COMPARISON BETWEEN PREDICTED AND OBSERVED SUBSIDENCE 
ALONG A BURIED CONCRETE WATERLINE 
MINED UNDER BY A LONGWALL PANEL

by 
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ABSTRACT

This paper compares the results of the observed subsidence and displacement to a 30-inch diameter concrete waterline by longwall mining with subsidence and displacement predicted using Surface Deformation Prediction System (SDPS) model. The SDPS model has been developed recently by the Virginia Polytechnic Institute and State University (VPISU) for the Office and Surface Mining Reclamation and Enforcement (OSM) and demonstrated good correlation. The model also predicts the strains, slope and the curvature. Thereby any potential damages to gas lines, highways, railroad, streams, and hazardous waste fills can be ascertained. These can be minimized or prevented by taking necessary measures.

Background

The study site is located near Washington, PA as shown on Figure 1. A 30-inch diameter concrete waterline was undermined by longwall operations (see Figure 2). The 30-inch concrete waterline lies near the center and curves nearly diagonally across the longwall panel as shown on Figure 2. Mining depth varies from 600 to 650 feet, mining height is 6.0 feet, and the panel width is 900 feet. A mining consultant was also retained to predict subsidence and associated damages to the pipeline caused by mining on the basis of which, necessary measures to prevent damage to the pipeline were taken by cribbing and/or jacking during mining. The observed maximum subsidence to the waterline was 4.5 feet near the middle of the panel, decreasing on both sides over the chain pillars (see Figure 3). The observed maximum displacement was 1.2 feet. The pipeline was kept level at all the time by cribbing and/or jacking.

Figure 1. Site Location Map

Figure 2. Mine Map and Pipeline Layout


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Surface Deformation Prediction System

The Surface Deformation Prediction System (SDPS) developed by VP & SU for OSM (Karmis & Agioutantis, 1999) is applied to predict the subsidence and the displacement along the waterline. Two popular methods of SDPS namely 1) Profile Function, 2) Influence Function for predicting subsidence and other parameters are explained here. The predicting technique is based on several empirical relationships, developed through statistical analysis of data from many case studies.

The Profile Function Method. The Profile Function Method can predict maximum subsidence, the subsidence profile and the angle of draw (see Figure 4) for simple mine layouts. The location of prediction points is automatically calculated, from the point of maximum subsidence (i.e., the center line of the panel) to the zero subsidence limit. The empirical parameters required are already built into the profile function equation (VP & SU, 1994)

The input parameters for this method are:
- Percent of hard rock in the overburden
- Mining height
- Depth and width of mine opening

The Influence Function Method. The influence Function Method can predict the following for complex mine layouts:
- the vertical subsidence at any point the surface,
- the subsidence profile,
- the horizontal displacement,
- the angle of draw,
- the slope,
- the strains
- the curvature at any point on the surface.

These parameters are shown in Figure 5.

Subsidence and Damage Criteria

Surface ground movements caused by underground mining are usually described by a number of characteristic indices (Singh, 1992), including:

Vertical Subsidence. Uniform vertical subsidence over an area does not cause damage, even the structure may subside several feet. However, the structure must be strong enough to resist the dynamic strains caused during mining to prevent any damage.

Horizontal Displacement and Strains. Horizontal displacement induces tensile and compressive strains on the structures. Most damages are caused by the strains. Tensile strain has been found to be a major factor to cause structural damages because the masonry structures are weaker in tension. Also, pipes, cables, roads, railways, walls and other types of building components...
buckle readily under compressive strains. Strains can also
induce distortion, fractures, or even failure.

When the stresses/strains caused by surface ground
movement on the structure exceed the strength of the
structure, it will cause damage. The severity of the
damages depend on the structure’s ability to resist
additional stresses caused by subsidence.

Slope (Tilt). Differential vertical ground displacement
causes slopes to form and induce tilting. The formation
of slopes may cause structures to tilt and can greatly
change the gradients of a railroad and highways. Tall
structures with small base areas, such as water towers,
chimneys, power transmission tower, and buried
transportation lines are sensitive to slope.

Curvature (flexure). Curvature causes two types of
deformation on the structures:

1. Shear strain that induces angular distortion to the
buildings.

2. Flexure (bending) that causes strains in long load-
bearing members. Concave curvature causes tension
along the bottom and compression along the top of the
building.

The surface ground movements have been utilized in a
number of damage classification schemes to develop
structural damage criteria. The National Coal Board
(1975), proposed one of the earliest and most widely used
damage classification system.

Similar system was developed by Bruhn et. al. (1982) for
the North Appalachian Coalfields.

Singh (1992) published a table showing damage
classification schemes in several European countries in
which building categories, movement types and range of
damage-limits are summarized.

DISCUSSION OF ANALYSIS

Since the pipeline layout over the longwall panel is
complex, the Influence Function Method can be applied
to predict the maximum vertical subsidence, subsidence
profile, horizontal displacements and strains. The
strains predicted were higher than the maximum
allowable for the pipeline. Therefore to prevent damage
to the pipeline, the line was uncovered and kept level as
it was being undermined. The pipeline was shut down
during this period. Within six weeks after the pipeline
was undermined, the subsidence was determined to be
complete. The pipeline was covered and commissioned.

Figure 3 shows the predicted and observed maximum
vertical subsidence profiles along the pipeline over the
longwall panel.

1) The predicted and the observed maximum
vertical subsidence are 4.2 and 4.5 ft.
respectively. This is a good correlation.

2) The predicted and observed subsidence profiles
along the pipeline are shown in Figure 3; also
has a good correlation.

3) The predicted and the observed maximum
horizontal displacements are 1.4 and 1.2 ft.
respectively.

4) The predicted maximum horizontal strain was 3
x10^3. The maximum allowable strain for the
waterline is 1x10^3. It was prudent to uncover
the pipeline, maintain a level position and
prevent damage.

5) The predicted maximum angular strain was
4x10^3. The allowable maximum angular strain
was 5x10^3. This supported the uncovering of
the pipeline and keep it level to prevent damage.

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