UtahStateUniversity

Geographic Information System in Water Resources

CEE6440

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Management and Sharing of Hydrologic Information of Cache County

To:

Dr. David Tarboton

Instructor

By:

Tian Gan

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I. Introduction

Hydrologic information as the base of hydrologic research usually involves geospatial data and temporal data (time series data). And the collection, management and visualization for different types of hydrologic data are important issues. Especially for data management, approaches need to be considered for how to store the spatial as well as the temporal data and the surface as well as subsurface hydrologic data in an organized way and how to establish relationships to connect them together. Meanwhile, data sharing as a way to promote academic research and collaboration now is in an increasing trend, and how to conveniently share the data online is also important.

As ArcGIS can provide a good way for storing, visualizing and sharing hydrologic information, this project utilized ArcGIS toolboxes as well as other tools and took Cache County, Utah as the study area to realize three objectives: first to collect and store hydrologic data for this area; then to visualize the stored data and to discover some hydrologic phenomena; finally to share maps and stored data online so as to provide useful information to other people.

This report first introduces the major steps and methods used in this project. It then provides maps and graphs to introduce the general and hydrologic condition of the study area and to discuss some of hydrologic phenomena. Finally it summarizes the key points got from the whole process and points out the future work.

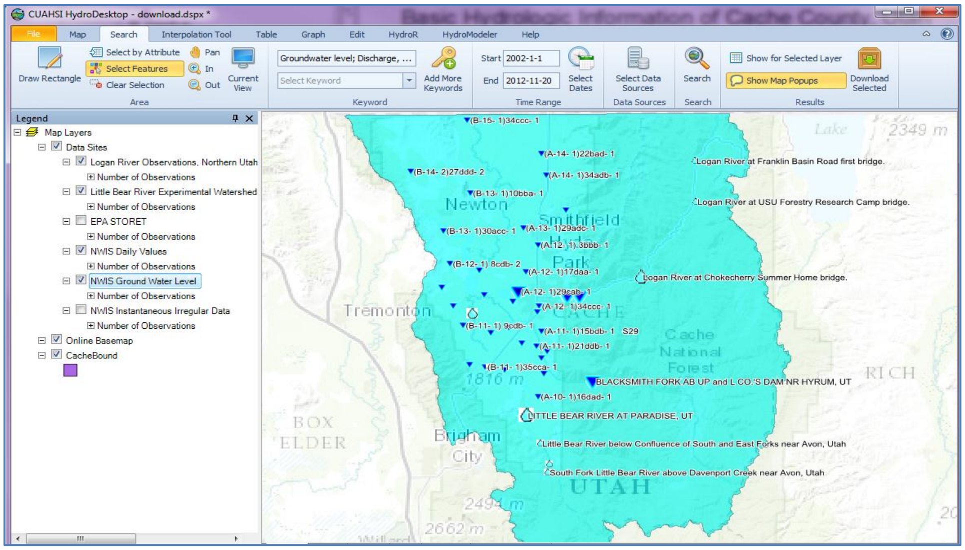
II. Methods

There are four major steps to accomplish the project objectives: 1) Collect hydrologic data from different data sources and preprocess the data. 2) Setup geodatabase to store the preprocessed data. 3) Generate maps and time series graphs. 4) Share the maps and stored data online. The following subsections will introduce the methods used in each step.

A. Collecting and Preprocessing Data

Data collected in this project include three aspects: 1) boundary and population information for Cache County and its municipalities; 2) surface hydrologic information about watershed, water line, water body, monitoring sites and time series data of stream discharge; 3) subsurface hydrologic information of major aquifer, wells and time series data about groundwater level. As to the three aspects of data, the spatial data was mainly obtained from UTAH Automated Geographic Center [1,2], National Hydrograph Dataset Plus [3]. The time series data and sites information was mainly obtained from USGS National Water Information System and registered data services from CUAHSI HIS (Consortium of Universities for the Advancement of Hydrologic Science Hydrologic Information System).

In this project, HydroDesktop is utilized to get the time series data and the sites information. By defining the boundary of Cache County as search area, entering the keywords (“Discharge, stream” and “Ground Water Level”) and the time range (from 2002-1-1 to 2012-11-15), it quickly searched the sites which satisfied the requirements and showed them on the map (See Fig.1). Then people can download the time series data of selected sites and save them as CSV file format. And for this project, only the monitoring sites and wells with long term time series data were selected.



Groundwater level; Discharge, ...

Start 2002-1-1

End 2012-11-20

Fig.1 Screenshot of using Hydrodesktop to download time series data

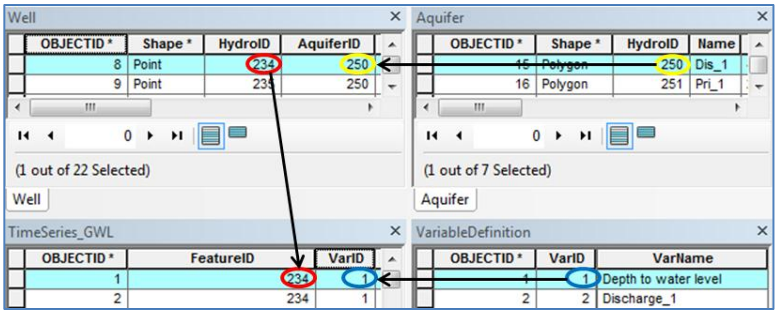
As some of the original spatial data obtained from the data source provides information in a larger spatial range (e.g. watershed information obtained from NHDPlus), "Clip" tool in ArcGIS was used to extract the spatial information for Cache County. And "Projections and Transformations" tool was used to convert the coordinate systems of different spatial data into the same coordinate system.

B. Storing Data

Arc Hydro Ground Water (AHGW) geodatabase [4] is applied to store all the processed data. Because this kind of geodatabase is specially designed to store the surface and subsurface hydrologic information, which not only stores the spatial and time series data, but also setup relationships to connect them together. In AHGW geodatabase, it mainly contains three datasets including "Framework", "Subsurface" and "Simulation". According to the characters of these datasets, the collected data in this project was mainly stored in the "Framework" dataset.

The following steps present how the processed data was stored into the AHGW geodatabase: 1) create an empty AHGW geodatabase; 2) define the spatial reference and add project specific classes in the geodatabase; 3) import processed data into the geodatabase; 4) assign HydroID which is an integer attribute to uniquely identify spatial features in the geodatabase; 5) establish relationships among the spatial and temporal data.

In these steps, AHGW toolbox[5] is applied to create an empty geodatabase ("Create Blank AHGW Geodatabase" tool), import time series data from CSV file to a time series table in the geodatabase ("Text Import" tool), and assign HydroID to the features ("Assign HydroID GW" tool). In order to establish relationships among different hydrologic data, "HydroID" and "VarID" (Variable ID) were used to connect time series with the sites (wells or monitoring sites) and variables. At the same time the well and aquifers were also connected by "HydroID" (See Fig.2). These relationships can logically connect the spatial as well as temporal data together which will facilitate data query and generating maps and time series graphs.



Well

OBJECTID *	Shape *	HydroID	AquiferID
8	Point	234	250
9	Point	235	250

(1 out of 22 Selected)

Aquifer

OBJECTID *	Shape *	HydroID	Name
15	Polygon	250	Dis_1
16	Polygon	251	Pri_1

(1 out of 7 Selected)

TimeSeries_GWL

OBJECTID *	FeatureID	VarID
1	234	1
2	234	1

VariableDefinition

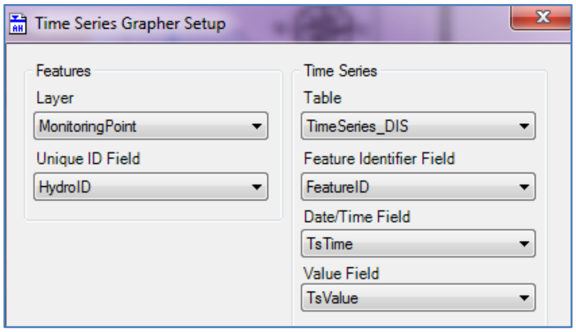
OBJECTID *	VarID	VarName
1	1	Depth to water level
2	2	Discharge_1

Fig.2 Example of setting up relationships among spatial and temporal data

C. Generating Maps and Graphs

After storing the preprocessed data in the geodatabase, ArcGIS toolboxes were used to derive new data and to generate maps and time series graphs showing the general and hydrologic information of Cache County as well as some hydrologic phenomena. In this subsection, key methods used for generating the time series graphs and some maps are introduced.

To generate time series graphs, "Time Series Grapher Setup" tool in AHGW toolbox was used (See Fig.3). This tool connects the point feature (monitoring sites or wells) and time series table with unique identifier (HydroID and Feature ID), so with this tool just by conveniently clicking on the sites on the map, it will automatically create a graph showing the observed time series values from the sites.



Time Series Grapher Setup

Features

Layer: MonitoringPoint

Unique ID Field: HydroID

Time Series

Table: TimeSeries_DIS

Feature Identifier Field: FeatureID

Date/Time Field: TsTime

Value Field: TsValue

Fig.3 "Time Series Grapher Setup" tool

Besides, two models were created aiming to find out the changing trend of groundwater level in Cache County. Model 1 (See Fig.4) used "Make Time Series Statistics" tool in AHGW toolbox to calculate the average groundwater level value with the stored time series data for each well in every half year from 2003 to 2012. The model inputs include the well feature class, time series table of groundwater level, start time and end time for time series statistic. The model output is a point feature class showing the wells that has average groundwater level value for the designated start time and end time and its attribute table stored the average values and other information (See Fig.5). As this project needs to get the point feature classes for nearly ten years, "Batch" function was used to generate all the outputs with one operation so as to simplify the process.

Model 2 (See Fig.6) finishes two tasks: first use the outputs of model 1 to create interpolated groundwater level surface for each half year; second store all the interpolated surfaces in the raster series. The reason to do the second task is that raster series are useful for describing the spatially continuous phenomena like variations in groundwater levels over time. In this model, "IDW" tool of Spatial Analysis toolbox was used to create interpolated surfaces, and "Add to Raster Series" tool of AHGW toolbox was used to store all the created interpolated surfaces in the designated raster series.

Moreover, "Flow Direction Generator" tool of AHGW toolbox was used to show the groundwater flow direction based on the interpolated groundwater level surface.

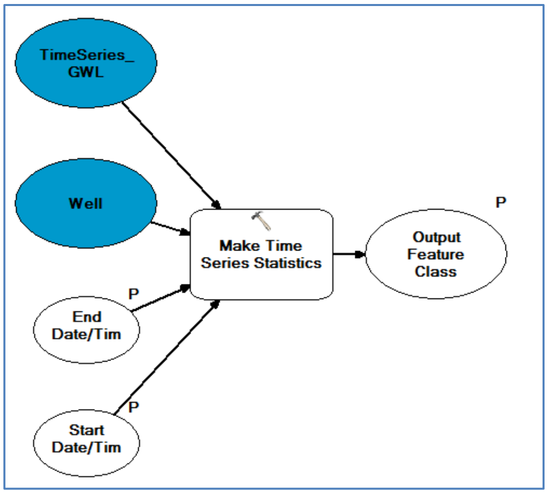
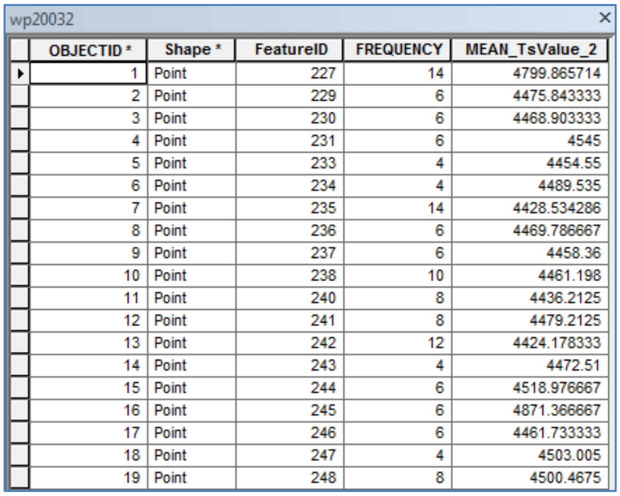


Fig.4 Layout of Model 1



OBJECTID *	Shape *	FeatureID	FREQUENCY	MEAN_TsValue_2
1	Point	227	14	4799.865714
2	Point	229	6	4475.843333
3	Point	230	6	4468.903333
4	Point	231	6	4545
5	Point	233	4	4454.55
6	Point	234	4	4489.535
7	Point	235	14	4428.534286
8	Point	236	6	4469.786667
9	Point	237	6	4458.36
10	Point	238	10	4461.198
11	Point	240	8	4436.2125
12	Point	241	8	4479.2125
13	Point	242	12	4424.178333
14	Point	243	4	4472.51
15	Point	244	6	4518.976667
16	Point	245	6	4871.366667
17	Point	246	6	4461.733333
18	Point	247	4	4503.005
19	Point	248	8	4500.4675

Fig.5 Attribute table of Model 1 output

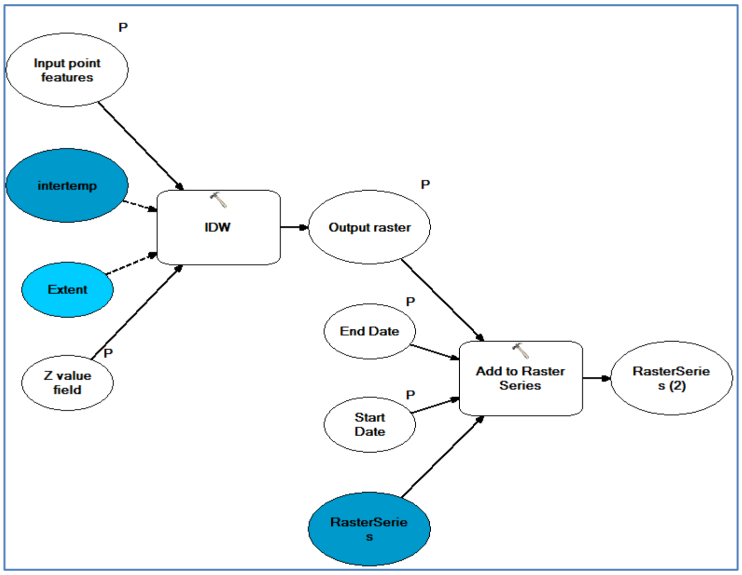


Fig.6 Layout of Model 2

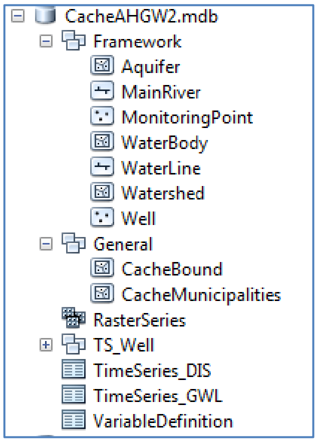
D. Sharing Data

With an ArcGIS Online account, people can share their maps and make them searchable on the website. This provides people a convenient way to store their maps and also make it easier for other people to access the maps. ArcGIS provides functions to compress the map and its referenced data together as a map package and automatically share it to the web. But if the package is in a large file size, it took long time to finish the packaging and uploading process. In this project, it mainly shared the maps showing the general and hydrologic information of Cache County which will be shown in the following section.

III. Results and Discussions

A. Project Geodatabase

The project geodatabase is established based on the AHGW geodatabase. It stored the collected data as well as the derived data in an organized way (See Fig.7). “Framework” dataset stored the basic surface and subsurface hydrologic data. “General” dataset stored the location and population information of Cache County and its municipalities. The three tables separately stored the discharge time series of all the monitoring sites, groundwater level time series of all the wells, and the description of variables used for different time series. “TS_Well” stored the well feature classes which are the outputs of Model 1. “Raster Series” stored the interpolated groundwater level surfaces which are the outputs of Model 2.



- CacheAHGW2.mdb
  - Framework
    - Aquifer
    - MainRiver
    - MonitoringPoint
    - WaterBody
    - WaterLine
    - Watershed
    - Well
  - General
    - CacheBound
    - CacheMunicipalities
  - RasterSeries
  - TS_Well
  - TimeSeries_DIS
  - TimeSeries_GWL
  - VariableDefinition

Fig.7 Project geodatabase

B. General Information

To show the general information of Cache County, two maps were generated. Fig.8 shows the location information of Cache County and its municipalities. From Fig.8 it can be seen that Cache County lies along the northern border of Utah State. It consists of 19 municipalities most of which locates on its central western and northern part. Fig.9 shows the population condition of all the municipalities, and from the collected data, it shows that Logan has the largest population and Cornish has the smallest population.

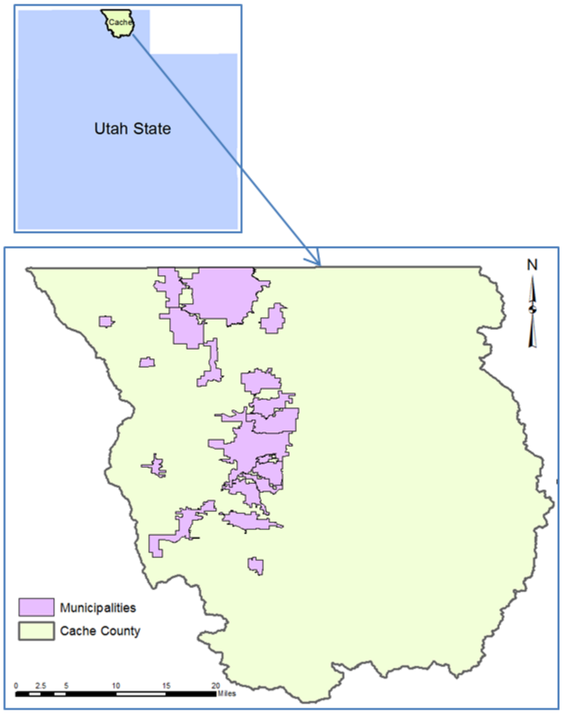


Fig.8 Location information of Cache County

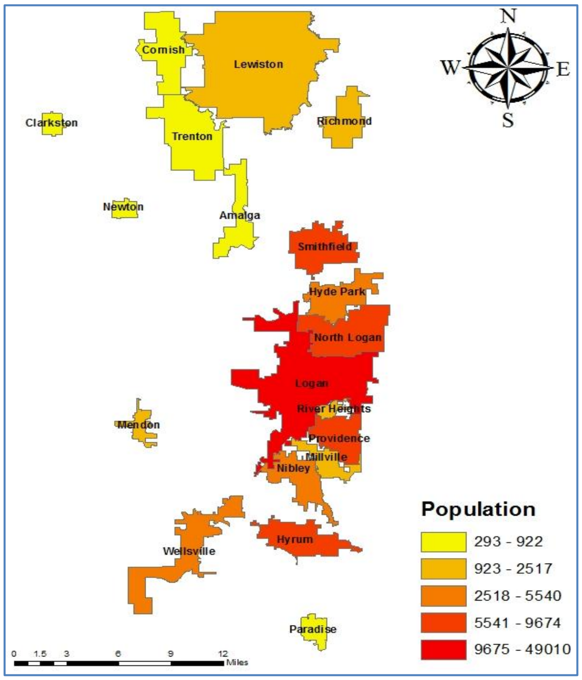


Fig.9 Population condition of Cache County

C. Hydrologic Information

To show the hydrologic information in Cache County, two maps were generated. Fig.10 shows the surface hydrologic infromation and Fig.11 presents the subsurface hydrologic information. In Cache county, there are 8 major HUC10 watershedsands, 4 major reservoirs and 4 major rivers among which Logan River, Black smith Fork River and Little Bear River flow from the upstream and converge in the Cutler Reservoir and then combine with the Bear River to finally flow out of Cache County from its west boundary.

The major aquifer for water resources development lies in the western part of Cache County, and "Valley Fill" is the type for this aquifer. Besides, this aquifer is devided into three subtypes including primary recharge area, secondary recharge area and discharge area [6].From Fig.11 it can be seen that most of the selected wells locates in the discharge area and secondary area.

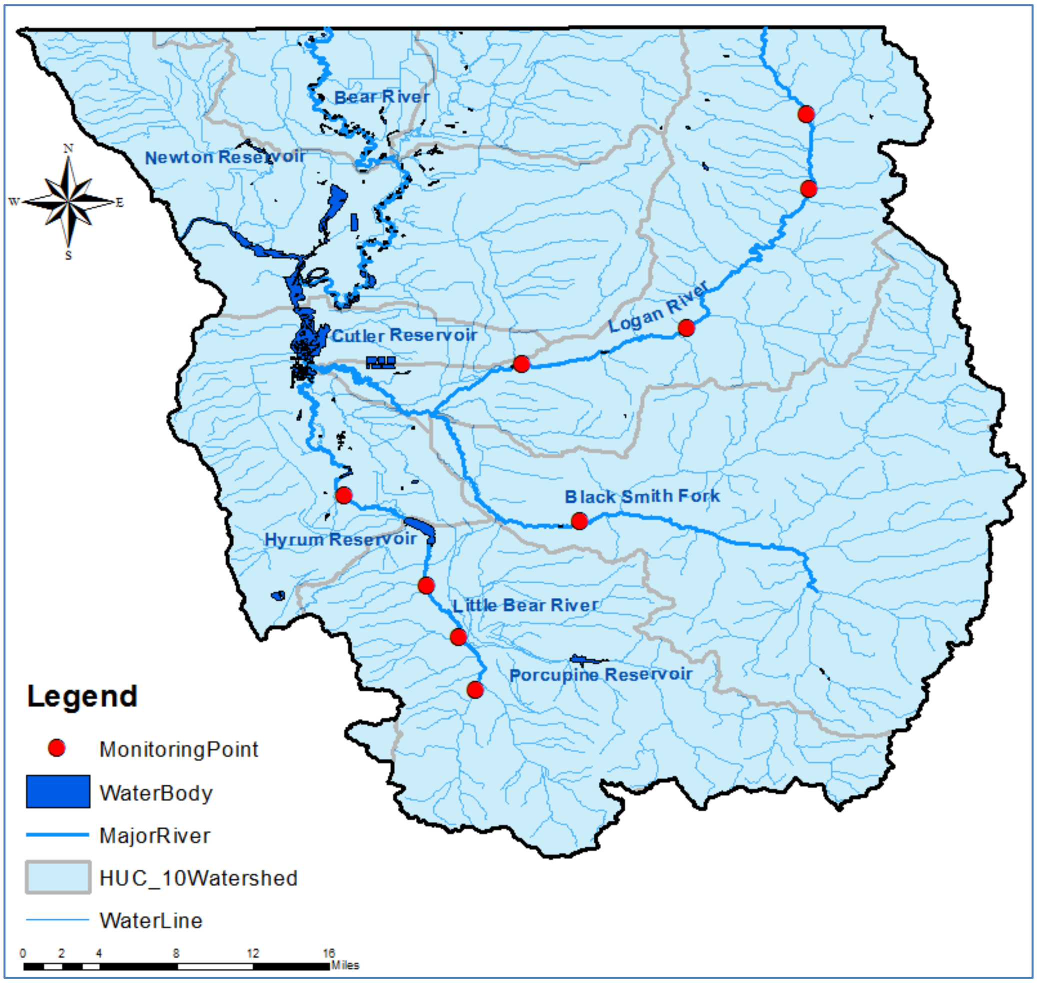


Fig.10 Surface hydrologic information of Cache County

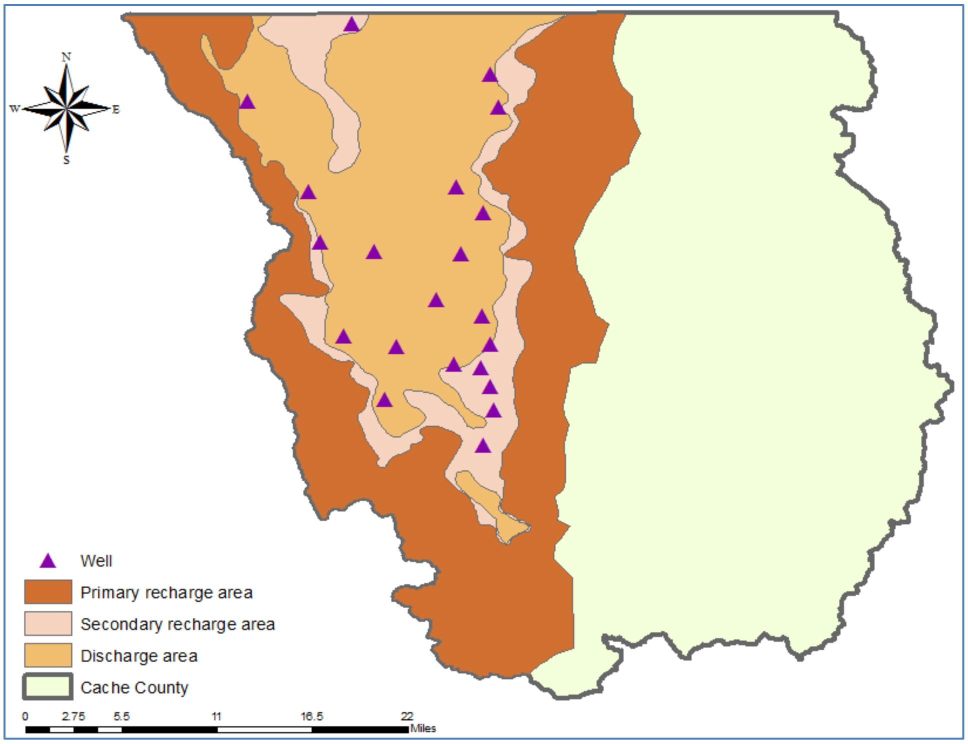


Fig.11 Subsurface hydrologic information of Cache County

D. Hydrologic Phenomena

In order to find out some surface hydrologic phenomena, stream discharge time series data of the sites along the Logan River and the Little Bear River was examined. From Fig.12 it could be seen that in the Logan River discharge time series data has good relationships among the sites from upstream to downstream. And the discharge values increased from the upstream to downstream. This is because in natural condition discharges increase downstream in a river as more tributaries enter. Fig.13 is the discharge time series of the sites along the Little Bear River. This graph shows that the time series data of two sites on the southern side of Hyrum Reservoir has good relationship and the values increased along upstream to downstream. However the discharge values of the site on the northern side of Hyrum Reservoir sometimes decreased. This phenomenon was probably caused by the reservoir operation that part of the discharge from upstream was stored in the reservoir, so the discharge didn’t increase as the natural condition.

To explore the subsurface hydrologic phenomena, three aspects were examined. The first aspect is to examine the groundwater level time series characters. Two phenomena were found: 1) most of the wells in secondary recharge area had clearer changing cycle of the groundwater level than the wells in the discharge area and for the wells that have changing cycle, the groundwater level reaches the peak value around August and September (See Fig.14); 2) some of the wells that are closer to each other may have similar changing trend of the groundwater level (See Fig.15).These phenomena may mainly relate to the geological condition, precipitation and other factors in this area. So in the future, more data need to be collected to explain them.

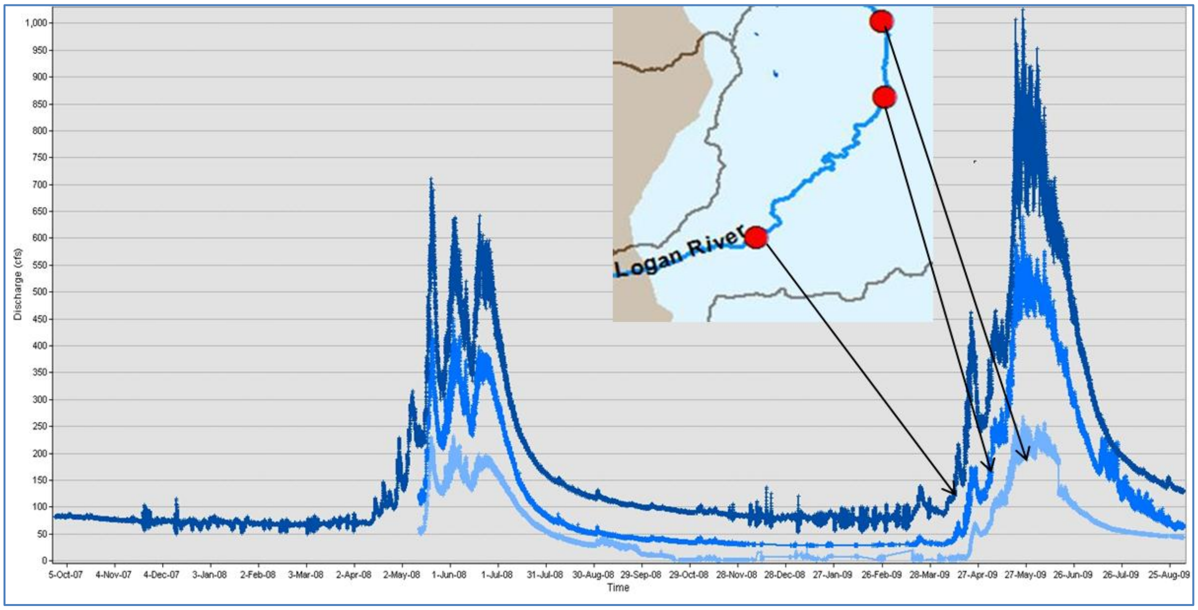


Fig.12 Discharge time series of the sites along Logan River

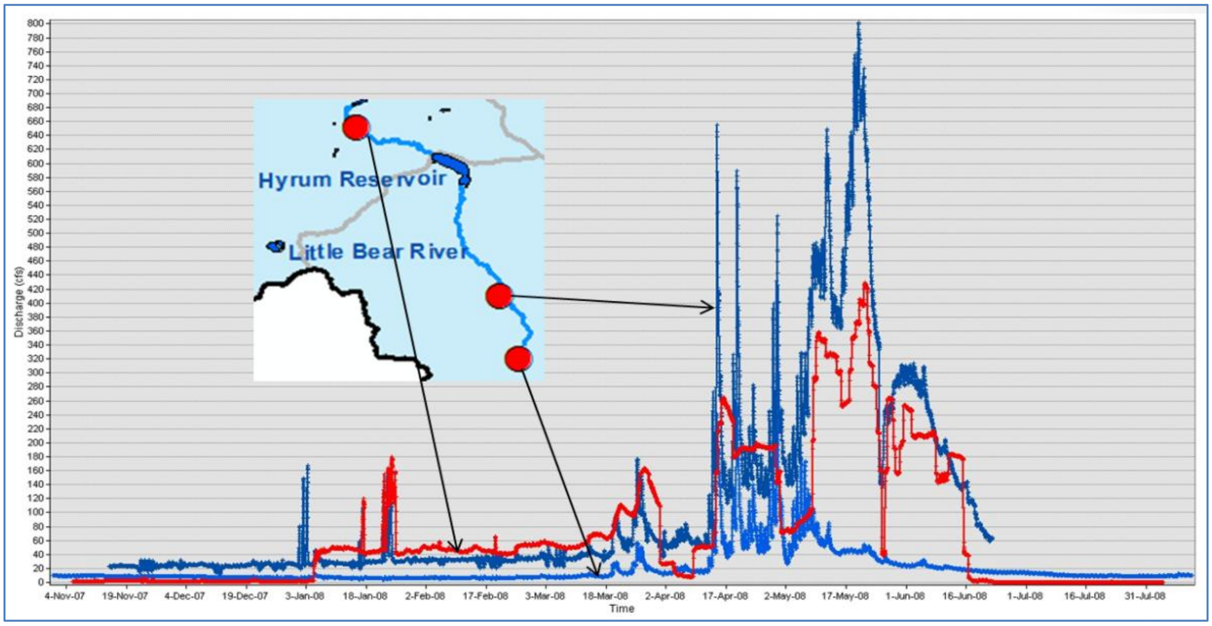


Fig.13 Discharge time series of the sites along Little Bear River

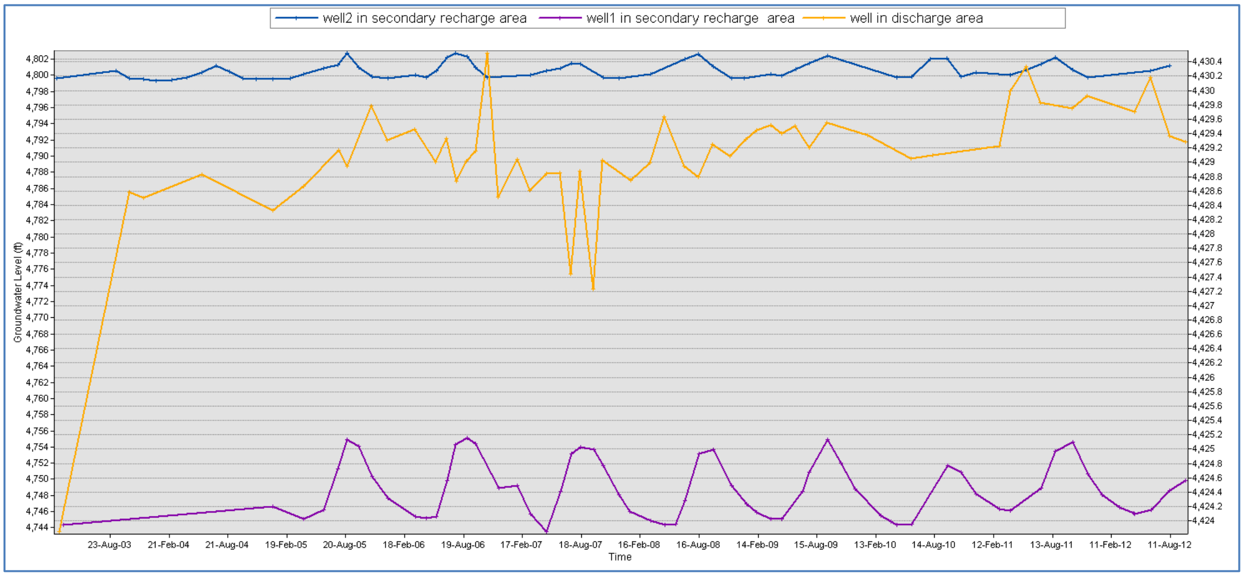


Fig.14 Groundwater level time series of wells in discharge and secondary recharge areas

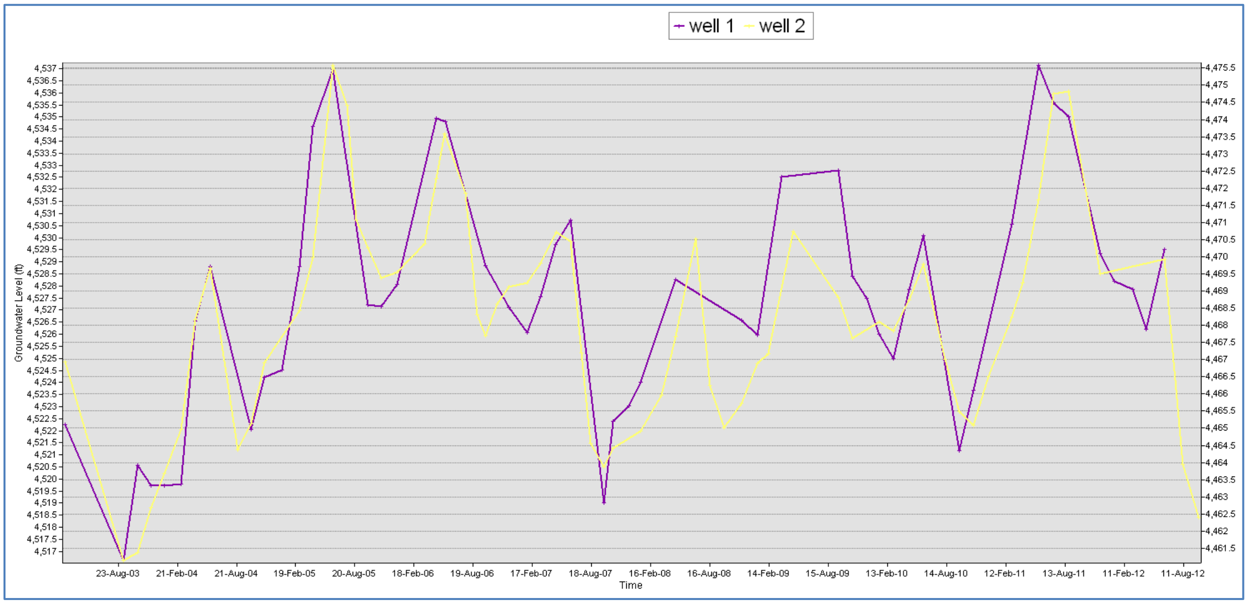


Fig.15 Groundwater level time series of two wells closer to each other

The second aspect is to see the groundwater flow direction in Cache County. Fig.16 shows the groundwater level interpolated surface and its flow direction (green arrows) for the first half year of 2012. In this figure, it shows that the groundwater level was high in the northwestern and southeastern part of the aquifer and low in the central and western part. This affected the groundwater flow direction, and in Cache County the groundwater generally flows from northwestern and southeastern part to the central and western part.

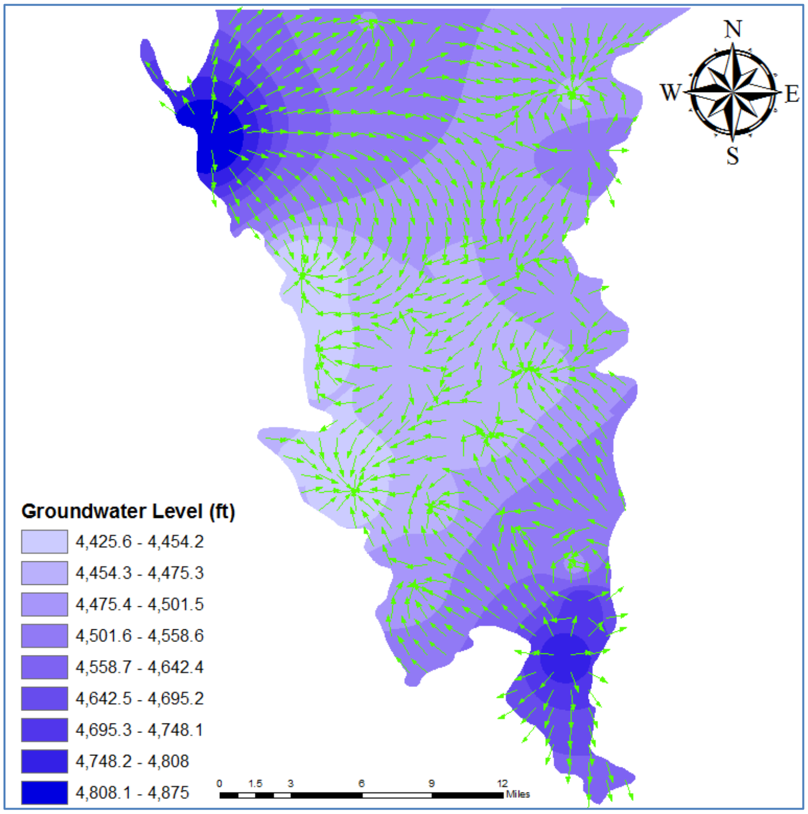


Fig.16 Interpolated groundwater level surface and groundwater flow direction

The third aspect is to examine the changing trend of groundwater level from year 2003 to 2012 in Cache County. This was mainly done by generating the interpolated groundwater level surfaces for each half year from 2003 to 2012, and then using "Time Slider" function in ArcGIS to show the interpolated groundwater level surfaces with time sequence. As not all the wells have average values for each half year, it is a little bit hard to accurately compare the changing condition among different time periods. But generally, the southern part of the groundwater level has an increasing trend, as the area with high groundwater level expanded through the whole period. By comparison, the groundwater level of the northwestern part stayed stable with small fluctuations. And the central as well as the northeastern part has more obvious changes of groundwater level, with values decreasing or increasing through the whole period. Fig.17 shows interpolated groundwater level surfaces of 4 time periods and demonstrates the phenomena mentioned here.

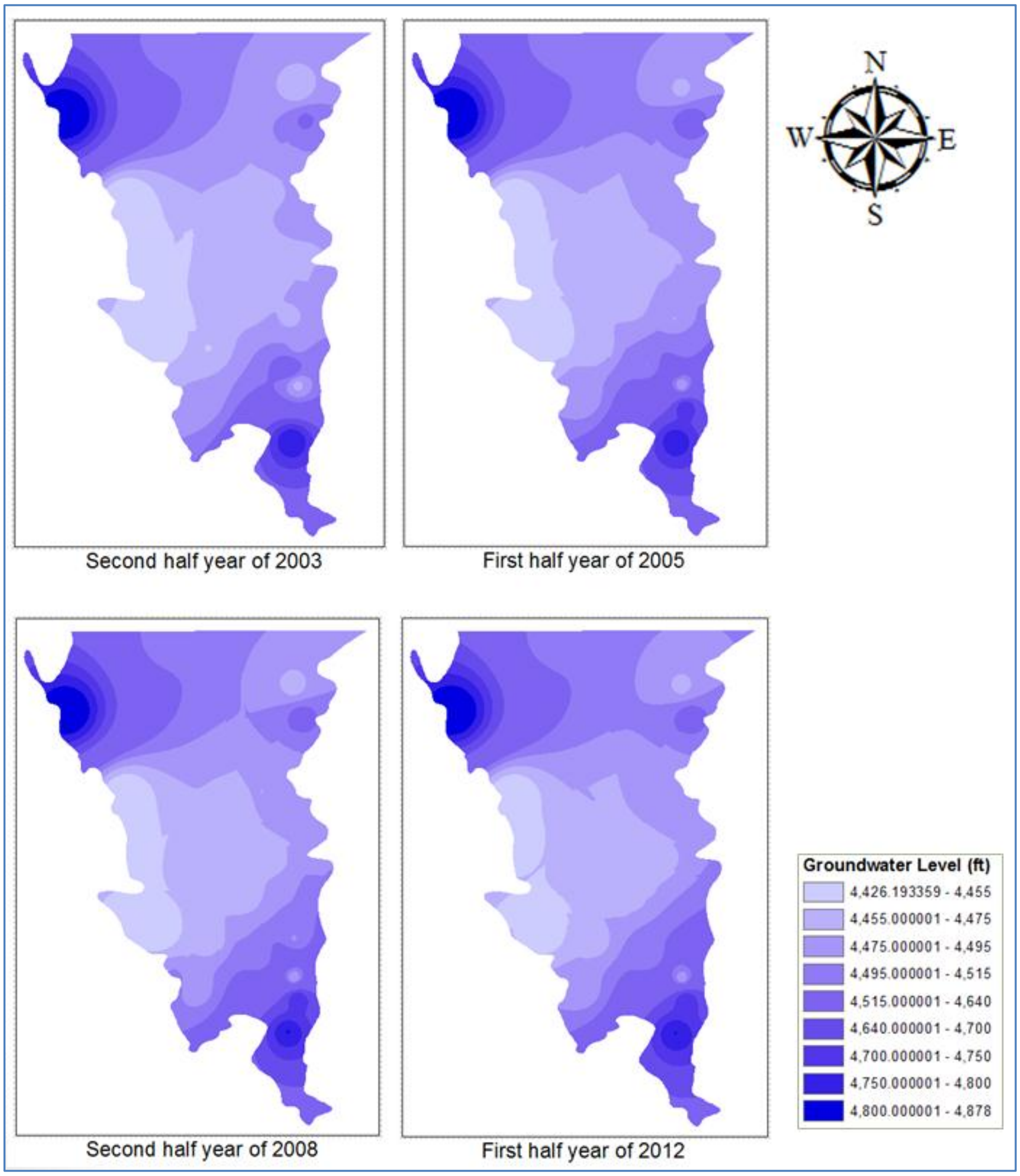


Fig.17 Interpolated groundwater level surfaces of four time periods

IV. Conclusions and Future Work

This project collected general and hydrologic information of Cache County from different data sources and managed the information with AHGW geodatabase. Then maps and graphs were generated based on the collected and derived data to show general and hydrologic information and to discover the hydrologic phenomena of this area. Finally, the major maps were shared online so as to provide useful information for other people.

During the whole process, Hydrodesktop and ArcGIS toolboxes were utilized and they provide convenience to collect, manage and visualize hydrologic data, especially the AHGW toolbox showed its powerful functions for dealing with hydrologic information. Besides, some of the surface and subsurface hydrologic phenomena were discovered from the collected and derived data, but more information from other related aspects still needs to be obtained to explain the reasons for them.

In the future, more hydrologic, climate and geologic data is planned to be collected. This will help to explain the phenomena discovered in the project and to expand the existing geodatabase with “Subsurface” dataset and “Simulation” dataset. By sharing the expanded geodatabase, it can provide people more subsurface hydrologic information which will be useful for groundwater model simulations.

References

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