OPTIMIZING GIS FOR SNOW SAFETY OPERATIONS AT TAOS SKI VALLEY: AVALANCHE AND EXPLOSIVES TRACKING AND DIGITIAL AVALANCHE ATLAS APPS

Rachel Moscarella [1], Andy Bond [1] and Wetherbee Dorshow[2]

[1]Taos Ski Valley Inc, Taos Ski Valley, NM, USA
[2]Earh Analytic, Santa Fe, NM, USA

ABSTRACT: Given the tenet that ski patrollers are inherently reluctant to complete paperwork, we felt compelled to make the recording of explosive use and avalanche occurrences as quick and painless as possible, while improving accuracy. To that end, we have leveraged GIS to create a digital avalanche atlas that works in tandem with a user-friendly web based application. This enables patrollers to enter data using tablets, freehand drawing tools, and simple drop down menus to record explosive use and avalanche occurrences. Forecasters and patrollers can then track this up to date information in both graphical and tabular formats to visualize explosive placement and results throughout storm cycles.

Knowing that GIS is increasingly prevalent in the industry, and given a lack of comprehensive information about our 300+ avalanche paths, we were led to the concept of using GIS and digital elevation models to complete an accurate and robust digital avalanche atlas. Time was spent preseason to map the avalanche paths using ArcGIS desktop software.

Since the data entry records are in a centralized geodatabase, access to the information for a future analysis or inquiry will be straightforward. Using the time-slider tool, avalanche occurrences and explosives placements can be visualized as a dynamic time series that plays back the results from a specific day, storm event, or other interval.

The patrol has embraced the new paradigm, which has fostered a more inquisitive and engaged snow safety culture. Currently under development are web app tools and interfaces for (1) logging, viewing and analyzing snow pit profiles (2) terrestrial lidar snow depth analysis, optimizing and visualizing Gazex Exploder placements, and weather data integration and analysis.

KEYWORDS: GIS, Risk Management, Avalanche Mapping

1. INTRODUCTION

Our initial objective was to create a GIS-based avalanche atlas and to enhance the workflow for documenting avalanche occurrences and explosive use. Throughout the 60 years of operation of Taos Ski Valley, some 265-avalanche paths were identified and described in logbooks, but large-scale maps were never created or used systematically.

Early on in the process, we discovered that paths with frequent avalanche activity were better documented and more consistently named than less active paths. Using logbooks and sketches, along with anecdotal information from long-time staff, we found numerous cases of the same path having different names and varying terrain descriptions. We also determined that several avalanche paths had never been documented. Much of the avalanche terrain at Taos Ski Valley is at tree line with intricate and poorly defined starting zones. Even with good aerial photographs we felt like we didn't have enough information to complete the avalanche atlas. Utilizing the newly acquired lidar data for Taos Ski Valley we were able to complete this task with confidence. In addition to having a more reliable basemap, an accurate and comprehensive avalanche atlas, allows for better record keeping and communications.

The Taos Ski Valley avalanche atlas was created to address three key objectives: (1) Taos Ski Patrol training and safety, (2) user-friendly data entry using a web based application, (3) and a working real-time database of avalanche occurrences and explosive use. The use of GIS is becoming more prevalent in the ski industry for hazard mapping and risk analysis (McCollister et al., (2002); Cappabianca et al., (2008); Teich and Bebi (2009); Peitzsch et al., (2010)) as well as documentation (McNeally et al., (2012)). A major focus was creating a user-friendly application where practitioners are able to draw in avalanche occurrences and explosive use following Snow, Weather, and Avalanches: Observational

Guidelines for Avalanche Programs in the United States (SWAG) compliant formats.

2. CREATING THE TAOS AVALANCHE GEODATABASE AND ATLAS

Taos Ski Valley is located in Northern New Mexico in the Sangre de Cristo Mountains. Taos Ski Valley consists of 1200 acres with a vertical drop of 3,274 feet and an elevation that ranges from 9,207 feet to 12,481 feet.

Taos Ski Valley teamed with Earth Analytic to design and populate a centralized GIS system for the ski area, integrating legacy map and tabular data with newly collected, high-resolution (2014) orthophoto and lidar datasets. We generate a suite of terrain and hydrological datasets from the lidar to support the digitizing and analysis of avalanche paths and start zones.

First, we created a two-foot resolution elevation raster (image) from the bare-earth lidar data. This "treeless" elevation surface was then further processed to generate slope, aspect, and shaded relief datasets, as well as hydrologic catchments and drainage flowlines at multiple scales. We also generated a tree canopy height dataset from the lidar, useful for assessing tree age within avalanche paths among other things. This entailed the subtraction of the first-return surface from the bare-earth surface (See Fig. 1)

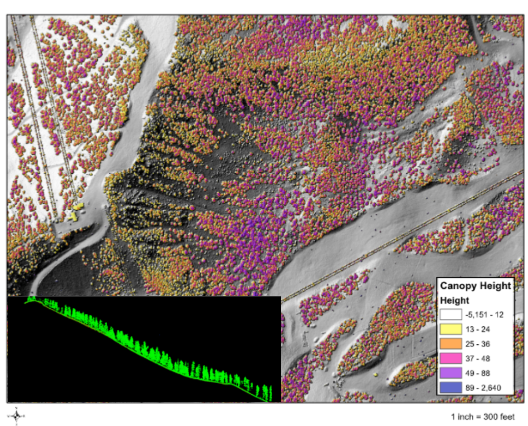

Fig. 1: Tree-canopy height map with sample profile overlay.

Additionally, we designed and created a suite of feature classes and tables for avalanche management features, defining the appropriate fields and attribute domains ("dropdown lists") using industry-standard terminology.

Once these preliminary steps were completed, we created and tuned two desktop GIS applications—ArcMap and ArcGIS Pro—to support the creation of avalanche paths, start zones, routes and other related datasets in both 2D and 3D. In addition to the editable feature layers, the various terrain, imagery and hydrologic datasets were included in these map documents.

Rachel Moscarella and Andy Bond digitized path and start zones in ArcMap, using the GIS layers, field-observations, GPS data, and historical knowledge for reference.

ArcGis Pro provided a 3D rendering of the area with the ability to look at terrain in a more realistic manner. Additional time was spent in the field with a Juno Trimble GPS Unit to help verify the more intricate terrain.

The Taos Avalanche atlas, and the underlying spatial database was completed by the end of August 2015. Large format paper copies were available to the ski patrol with routes, shot locations, avalanche paths and avalanche start zones displayed. The overall formatting of the avalanche atlas was completed July of 2016 (See Fig. 2).

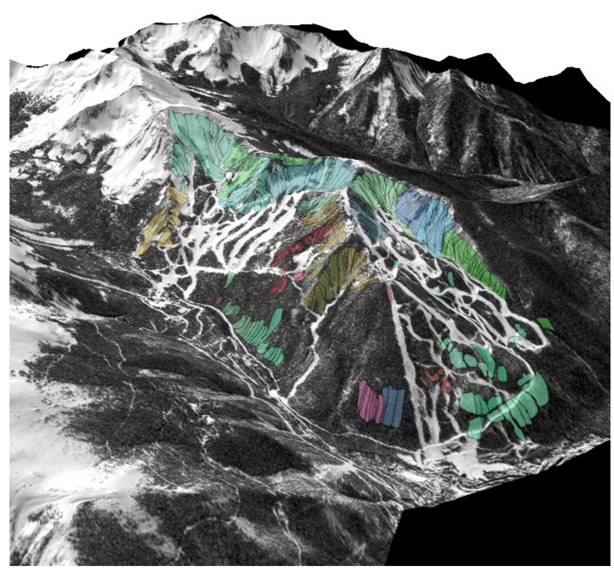

Fig. 2: Taos Ski Valley avalanche atlas.

3. AVALANCHE & EXPLOSIVES TRACKING APPLICATION

In the fall of 2015 we conducted several testing/training sessions with a small group of tech savvy patrollers in order to fine tune the web based app for data entry. The final product of the web app was introduced to the Taos Ski Patrol in the winter of 2015/2016. Five surface pro 3 tablets were available for data entry (See Fig. 3). Data was typically entered soon after the completion of mitigation efforts.

Fig. 3: Ski patrol entering data after avalanche mitigation.

Explosive type and size are selected from the template and positioned on the map using a mouse or stylus pen. If the explosive triggered an avalanche users first determine the destructive size (D) of the avalanche selecting the corresponding D size icon. Users are then able to freehand draw in the avalanche occurrence. Once the occurrence is drawn in a drop down menu will automatically appear on the screen where avalanche occurrences can be documented according to SWAG (See Fig. 4). This process improved speed and accuracy of data entry. Graphical representations were readily available to forecasters and patrollers (See Fig. 5).

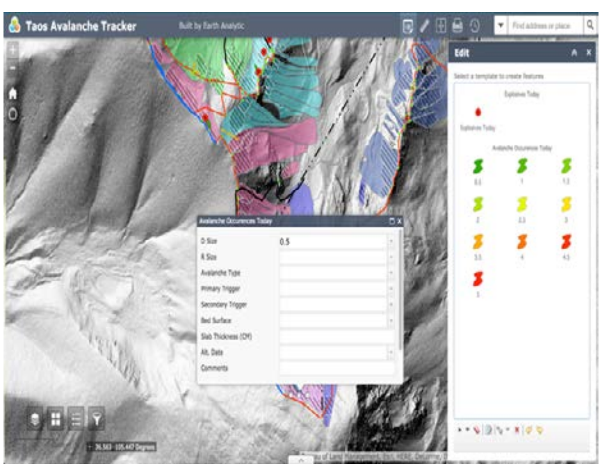

Fig. 4: Taos avalanche tracker with dropdown menus and editing template.

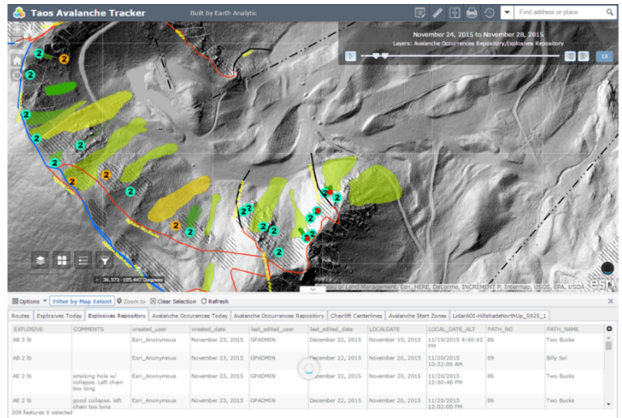

Fig. 5: Graphical display of avalanche occurrences and explosive use with time slider.

The time slider feature enables users to view the history of avalanche occurrences and explosive use over a set period of time.

An additional report tool allows for easy querying of explosive use and avalanche occurrence with a wide range of parameters (e.g. avalanche path, avalanche size, storm cycle, etc.).

4. DISCUSSION AND CONCLUSION

Creation of the avalanche atlas facilitated the development of the web based app allowing for key objectives to be met. The avalanche atlas is a useful tool in several ways such as, training patrollers on routes, particularly ones that are run less frequently and codifying avalanche path names for better communication. The move from paper record keeping to digital data entry and database went smoothly for the patrol. Extra efforts were made to simplify this process with the use of templates and drop down menus. Credibility for the process was established by the immediate access to the records generated.

Real time access seemed to be the key component to engage and foster discussions about current conditions and future mitigation planning. Awareness was increased on the individual specific routes as well as on the entire mountain. This benefited forecasters with the overall mitigation plan by being able to spatially analyze past mitigation efforts and results.

During the season we worked on expanding the capabilities of the GIS platform to produce reports that include avalanche occurrences and explosive use queried by route, day, path, month etc. These reports are not only useful for the forecasters but to other ski area operational personnel as well. Another ongoing project is the integration of Avanet data and photos into the web based app.

In the future we hope to enhance the avalanche atlas with interactive features including descriptive and graphical information about each avalanche path. This will lead to better training for our younger patrollers going forward. Another potential avenue is to increase avalanche awareness within the community. Currently the avalanche atlas only includes inbounds avalanche paths with data access for in house use only, however the possibility exists to share the information with the broader public. If the avalanche atlas was broadened to include the backcountry the potential is there for the web based app to be used by backcountry recreationalists to record observations.

ACKNOWLEDGEMENTS

We would like to thank the Taos Ski Patrol for their willingness and enthusiasm in using the newly created web apps. Professor Bill Hegman GIS Specialist Middlebury College for providing support and encouragement at the beginning stages of this project. Finally this project would not have been possible without the support from Taos Ski Valley Inc.

REFERENCES

Cappabianca, F, Barboli M., Natale, L., 2008. Snow avalanche risk assessment and mapping: A new method based on a combination of statistical analysis, avalanche dynamics simulation and empirically-based vulnerability relations integrated in a GIS platform. Cold Regions Science and Technology, 54 (3), 193-205.

Greene, E. et al, 2010. Snow, Weather, and Avalanches: Observational Guidelines for Avalanche Programs in the United States. American Avalanche Association, Pagosa Springs, CO, USA.

McCollister, C.M., Birkeland, K., Hansen, K.,Aspinall, R, Comey, R., 2002. Exploring multi-scale spatial patterns in historical avalanche data, Jackson Hole Mountain Resort, Wyoming. Cold Regions Science and Technology 37 (3), 299-313.

McNeally,P. J. Collinson, R. Trover, P. Schory, 2012: Snow safety control operations: An interactive web-based approach. Proceedings of the International Snow Science Workshop, Anchorage, AK, 290-293.

Peitzsch. E.H., Fagre, D., Dundas, M. 2010. Using GIS and google earth for the creation of the going-to-the sun road, Glacier National Park, Montana, USA. Proceedings of the International Snow Science Workshop, Squaw Valley, CA, 819-823.

Teich, M and Bebi, P., 2009. Evaluating the benefit of avalanche protection forest with GIS-based risk analyses - A case study in Switzerland. Forest Ecology and Management 257 (9), 1910-1919.