

“HEADWATERS OF TECHNOLOGY”

Integrating a GPS mobile workforce with GIS data collection and management

By Jeffrey Mihalik, GIS Manager, Wallace & Pancher, Inc.

Wallace & Pancher, Inc. (WPI) has developed an innovative approach to integrate a mobile work force with environmental GIS data collection and management. WPI was recently awarded a service contract from two major long-wall mining operations to monitor stream condition and flow of hundreds of miles of stream located above these underground long-wall mining operations. The goal of the project is to monitor and predict potential physical and/or biological variations to surface waters pre and post mining. Immediate needs to implement this project necessitated a very tight schedule to obtain sound and practical solutions in a timely manner. WPI's engineers and biologists, along with WPI's and the mines' GIS departments and management, worked closely to develop an effective data collection and management system.

The Project:

The contract called for two specific types of monitoring:

1. Stream Condition Monitoring (SCM) to document current stream field conditions, and;
2. Direct Flow Measurements to determine discharge (i.e. flow).

Stream Condition Monitoring involves traversing a stream from its downstream confluence to its headwaters and determining the starting and end point (distance) of the various stream flow regimes such as flow, puddle, pool, dry, and non-continuous flow.



Direct Flow Measurements are taken at specific locations along each stream and were chosen based on several factors such as access, proximity to mining operations, and stream characteristics. Flow measurements are currently being gathered at over 800 locations.



The contract also called for WPI to provide the mines with the field data results within 48 hours of collection. Therefore, WPI needed to develop a quick response approach and technology to accomplish these tasks.

Tools and Equipment:

WPI purchased eight (8) Trimble Nomad and two (2) GeoXT handheld GPS units installed with ESRI ArcPad (7.1.1) and GPScorrect software. ArcPad software provides an easy-view environment for field biologists to visualize and document not only their physical location along the stream while conducting the SCM but also verifies and documents the location and associated field data in a format that is GIS compatible. Custom data entry forms were needed for collecting both the SCM observations and direct flow measurement.

In order to obtain direct flow measurements in the field WPI purchased eight (8) Hach FlowMates. Field crews were also equipped with portable weirs and other necessary equipment for taking flow measurements in challenging field conditions such as low flow or constricted small tributary systems.

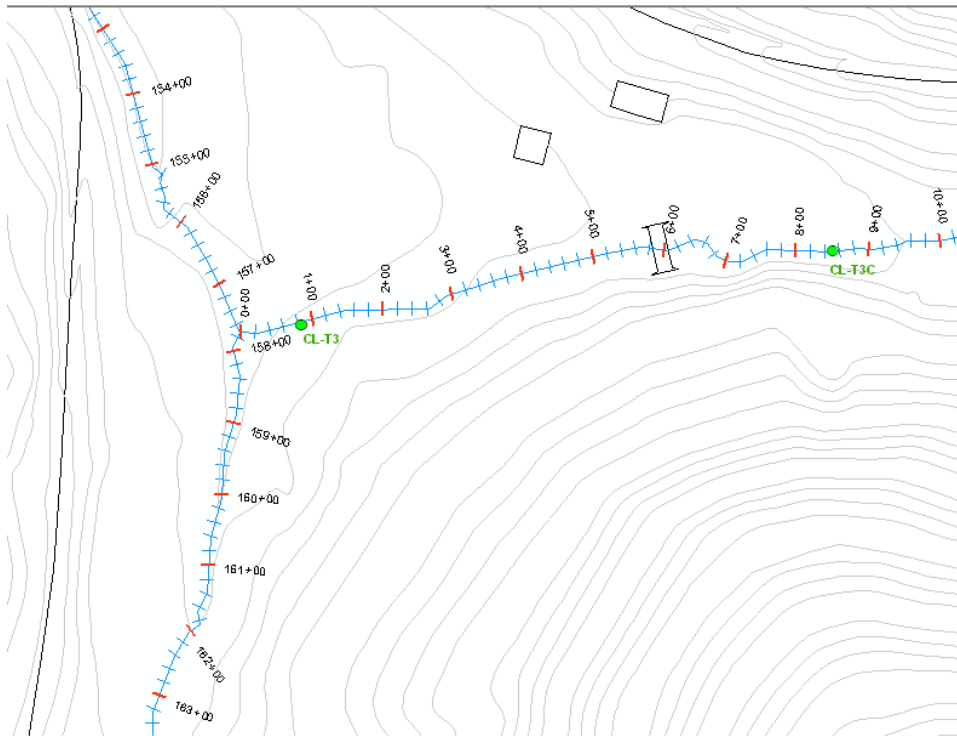
Base Mapping:

A networked hydrology layer for the project base mapping was the first layer of information developed. Next, all 2,000 individual stream segments (over 500 miles of stream) were individually labeled in ArcMap using an established five digit coding system developed by the

Pennsylvania Department of Environmental Protection (PADEP) and then modified (by WPI) to account for smaller tributaries that were not included in the original PADEP codes.

Some sampling locations were already established by another company and a rudimentary GIS layer existed. These site locations (as a point layer) and the hydrologic network (as a polyline) were the primary components of the base mapping and were housed in an SDE geodatabase in SQLExpress.

Using AutoCAD, the streams were stationed at 20' intervals. This allowed field crews to document the relative location of various stream conditions as they traversed the streams. A GIS layer of each 100' station interval was developed and assigned a red line color to make it easier for the data collectors to associate the CAD annotation (that labeled only the 100' station intervals) with the proper interval line segment. The AutoCAD stationing, along with other GIS layers of roadways, structures, mine panels, and contours were then exported to a shapefile format and uploaded to the GPS units.



Custom Forms:

The next step was to develop custom data entry forms. By coordinating with the mines, WPI identified four methods of acquiring flow data in the field: 1) small stream method using a flow meter, 2) large stream method using a flow meter, 3) volumetric method by constricting stream flow and using a container of known proportion- typically a weir and plastic container are used with this method, and 4) the float method using a ping pong ball and stop watch. WPI developed structure formulas for each method to suit drop down menus and data entry boxes within the customized forms. The robust math calculations within the forms allowed for a discharge rate in

CFS and GPM to be derived from the data entered in the field. The forms tracked time/date, crew personnel, current flow conditions, and provided room to document any additional comments. SCM forms were also developed in a manner to ease the collection and entry of various field measurements. The forms were developed in ArcPad Studio and uploaded as .apl files. The SCM form was linked to the hydrology layer using a table relation, then each file was linked to the appropriate GIS feature class layer by using ArcPad Manager tools during the ArcPad check out process. The flow data and SCM forms were activated during edit sessions in ArcPad.

Mobile Workforce Implementation:

Time constraints only permitted a limited amount of field testing with the GPS units and with the overall GIS data management strategy. However, within three months WPI opened and staffed a new field office, implemented the GIS and GPS technologies, and began sampling the entire project area. The frequency of sampling at each location was dependent on the actual location of the active underground mining operation and ranged from daily to once every four months. As the mine “face” moves forward towards a stream, the frequency of sampling increases. When the mine “face” is within 1000’ ahead or behind a stream, the monitoring is done each day. As the mine “face” recedes, so does the frequency of sampling.

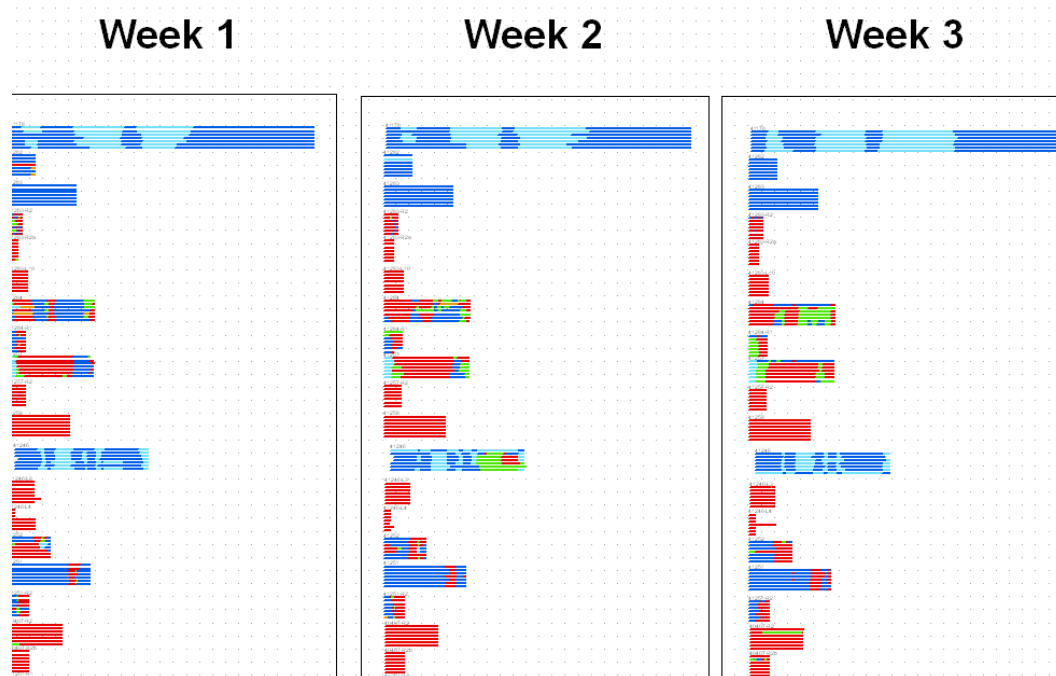
WPI had a trained and experienced field crew in place but hired an additional 12 employees to meet the needs of frequent field sampling and GIS needs associated with this project. Both of these were addressed by locating field and technical crew members in a local field office in close proximity to the project area. It became obvious early in the implementation that the GIS staff would need to work closely with the field crews. The GIS staff provided field crews with training using ArcPad (which was new to all data collectors), support for GPS issues in the field, and also provide a daily QA/QC to insure the consistency and reliability of the collected data.

Data Storage, Processing, and Delivery to the Client:

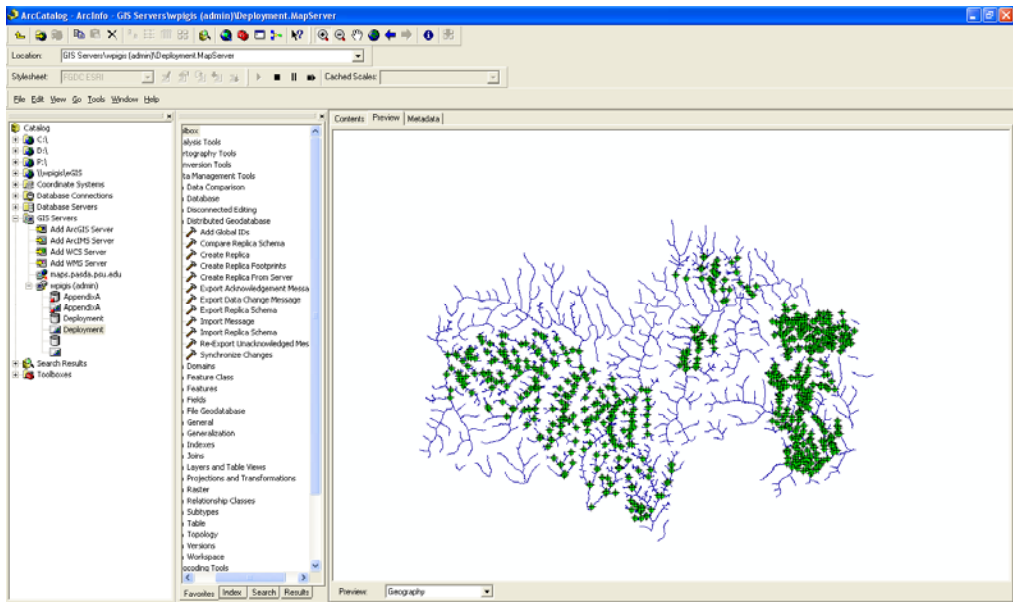
Stream polyline and flow monitoring point layers were stored as feature classes in an SDE enabled distributed geodatabase. WPI uses a standard workgroup level license and houses the data in SQLExpress. Field crews returning to the office turn in the GPS unit they used for the day and provide the GIS staff with a field reconnaissance form. This form contains information regarding flow monitoring points they sampled that day and detail GPS location data that may have been gathered. Flow and SCM data are stored in an .axf file on the GPS unit. The GPS, Flow, and SCM data are then copied and pasted into appropriate folders. Then a map document containing the flow monitoring points and stream layers is opened and using ArcPad Data Manager, the .axf files from each GPS unit are checked in. As each file is checked in the GIS staff QA/QC the reconnaissance forms to ensure data accuracy.

The field edited SCM form writes to a table and is updated during the check in. The table is used during the dynamic segmentation process. This process involved creating routes of each stream being monitored. The SCM table (containing From and To fields of stream condition lengths) is linked to the route and used to dynamically segment stream lines with attributes of the various stream conditions. The SCM monitoring process occurs at the same frequency as the direct flow measurements. By monitoring flow *and* stream condition, any changes in flow (both natural and induced) could be tracked throughout the year. Dynamic segmentation was run on the stream polyline and on a straight line of the same length representing each stream. Because some

streams are monitored daily, it was difficult to visually offset the stream polylines on a map (especially dendritic streams with many tributaries). Therefore, the straight line representation alleviated this problem and daily or weekly changes could be easily visualized by simply changing colors on the map.

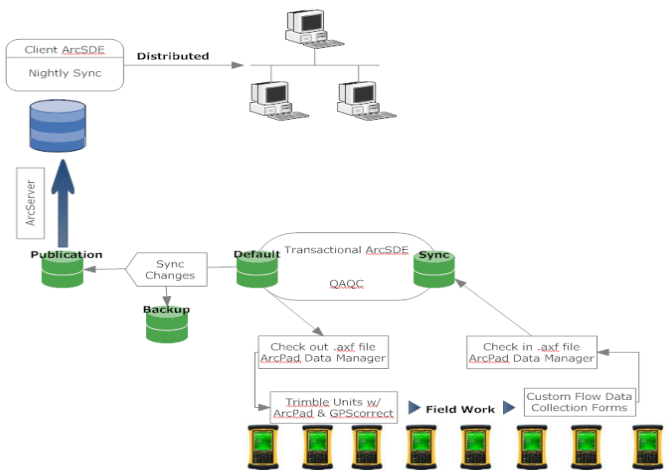


After checking in all flow data a synchronization was completed; first to a backup geodatabase then secondly to the production geodatabase. The production geodatabase was uploaded to the client using ArcGIS Server (Standard Edition). Finally, the client synchronized with the production geodatabase using a custom python script and Windows Messenger to automatically run the synchronization each night at 2:00am during off peak hours. SCM data was delivered using the same process; however, these data were generated weekly. At the completion of each field day ArcPad Data Manager was used to check out the most current geodatabase which were uploaded to the GPS units. This prevented individuals from mismanaging field data at the start of each day because they all started with identical databases. Additionally, GPS units do not monitor the same stream locations so all incoming edits are “fresh”.



Advantages and Client usage:

After synchronizing the flow and SCM data, the client displayed the data in a custom intranet application. This allowed the client to have full access to field data within 24 hours of field collection. Up to the point where this program was initiated, field data was not readily available to the client for periods up to and exceeding 3 or 4 weeks. The ability to have almost instantaneous access to data provided the client with the ability to foresee problems before they arise (change detection), have current geo-spatial data in hand to answer complex questions, and visually assess environmental concerns and state/federal permitting issues in almost real time. The development and implementation of this methodology has enabled the client to provide a quick response to environmental concerns.



Future issue resolutions and projects:

During Flow and SCM monitoring, numerous pictures are taken. Several methods to streamline the download and integration of these images are being considered. Currently, all photos are taken with digital cameras, downloaded to the local drive on computers in the field office, renamed, and filed. The pictures are then saved on DVD for delivery to the client. GPS cameras and or GPS photo link software are being considered to facilitate photo acquisition, storage and delivery using GIS based methods. ArcPad 8, currently being released by ESRI, has much of the same look and functionality, tool locations and usages but is different enough to warrant additional training.

WPI is evaluating the potential for utilizing similar GPS/GIS methods of data acquisition and delivery for existing and future clients. An enterprise level GIS Server license is on the horizon to facilitate WPI's GIS department expanding data storage and retrieval needs.

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About the Author:

Jeffrey Mihalik is the GIS Manager for Wallace & Pancher, Inc. He has Masters Degrees in both GIS and Biology and a Bachelor's degree in Environmental Science. Jeff has over seven years of experience developing and utilizing GIS application for the coal industry. For more information Jeff can be contacted at jmihalik@wallacepancher.com.