Utilizing NAIP Aerial Photography and Digital Globe Satellite Imagery to Monitor Differential Settling on Reclaimed Lands in North Dakota

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Abstract. The North Dakota Reclamation Division used NAIP (National Agricultural Imagery Program) and Digital Globe satellite imagery to determine if differential settling had occurred on reclaimed lands at North Dakota's four large surface mines. Water may temporarily pond where differential settling occurs and these features can be considered detrimental to some postmine land uses, such as cropland. Suspected subsidence areas were digitized to determine area extent. Over 820 differential settling features were identified at the four active mines. Most of the differential settling features are less than 0.1 acre in size but some are over 1.0 acre in size. Suspected areas of subsidence were field inspected using mobile computing devices to verify that the areas were subsidence features. NAIP imagery was not available for 2007 due to budget cuts in the program; therefore satellite imagery from Digital Globe was used. This technology allowed the Reclamation Division to efficiently and thoroughly investigate the extent of subsidence features on reclaimed lands, and demonstrates the capability and efficiency of high resolution imagery for monitoring of reclaimed lands prior to bond release.

Additional Key Words: NAIP aerial photography, digital globe satellite imagery, differential settling, subsidence

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Introduction

North Dakota produces over 27 million metric tons of lignite coal per year. The Public Service Commission is the state regulatory authority for surface coal mining activities within the state. Approximately 44,550 hectares (110,000 acres) of land are permitted for surface coal mining activities in North Dakota, of which approximately 12,960 hectares (32,000 acres) have been mined and reclaimed. The primary pre- and post-mining land uses are cropland, native grassland, tame pastureland, hayland, wetlands and woodlands with cropland comprising approximately 58 percent of the permitted acreage.

Subsidence or differential settling is a common problem on reclaimed land in North Dakota. These features form over time, usually several years, as the graded spoil settles following reclamation. Surface water ponds or accumulates in these subsidence features following snowmelt or rainfall events resulting in saturated soils and the formation of a wetland environment. The resulting wet areas in cropland may limit farming operations, hinder crop emergence and development, and may delay final bond release. Figure 1 is a July 26, 2000 photograph of settling features on reclaimed cropland that was reclaimed between 1992 and 1995. Note that many of the settling features were too wet to farm through.

Figure 1: Photograph of subsidence on reclaimed cropland.

A certain amount of subsidence features may be retained in cropland as replacement for temporary and ephemeral wetlands that were destroyed by mining. In addition, settling features that form in native grassland are generally allowed to remain as they provide landscape diversity and do not hinder agricultural operations. The remainder of the settling features in cropland will need to be repaired. Several years ago the Commission recognized the need to determine the extent of the subsidence problem in cropland areas and provide a mechanism to monitor subsidence features.

Prior to GIS and readily available ortho imagery, subsidence features were difficult to detect and were usually discovered by field inspectors or landowner/operator reporting the features. Aerial photos supplied by the mine operators were usually taken in late summer or early fall when conditions were dry which made the subsidence features difficult to detect by photo interpretation alone. However, the ready availability of ortho imagery coupled with the capability of GIS provided a mechanism to identify and monitor or track the subsidence features.

Methodology

The Reclamation Division used GIS software and National Agricultural Imagery Program (NAIP) digital ortho-imagery to detect and determine the extent of subsidence on reclaimed lands in North Dakota. The NAIP aerial images are available as compressed county mosaics in MrSID format. The 2005 NAIP aerial images were acquired during the "peak leaf" period of the growing season and have one meter resolution. The image contrast between the subsidence areas (generally wet) and the adjacent upland areas (generally dry) is greatest at this time. The vegetation on the subsidence areas may be significantly different or more stressed than the adjacent upland areas, making delineation of subsidence features easier based on image interpretation.

The Reclamation Division had already created many GIS feature classes for the four major mines. The feature classes include the mine's permit boundaries, pit layout, post-mine land uses, and other mining feature classes such as Suitable Plant Growth Material (SPGM) stockpiles, sediment ponds and haul roads. A subsidence polygon shape file was created for each mine. Fields were added to the shape file's attribute table so that information such as

permit number, section number, size (acres), feature number, post-mine land use, and comments pertaining to each subsidence feature could be recorded. Annual maps and pit layout and facilities maps were used to ensure that the locations of potential subsidence features were actually on reclaimed land. Post-mine land use information was needed to determine if the subsidence feature was not actually a created reclaimed wetland. There are approximately 900 hectares (2,222 acres) of seasonal or more permanent wetlands on permitted lands in North Dakota and, if disturbed, they are required to be replaced on an acre for acre basis. The pre-mine ephemeral and temporary wetlands are not considered a separate land use, but their presence is documented.

Areas that pond water or remain saturated for extended periods appear as dark objects on the imagery. Each of these areas was digitized as a polygon in the subsidence shape file and relevant information was added to the attribute table. Figure 2 is an image showing a portion of the 2005 NAIP imagery for a quarter section (160 acres) of reclaimed cropland.

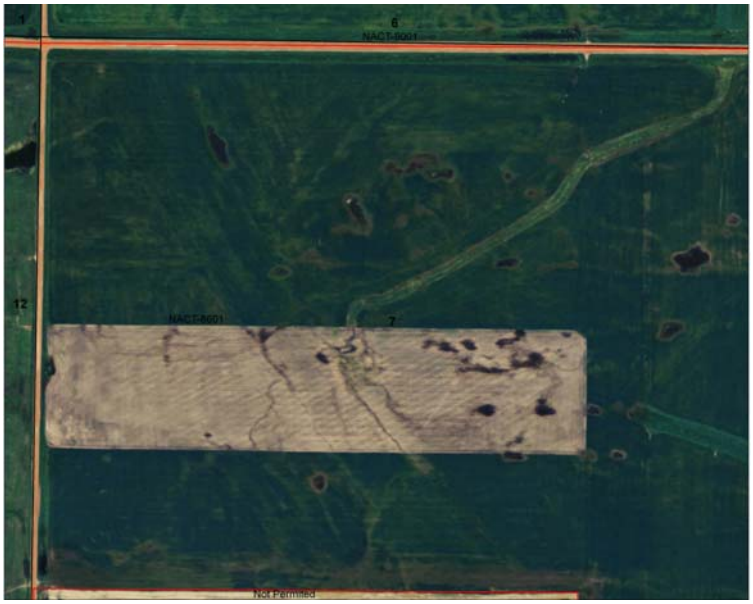

Figure 2: 2005 NAIP imagery of reclaimed cropland showing subsidence areas overlain on ortho imagery.

The subsidence features were digitized while zoomed into the ortho imagery to the extent necessary. The layer capabilities of ArcMap enabled the Reclamation Division to simultaneously assess the permit area, pit layout, topography, post-mine land use and other

features of the reclaimed land. Figure 3 shows digitized subsidence features which are outlined in red within this tract of land.

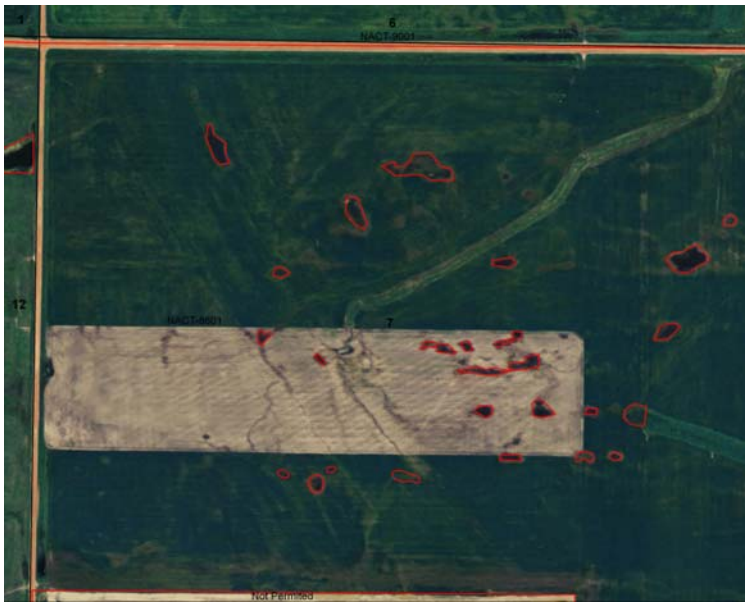

Figure 3: Subsidence features delineated using 2005 NAIP imagery.

For each of the mines, the area of the subsidence features was calculated within ArcMap. A total of 815 subsidence features totaling 69.8 hectares (172.35 acres) were identified at the four mines. In the spring of 2006 the Reclamation Division used mobile computing to field verify the areas of potential subsidence. The subsidence polygon shape file was transferred to GPS – enabled tablet computers with ArcPad installed and used for field verification of the potential subsidence features. In several instances, areas identified as subsidence were actually rock piles, bare areas and electric power line poles. New subsidence features discovered in the field were mapped with GPS and added to the subsidence shape file. In early 2007 the Reclamation Division made a request to OSMRE – TIPS for satellite imagery of the four major mines in North Dakota. OSMRE – TIPS arranged for Digital Globe Quickbird imagery to be acquired in mid-June of 2007 that will be used to re-evaluate and update the information obtained from the 2005 NAIP imagery. This information can be used to determine if a subsidence feature is growing in size over time or if past repair work has been successful.

Conclusion

From an environmental perspective, GIS software and NAIP imagery allowed the Reclamation Division of the Public Service Commission to evaluate the extent and impact of subsidence or differential settling on reclaimed mined lands in North Dakota. ArcGIS enables us to visualize the relationships and timing of the mining and reclamation operations to better understand the interaction of the features. The Reclamation Division was able to evaluate the settling features on reclaimed lands during the growing season and avoid issues such as traversing seeded areas or wet and muddy ground conditions. With the aid of GIS, we believe potential issues are more likely to be identified and addressed well before final bond release and help insure that mined lands are returned to their highest and best use in a timely fashion.

From a business perspective, GIS leverages time and money. Assuming good ground and weather conditions, we estimate that several weeks would be necessary to physically inspect all reclaimed lands for possible settling features. The mines are a significant distance from the Reclamation Division office. A two to four hour round-trip travel time to the mines is typical. Transportation costs are significant and are increasing rapidly. Mapping subsidence features by remote sensing with good quality aerial imagery in the office offers savings in man-hours in the field. Organizing data in a GIS creates datasets that are reusable and geographically referenced, and imagery and vector data used in the subsidence study is also available for other projects. Imagery is used for monitoring mining activity, midterm reviews and permit renewals, aids in verification of Annual Mine Map submittals, and mobile computing. Using GIS is enabling the Reclamation Division to move away from the paper format and towards managing mining information in a digital format that can be retrieved and manipulated rapidly.

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