Overcoming the Pitfalls of abandoned mine workings in the Sydney Coalfield

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Abstract The legacy of over two centuries of coal mining in the Sydney Coalfield includes a phenomenon known as bootleg pits, or shallow unrecorded underground coal extraction, which pose several pitfalls including: i) those affecting public safety; and ii) those impacting groundwater flow. The Enterprise Cape Breton Corporation (ECBC) is completing a comprehensive mine site closure and reclamation program to address such historical mining issues. This paper addresses remediation of both pitfalls outlining issues involved, influencing factors, and remedial approaches, while referring to recent remediation examples. Observations during construction lent confidence to the selected remediation method making the area safe.

Key Words Abandoned Mine workings, Remediation, Subsidence

Introduction

Over two centuries of coal mining in the Sydney Coalfield has left behind a legacy of abandoned shallow workings of unrecorded location and extent known as crop pits or bootleg pits. These are usually located between the crop and official company workings. Such workings pose several pitfalls: i) those affecting public safety e.g. open holes, collapsing ground, and flooded depressions or sinkholes; and ii) those impacting groundwater flow e.g. providing pathways for meteoric water to enter into deeper company workings, or draining interconnecting bootleg workings into streams and wetlands.

The illegal nature of these workings means that responsibility for the safety hazards is unclear as there is no mining company to pursue to make safe or compensate third parties. Thus in Nova Scotia, where there are no specific laws addressing compensation or insurance requirements for mining subsidence whether from active or abandoned workings, this responsibility by default now lies with the land owner. The Cape Breton Development Corporation (CBDC) on formation in 1967 inherited many hundreds of parcels of lands, many containing bootleg pits and their associated hazards. Upon cessation of active mines in 2001, CBDC as landowner began a comprehensive mine site closure and reclamation program engaging Public Works & Government Services Canada (PWGSC) to manage this program. CBDC's mandate was transitioned to Enterprise Cape Breton Corporation on December 31, 2009.

AECOM was one of three consulting groups engaged to assist in implementation of the program to mitigate all hazards whether environmental or physical (including mining subsidence). Typically the work covered environmental assessment from Phase I to VI, i.e. from desk study through intrusive investigation to remedial action planning, remedial design, implementation and long term care and monitoring. This paper specifically addresses remediation of abandoned shallow bootleg coal extractions as experienced and practiced within the CBDC/PWGSC program discussing issues involved and influencing factors through recent examples.

Issues Involved

The hazards of abandoned coal mines have long been recognized e.g. they occupy a whole chapter in the classic textbook on Surface Mining Subsidence (Peng 1992). These hazards are both obvious in the form of open holes, flooded sinkholes, acid mine drainage with its characteristic orange colour and related threats to the ecosystem, and hidden hazards such as sinkhole cavities slowly creeping upwards to eventually create an open hole, or old vertical shafts whose old wooden cover is rotting causing a situation of apparently stable, but actually unstable ground. These hazards are of unknown location, type, and extent. They impact not only the safety of the general public but also construction workers involved in remedial activity and of course ecosystem receptors such as mammals, birds and benthics.

Mitigation of these hazards usually incorporates a qualitative approach to risk assessment and management to select the most appropriate remedial method on a site specific basis within the context of CBDC's Mine Workings Protocols (CRA 2008). Mining hazards related to mine work-

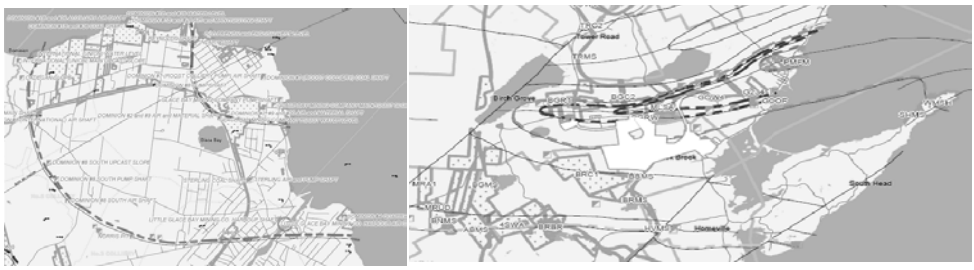

Figure 1 *Seam outrops in the Glace Bay & Port Morien areas of the Sydney Coalfield*

ings include the following: existing unstable ground formed by past subsidence events at the site; unstable ground that could potentially develop during and after site remediation; unsecured mine openings; the accidental discharge of untreated acid mine waters into the environment; and release of potentially hazardous gases.

The CBDC Mine Workings Protocols outline five stages of investigation: Stage 1 – Information Gathering; Stage 2 – Initial Mine Site Investigation; Stage 3 – The Mine Workings Report; Stage 4 – Detailed Mine Site Investigations; Stage 5 – Mine Opening Remediation; and Mine Site Monitoring. AECOM followed these stages on each site with abandoned mine issues, covering not only shallow mine hazards (sinkhole subsidence) but also deeper mine related ground movement (sag subsidence - not discussed in this paper).

Influencing Factors

Sinkhole subsidence hazards are dependent firstly on the location of the shallow mines which in turn are located close to the outcrop of the seam with the ground surface. The outcrop maps for the Glace Bay and Port Morien areas of the Sydney Coalfield are shown in Figure 1.

The ability for cavities to form and migrate up to impact the surface is also largely depth related with the specific stratigraphy playing a key role. For example, thin weak beds facilitate sinkhole development while strong hard beds bridge cavities and arrest such development, see Figure 2.

Typically sinkhole subsidence hazard maps are developed for each seam under each site based on simple guidelines in the CBDC Mine Working Protocols using on a ratio (D/M) of seam depth (D) to seam extraction height (M); as follows: D/M > 0 < 6 = High risk: long-term visual monitoring is required (red zone); D/M > 6 < 12 = Moderate risk: long-term visual monitoring is suggested (orange zone); D/M >12 = Low risk: long-term visual monitoring is not required (green zone); D/M infinity i.e. no mining = No risk: long-term visual monitoring is not required (green zone). Figure 3 shows such a map for the Phalen Seam at the Dominion No.3 Site and also shows the company mines and areas where bootleg mining was identified and mapped prior to mine closure.

Other key factors to be included are the roles of water and of gas. Related to water, shallow bootleg mines typically were open holes and within the influence of the water table. Thus once abandoned they fill with groundwater, adding drowning to the list of safety hazards. Bootleg miners were often well versed in mining techniques and as mine water was a nuisance and a danger,

Figure 2 *Old Abandoned Shallow Workings: a) Sinkhole; b) Spencer Test Slope; c) Port Morien*

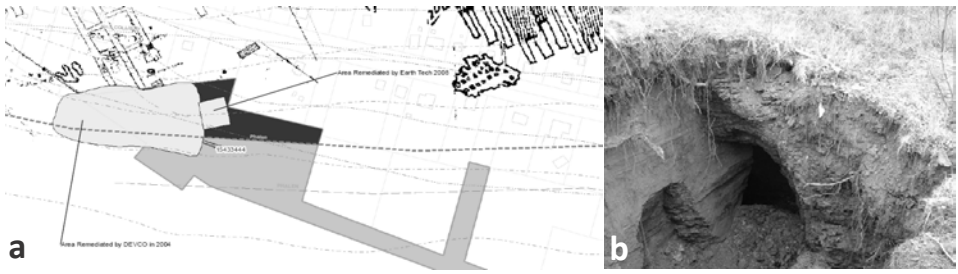

Figure 3 *Dominion No.3 Site – mining hazards: a) hazard map; b) hidden shallow workings*

they often managed this risk by tunneling to break through to the company workings, allowing their water to drain away. The Phalen Seam company workings in the Glace Bay area were often interlinked and drained to old adits (i.e. drainage tunnels allowing gravity flow out of the mine) on the adjacent shoreline. Concerning the gas hazard, whenever coal is mined it breaks and the inherent methane gas is released. Methane is lighter than air so rises and is potentially explosive when mixed with air from 5—15%. Thus whenever working around and remediating old mines this hazard must be identified, detected, and controlled.

It is also noted that typically there are some positional inaccuracies in the juxtaposition of company mine plans which impact detailed interpretation of past underground mine workings.

Recent Examples

Dominion No.3

The site of the former Dominion No.3 Colliery comprised three mine tunnel entrances on the Phalen Seam outcrop and a former rail track to take the coal to the nearby No.11 site. This Colliery was also undermined in the Emery Seam. The site has a history of bootleg mining in the Phalen Seam (Figure 3a), resulting in safety hazards. Those associated with open workings and a few sinkholes were remediated by CBDC in December 2004. However, an additional remediation was undertaken using the CBDC Mine Workings Protocols after a test pit for environmental sampling purposes, located adjacent to the CBDC remediated area, gradually collapsed into shallow bootleg workings, during this field program (Figure 3b). The opening was opened up to define the hazard extent, large clean fill was packed into the openings and the excavation backfilled in layers using an excavator for compaction and restored to grade. Due to such unknowns of shallow bootleg mining, the north eastern part of the site is still classified under CBDC Mine Workings Protocols as a high risk zone and is subject to long-term visual monitoring of future subsidence and sinkhole development. The underground mine workings in the Phalen Seam are generally not flooded under the Site, any groundwater entering these old workings draining away underground to the

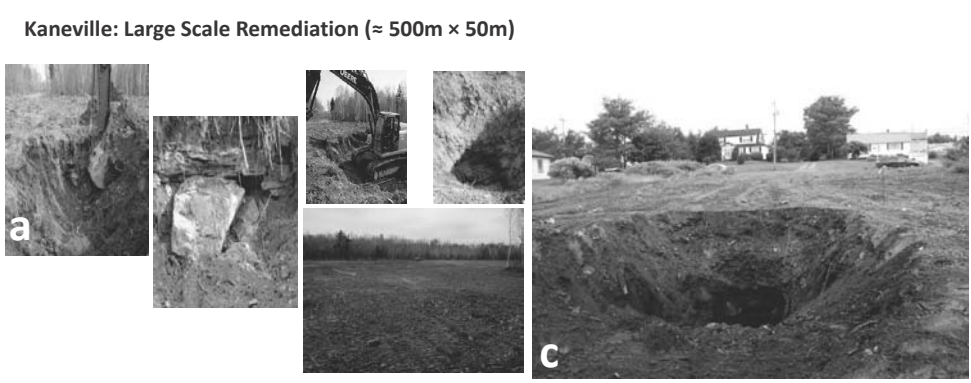

Figure 4 *a) Kaneville - Site Mine Remediation; b) Dominion No.5 Remediation*

ocean, north of the Site. Mine gas would generally only be a hazard if and when old workings were to be opened to the atmosphere, such activity requiring gas monitoring and safety procedures.

Dominion No.5 & 10

This Site was the location of the former No.5 & No.10 Collieries, housing the bankhead and shafts and slopes. Similar to No.3 there were several mine tunnel entrances on the Phalen Seam outcrop on the site with bootleg mining known locally however not within this site. The hazard here was different as it was associated with sinkhole development from collapse over the near-surface portions of the main access tunnels (No.5 Main Slope). They were located and remediated to CBDC Protocols, see Figure 4b. Elsewhere on adjacent sites bootleg or illegal shallow mine workings are known, with the most significant surface effects having been remediated, any un-remediated areas along the Phalen outcrop being subject to long-term visual monitoring.

Kaneville

The Kaneville site was different again, comprising many 'bootleg' pits from the 1940s or 50s covering approximately 500m of seam outcrop in a band approximately 50 m wide. The property was largely reforested with no buildings and no evidence of acid drainage, with some seepage at the downstream end. AECOM undertook the assessment, design, tendering and construction administration for the remediation of the existing health and safety hazards on the Kaneville (HSOK) site related to abandoned 'bootleg' mine workings. An initial exploration exercise exposed abandoned underground bootleg coal mine workings in the Harbour Seam, at depths of ≈ 2m to 7m. The rooms were flooded and not all collapsed. This work lent confidence to the remediation method subsequently used successfully. This comprised: clearing and grubbing; temporary access roads; erosion and sediment control measures; cleaning out and filling both closed-bottom and open-bottom holes; and restoring the site through re-grading, soil amendment and hydro-seeding. This was done from early March to mid May 2009 and was successfully completed within the anticipated time frame and safely, with zero onsite injuries, see Figure 4a.

Spencer Test Slope

A test adit from the 1920s in the Emery Seam near the Gowrie Wash Plant Site was abandoned without filling it. Then flooded and reforested, representing a remote but significant hazard to hunters. It was filled using CBDC protocols with provision to continue to drain into the natural drainage system (Figure 3c).

Conclusions

Using several examples, it has been shown that the hazard of shallow abandoned coal mines on former CBDC properties has been successfully mitigated through implementation of comprehensive protocols and procedures. Individual hazards are exposed, filled and backfilled. Larger areas are cleared, backfilled and re-graded with ongoing annual visual monitoring for future differential settlement. Provision is made for ongoing drainage of mine waters with treatment on an as required, site specific basis.

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