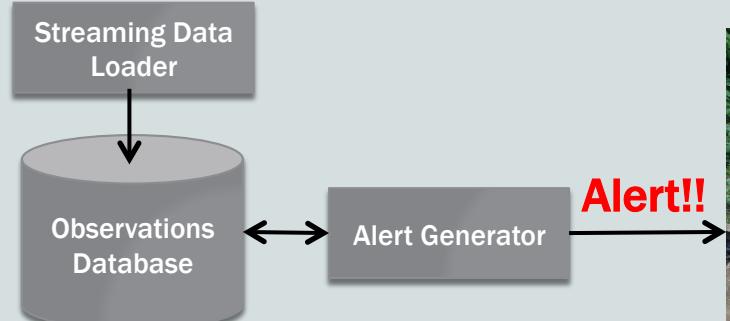


QAQC: Automated Alerts

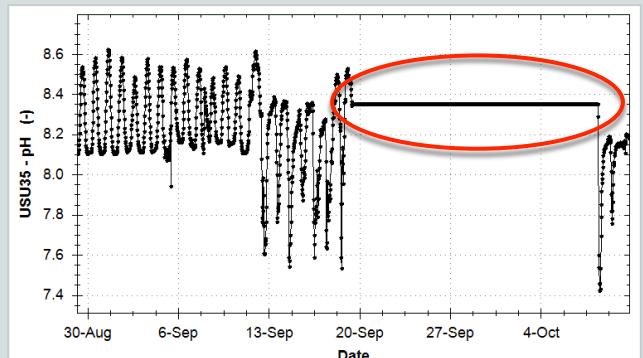
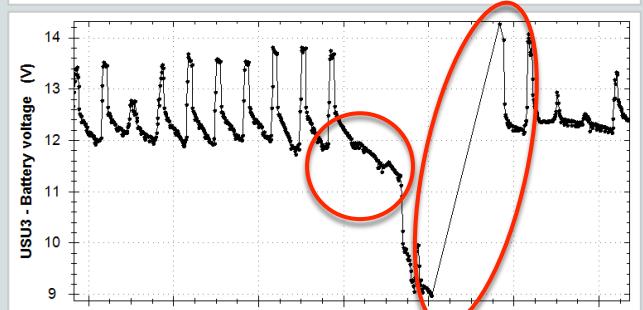
Technicians receive email alerts daily

1. Power: batter voltage < 12 volts
2. Persistence: value of a variable is unchanging
3. Updates: data are not being reported
4. NaNs: sensor is reporting “NaN” values

Additional alerts will be implemented as needed
(e.g., variable-specific range checks, internal
consistency, spatial consistency).



IUTAH Data Alerts <data.alerts@usu.edu>						
to chris.cox, amber.jones						
The following results are have repeated values in the past day.						
SiteID	SiteCode	VariableID	VariableCode	DataValue	Start	End
3	LR_MainStreet	61	ODD_Sat	84.90	2014-02-17 21:15	2014-02-18 01:15
4	LR_TWDEF_C	9	Precip_Tot	9.74	2014-02-17 18:00	2014-02-18 00:15
4	LR_TWDEF_C	13	SWIn_NR01_Avg	-4.68	2014-02-17 20:30	2014-02-18 00:30
4	LR_TWDEF_C	14	SWOut_NR01_Avg	.00	2014-02-17 18:30	2014-02-18 04:00
4	LR_TWDEF_C	24	PARIn_Avg	.00	2014-02-17 18:45	2014-02-18 04:15
4	LR_TWDEF_C	25	PAROut_Avg	.00	2014-02-17 18:45	2014-02-18 04:00
4	LR_TWDEF_C	41	SoilCond_20cm_Avg	.00	2014-02-17 06:15	2014-02-18 04:00
4	LR_TWDEF_C	45	SoilCond_50cm_Avg	.00	2014-02-17 06:15	2014-02-18 04:00
4	LR_TWDEF_C	48	SoilTemp_100cm_Avg	-2.05	2014-02-17 09:15	2014-02-17 13:15
4	LR_TWDEF_C	49	SoilCond_100cm_Avg	.00	2014-02-17 06:15	2014-02-18 04:00
4	LR_TWDEF_C	91	Precip_HrDiff	.00	2014-02-17 19:00	2014-02-18 01:00
5	LR_GC_C	5	BP_Avg	86.00	2014-02-17 21:45	2014-02-18 01:45
5	LR_GC_C	9	Precip_Tot	-0.9999	2014-02-17 06:15	2014-02-18 04:45
5	LR_GC_C	45	SoilCond_50cm_Avg	.00	2014-02-17 06:15	2014-02-18 04:45
5	LR_GC_C	91	Precip_HrDiff	.00	2014-02-17 06:15	2014-02-18 04:45



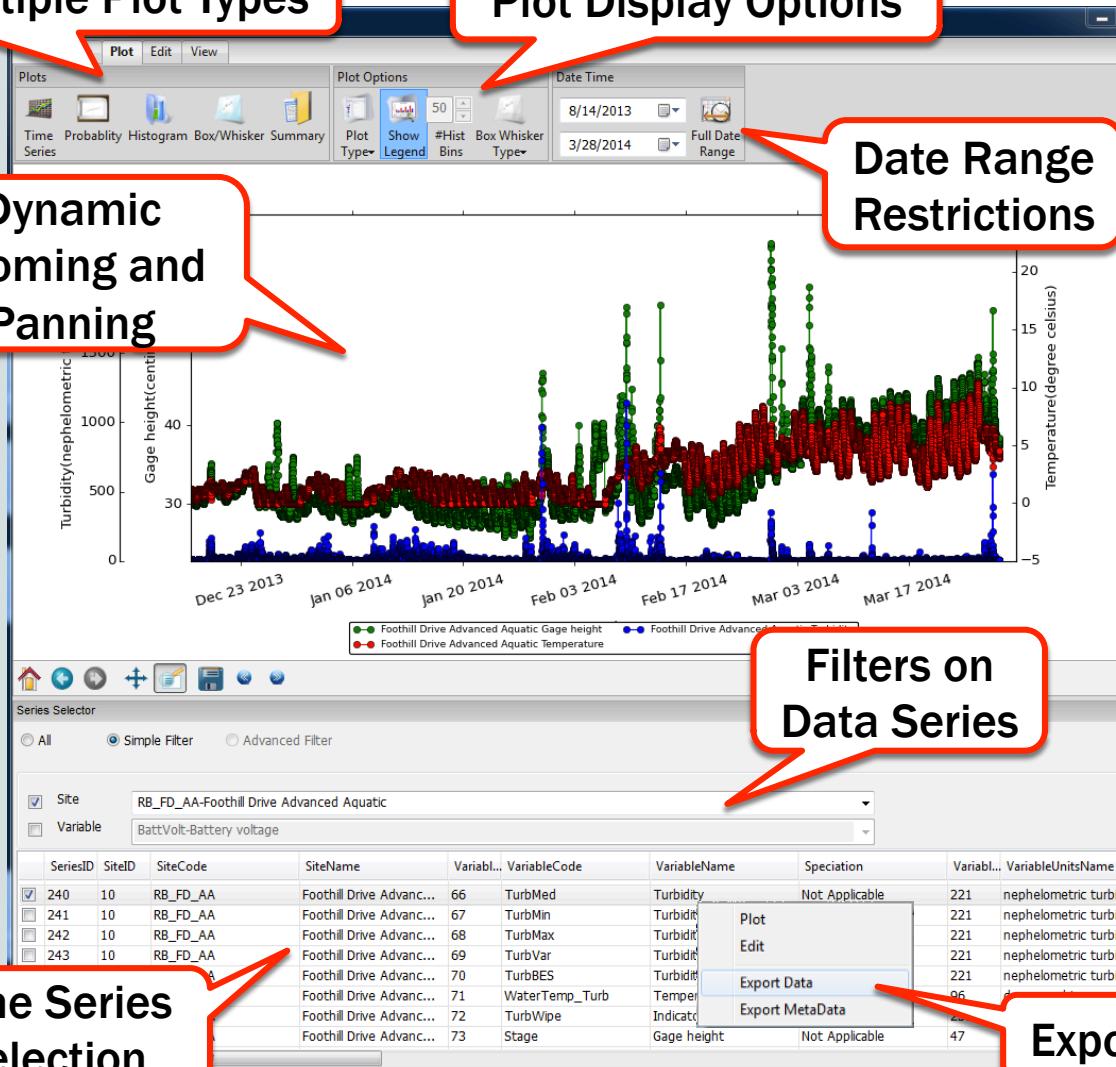
QAQC:

Data Visualization and Management

Multiple Plot Types

Plot Display Options

Dynamic Zooming and Panning



Date Range Restrictions

Filters on Data Series

Time Series Selection

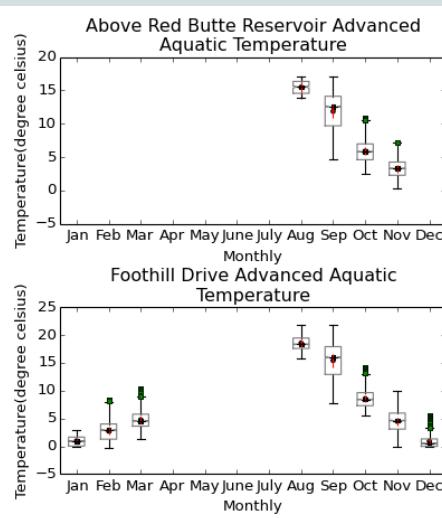
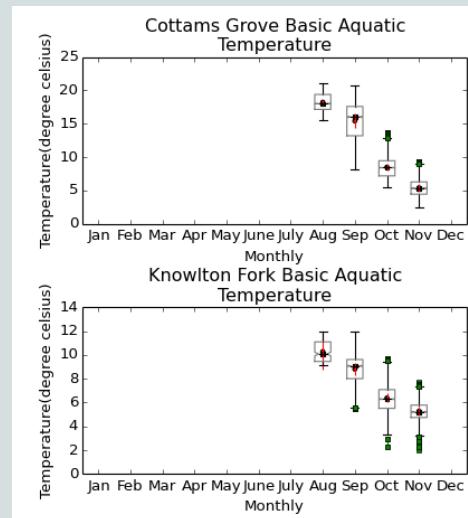
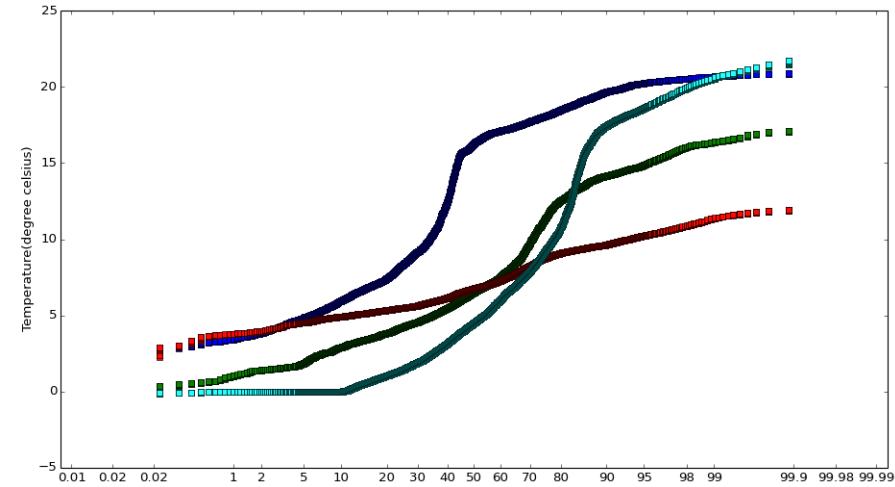
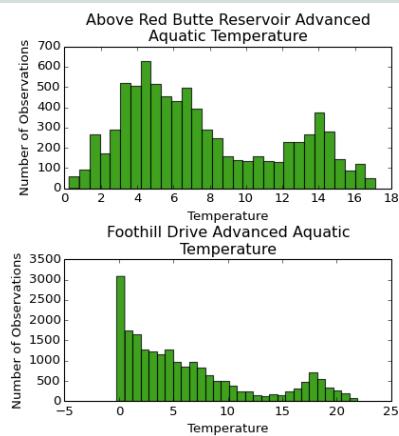
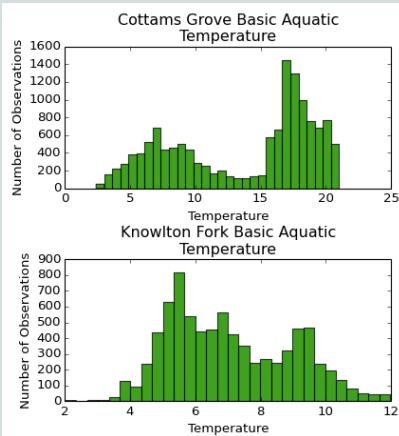
Export Data Series

Build Query

The screenshot shows the Query Builder window with the following details:

- Field Names:** A list box containing fields: SiteName, SiteCode, Latitude, Longitude, VariableName, VariableCode, Data Type, Value Type, and Speciation.
- Unique Values:** A list box showing the result for SiteName: 'Little Bear 11' and 'Little Bear River at M'.
- Operators:** Buttons for Is Null, Is Not Null, >=, <=, +, (), Like, And, Or, and Not.
- Value Input:** Minimum: Little, Maximum: Little.
- SQL Preview:** The generated SQL query is: `SELECT * FROM [Attributes] WHERE [SiteName] = 'Little Bear 11'`.
- Buttons:** Commit button at the bottom.

QAQC: Data Visualization and Management



QAQC: Post Processing

Data Editing Tools

Python Code Console

Dynamic Data Editing Display

Python Script Editor

The screenshot displays the ODM Tools application window. At the top, there's a menu bar with File, Plot, Edit, and View. Below the menu is a toolbar with various icons for editing series: Edit Series, Derive New Series, Restore Series, Save, Filter Points, Change Value, Interpolate, Flag, Add Point, Delete Point, and Record.

The main area features a plot titled "Little Bear River at Paradise, Utah Gage height". The Y-axis is labeled "Gage height(international foot)" and ranges from 4 to 10. The X-axis is labeled "Date Time" and shows dates from Dec 22 2007 to Apr 12 2008. The plot displays a black line representing the gage height over time, with a red line overlaid on specific data points. A red callout box labeled "Dynamic Data Editing Display" points to this red line.

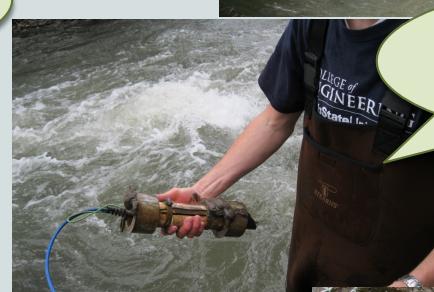
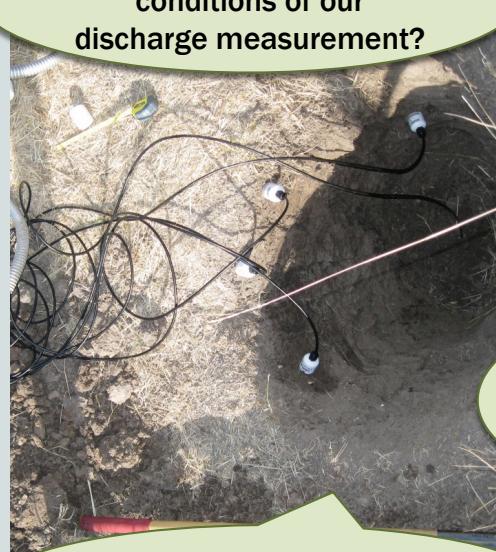
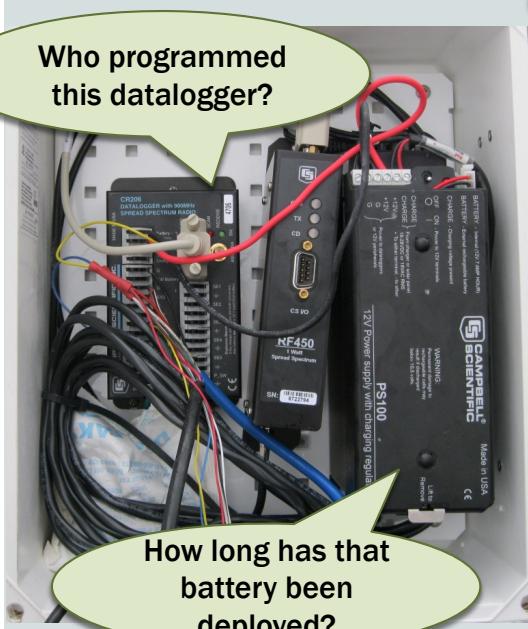
Below the plot is a "Series Selector" dialog box. It has tabs for All, Simple Filter, and Advanced Filter. Under the All tab, there's a table with columns: SeriesID, SiteID, SiteCode, SiteName, Variable..., VariableCode, VariableName, Speciation, Variable..., VariableUnitsName, SampleM. The table lists several entries, including:

SeriesID	SiteID	SiteCode	SiteName	Variable...	VariableCode	VariableName	Speciation	Variable...	VariableUnitsName	SampleM
165	11	USU-LBR-Confluence	Little Bear River below...	36	USU36	Temperature	Not Applicable	96	degree celsius	Surfa
166	11	USU-LBR-Confluence	Little Bear River below...	39	USU39	Phosphorus, total as P	P	199	milligrams per liter	Surfa
167	11	USU-LBR-Confluence	Little Bear River below...	40	USU40	Phosphorus, total as ...	P	199	milligrams per liter	Surfa
168	11	USU-LBR-Confluence	Little Bear River below...	41	USU41	Solids, total Suspended	Not Applicable	199	milligrams per liter	Surfa
169	12	10105900	Little Bear River at Pa...	42	USU42	Gage height	Not Applicable	48	international foot	Surfa
170	12	10105900	Little Bear River at Pa...	43	USU43	Discharge	Not Applicable	35	cubic feet per second	Surfa
171	12	10105900	Little Bear River at Pa...	42	USU42	Gage height	Not Applicable	48	international foot	Surfa

To the right of the plot is a "Python Console" window showing a session of Python code. The code imports the EditService module, creates a service object for series ID 171, and filters the data for values greater than 8. Below the console is an "Editing: Script Test.py" window with an Execute button.

At the bottom of the Python code window, another red callout box labeled "Python Script Editor" points to the code area.

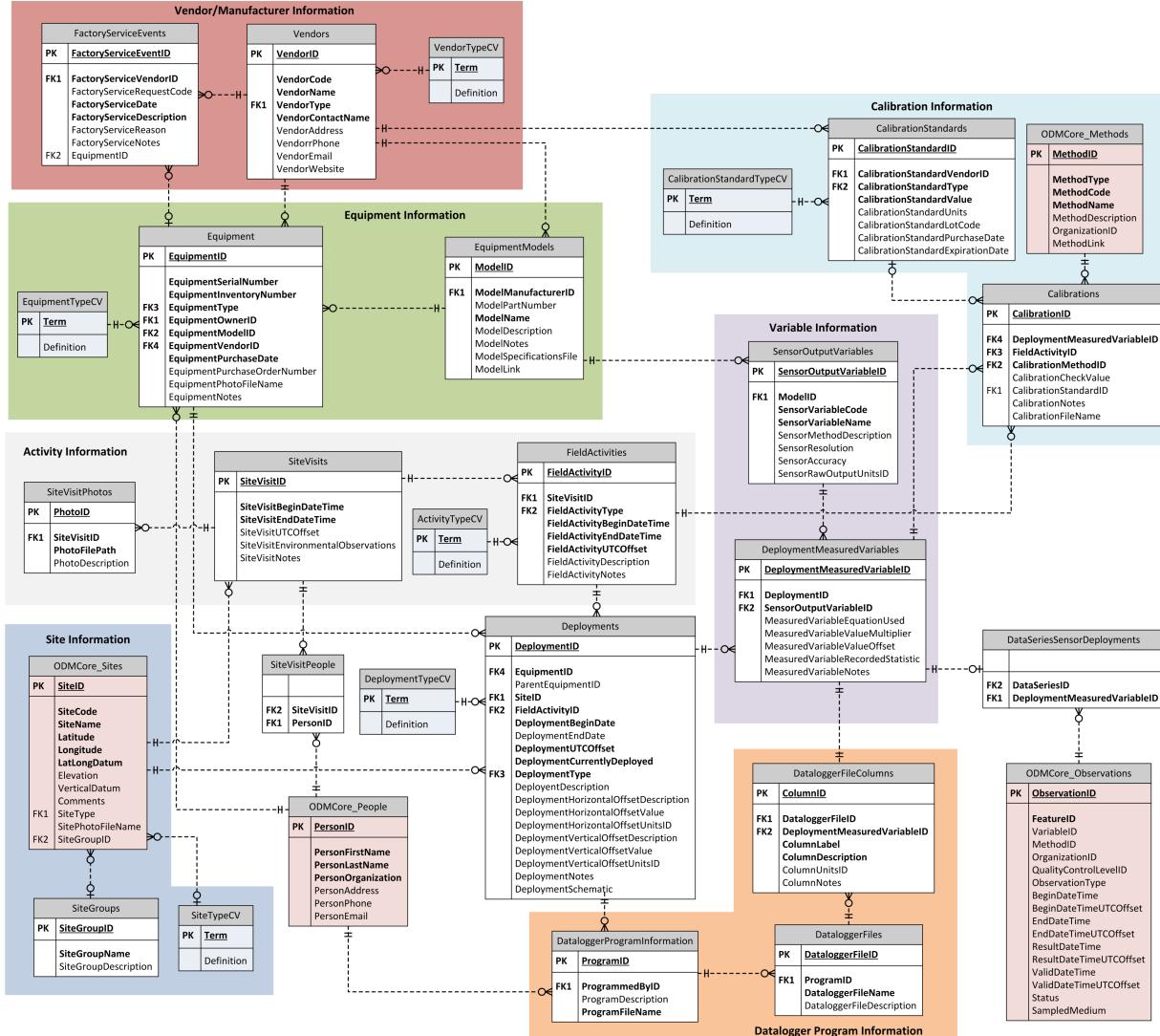
Monitoring Equipment Management



What is this dissolved oxygen sensor's calibration history?



Monitoring Equipment Management



Data Model developed to relate:

- Equipment
- Field Activities
- Deployments
- Calibrations
- Measured Variables
- Datalogger Programs

Database serves as underlying structure to web interface.

Monitoring Equipment Management

Sites

Site Code	Site Name	Site Group	Site Type
RB_KF_C	Knowlton Fork Climate	Red Butte Creek	Climate
RB_KF_R	Knowlton Fork Repeater	Red Butte Creek	Repeater
RB_KF_BA	Knowlton Fork Basic Aquatic	Red Butte Creek	Basic Aquatic
RB_KF_SF	Knowlton Fork Sapflux	Red Butte Creek	Sapflux

Site Details

Deployment Measured Variables

Variable Name	Recorded Status
Oxygen, dissolved	
pH	
Specific Conductance	
Temperature	
Oxygen, dissolved, transducer signal	

Deployment History of Main Street Bridge Basic Aquatic

Date	Equipment Serial Number	Equipment Type	Manufacturer	Model	Site
2013/12/06 12:00 PM to Present	953237	Radio	Campbell Scientific	RT450	Main Street Bridge Basic Aquatic
2013/12/06 12:00 PM to Present	25858	Datalogger	Campbell Scientific	CR800	Main Street Bridge Basic Aquatic
2013/12/06 12:00 PM to Present	BL12	Battery	Power Sonic	35 Batt	Main Street Bridge

Site Visits

Date	Site Name	Site Group	Crew
2014/02/11 10:30 AM	TWDEF Climate Station	Logan River	Chris Cox, Jobie Carlise, Joel Martin
2014/02/05 12:00 PM	TWDEF Climate Station	Logan River	Chris Cox, Allison Chan
2014/02/03 12:50 PM	Golf Course Climate	Logan River	Chris Cox
2014/02/03 12:00 PM	Miller	Miller	Miller
2014/01/21 03:35 PM	Miller	Miller	Miller
2014/01/24 03:00 PM	Gruber	Gruber	Gruber
2014/01/24 01:00 PM	Miller	Miller	Miller

Equipment

Serial Number	Type	Model	Manufacturer	Owner
6500000	Sensor	SDI-12 Soil	Acclima, Inc.	Chris Cox
6500840	Sensor	SDI-12 Soil	Acclima, Inc.	Chris Cox
6500841	Sensor	SDI-12 Soil	Acclima, Inc.	Chris Cox
6500842	Sensor	SDI-12 Soil	Acclima, Inc.	Chris Cox
6500843	Sensor	SDI-12 Soil	Acclima, Inc.	Dave Eirksson
6500844	Sensor	SDI-12 Soil	Acclima, Inc.	Chris Cox
6500845	Sensor	SDI-12 Soil	Acclima, Inc.	Chris Cox
6500846	Sensor	SDI-12 Soil	Acclima, Inc.	Chris Cox
6500847	Sensor	SDI-12 Soil	Acclima, Inc.	Chris Cox
6500848	Sensor	SDI-12 Soil	Acclima, Inc.	Chris Cox
6500849	Sensor	SDI-12 Soil	Acclima, Inc.	Chris Cox
6500850	Sensor	SDI-12 Soil	Acclima, Inc.	Chris Cox

Equipment Details

Equipment Description
Serial Number: 61012151
Model Name: EX023
Model Link:
Description: Model: EX023 Sensor
Inventory Number:
Purchase Date: 2013/04/02
Order Number: 192015
Notes:

Owner Information
Contact: Joe Crawford
Institution: Brigham Young University
Address:
Phone: 435-760-8334
Email: joe_crawford@byu.edu

Manufacturer Information
Name: Rotronic
Contact Name: unknown
Address:
Email:
Website: www.rotronic-usa.com
Phone:

Deployment Details

Deployment Description
Equipment Serial Number: 1211008007
Equipment Type: Sensor
Model Name: Sensor
Description: EX02 Sonde pH probe
Purchase Date: 2013/11/12
Equipment Notes:
Link:
Owner Institution: Utah State University
Owner Contact: Chris Cox
Owner Address:
Owner Phone: 505-250-5885
Email: chris.cox@usu.edu

Deployment History

Deployment Description
Site: Below Jordan Lake Aquatic
Deployment Start Date: 2013/09/25 10:00 AM
Deployment End Date: 2013/12/16 01:00 PM
See Retrieval Information
Deployment UTC Offset: -07:00
Currently Deployed: No
Deployment Type: Field monitoring
Deployment Description: This is the pH sensor installed on the sonde.
Deployment Notes:

Horizontal Offset Description: The sonde and the sensors were installed about 34' away from the data logger.
Horizontal Offset Units ID:
Vertical Offset Description:
Vertical Offset Units ID:
Vertical Offset Value:
Parent Equipment: EX023sonde
Deployment Schematic:

Measured Variables

New Deployment Measured Variable

No content found.

View Equipment's Deployment History Go to Site Visit

Monitoring Equipment Management

Equipment

- Model
- Serial number
- Owner
- Vendor
- Manufacturer
- Service history



Site Visits



Field Activities



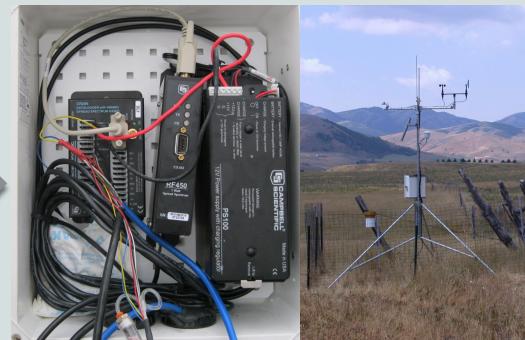
- Activity type
- Description
- Dates
- Date

Calibrations



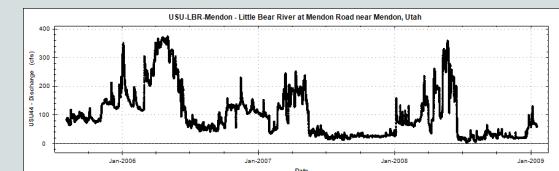
- Method
- Standard

Deployments



- Deployment type
- Description
- Dates
- Offsets

Time Series Observations



Open Source Code Repositories

- ODM Tools Python – Sensor Data Management
 - <https://github.com/UCHIC/ODMToolsPython>
- ODM2 Sensor – Sensor equipment management
 - <https://github.com/UCHIC/ODM2Sensor>
- WEBTSA – Time series data visualization
 - <https://github.com/UCHIC/WEBTSA>

GitHub





Questions?

Acknowledgements

iUTAH Watershed
Technicians:
Chris Cox
Joe Crawford
Dave Eiriksson

UWRL Student
Programmers:
Juan Caraballo
Jacob Meline
Mario Matos
Maurier Ramirez



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