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Derelict Mines' Impacts into Sydney's Drinking Water Catchments

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ABSTRACT: A large proportion of the residents in the state of New South Wales in Australia rely on the water supply catchments managed by the Sydney Catchment Authority (SCA). Established in 1998, the SCA is responsible for protecting and managing Sydney's water supply catchments covering an area of 16,000 km^2. It also provides bulk water to a large proportion of 4.5 million Greater Sydney residents.

There are over 100 derelict mines located within the drinking water catchments managed by the SCA. While the majority of these do not pose a significant risk to water quality and/or environment, there are a number of derelict mines within the catchment that may pose a significant water quality and/or environmental risk and, therefore, deserve further attention (necessitating development and implementation of appropriate rehabilitation plans).

This paper presents the outcome of an investigation into selected derelict mines within the SCA-managed Sydney's Drinking Water Catchments (DWCs). The focus is on the mines identified as posing a significant risk to water quality and/or environment. Likely hazards at each of the mines and potential impacts of these hazards on catchment water quality are presented. The outcome is a ranking of derelict mine sites, with the principal view of developing and implementing appropriate rehabilitation strategies. A brief review on derelict mine risk assessment and prioritisation process used in the study is also presented.

INTRODUCTION

Derelict mines are "mines and processing areas formerly held under a mining tenement where no individual, company or other organisation can be found responsible for their rehabilitation" (NSWDPI, 2004). There are hundreds of such mines scattered across the state of New South Wales (NSW) in Australia. These derelict mines range from single mine shafts to large mines with processing areas. More than one hundred of these are located within the drinking water catchment areas of Australia's most populated city, Sydney (Coffey, 2001). While the majority of these mines do not pose a significant risk to water quality in the catchment, or the environment in which they were abandoned, there are a number of derelict mines within Sydney's DWCs that may pose a significant water quality and/or environmental risk and, therefore, require further attention. It is important that these are identified, assessed and, if warranted, rehabilitated to reduce or eliminate potential adverse effects to drinking water quality.

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The SCA, established under the Sydney Water Catchment Management Act 1998, is responsible for managing and protecting Sydney's drinking water supply catchment areas (SCA, 2003). It provides bulk raw water to the Sydney Water Corporation, who supplies water to Sydney residents.

As a part of Rural Lands Strategy (under the Healthy Catchments Program), the SCA has developed the Derelict Mines Program. Under this program, in 2001, the SCA and New South Wales Department of Mineral Resources (NSW DMR) jointly commissioned Coffey Geosciences Pty Ltd. (Coffey) to conduct a survey and assessment of derelict mines in the Sydney DWCs. The survey included 891 mine sites, 124 of which were short-listed for desk-top risk analysis (Coffey, 2001). Out of the 124 derelict mines short-listed, 21 sites were selected for field assessment that included visual inspections, mapping and selective sampling. These sites were then ranked according to environmental risk (based on existing environmental status), water quality risk, safety risk, heritage value and impact on flora and/or fauna. The study resulted in recommendations to remediate seven 'high risk' sites (Coffey, 2001).

This study is the result of a follow-up effort on the Coffey (2001) report, taking into account the resources available for implementation. The investigation included identification of likely hazards at each of the mines and potential impacts of those hazards on catchment water quality. A rehabilitation priority list was re-established to assist the SCA in allocating scarce resources for rehabilitation projects. Detailed investigations were carried out to determine suitable rehabilitation options for high priority sites, with emphasis on protecting water quality. This paper presents the process used in this investigation. The resulting priority list, in order of preference, is also presented.

RISK ASSESSMENT TECHNIQUES—DERELICT MINES

The assessment of derelict mines within the Sydney DWCs was based on an analysis of the risks posed by each individual mine. The risk assessment methodology used by Coffey (2001), to rank and prioritise derelict mines in the Sydney DWCs, is similar to the risk profiling and ranking tool (Risk Tool) developed by URS (2001a, b). The URS risk assessment methodology developed for the DMR does not only identify consequence and likelihood scenarios; it also takes into account a review of methodology used in other areas of Australia and overseas. The URS methodology was developed based on selected, publicised abandoned/derelict mine database applications in existence in Australia and overseas (URS, 2001a).

The main difference between the URS and Coffey methods relate to the methods used to select the initial investigation datasets. The Coffey prioritisation applies an additional filter to focus specifically on the SCA's concerns for the protection of water quality. These concerns are reflected in the desk-based ranking system developed for the assessment and prioritisation process.

Risk Assessment Techniques—North America

The United States Department of Interior, Office of Surface Mining—Reclamation and Enforcement (USDI OSM-RE, 2005) has developed an Abandoned Mine Land Inventory similar to the database developed by Coffey for the Sydney DWC. The USDI also has a Bureau of Land Management (BLM) Abandoned Mine Lands Cleanup Program. The current US approach is to prioritise sites using a watershed approach, where environmental concerns (based on water quality) are of paramount importance (USDI BLM, 1996). The USDI BLM and other Federal land management agencies have found the use of the watershed approach as the best way to address abandoned mine problems. Within selected watersheds, cooperative efforts and available resources are concentrated first on abandoned mine sites and features causing serious environmental impacts, then on mitigation and removal of physical hazards.

The Californian Department of Conservation, Office of Mine Reclamation (CDC OMR) also uses a 'watershed approach' to abandoned mine assessment and remediation. Advantages of this approach include the fact that it concentrates inventories in the watersheds most at risk for environmental impacts by Acid Mine Drainage (AMD) and heavy metals. Once watersheds are identified for assessment, staff can inventory, characterize and remediate the contaminated sites that have potential for the most positive improvements in water and ecosystem quality within the watershed (CDC OMR, 2000).

In the State of Nevada, Commission on Mineral Resources—Division on Minerals (CMR-DM) conducts the State's program and uses a similar methodology to identify inactive mine sites in the State, rank their degree of hazard and carry out activities to secure the sites. As there are anywhere from 200,000 to 500,000 abandoned mine land "features" in Nevada, sites are nominated by participating agencies for remedial consideration (State of Nevada CMR-DM, 2004). It has been argued that the Nevada methodology appears to place budget considerations before public health and safety.

In Canada, the Ontario Ministry of Northern Development and Mines' (OMNDM) risk assessment approach involves a risk ranking program, similar to the Coffey methodology, where hazard level ratings and rankings are applied to abandoned mines in Ontario (URS, 2001a). The Ontario Abandoned Mines Information System (AMIS) is a database containing basic information on all known abandoned and inactive mines located on both Crown and privately owned lands within the province of Ontario (OMNDM, 2005). It is important to note that the abandoned mines program developed in Canada uses information gathered for the Mining for the Future Abandoned Mines Working Paper (IIED, 2002), including the programs used in South Africa.

Risk Assessment Technique—United Kingdom

The United Kingdom Environment Agency (UKEA Wales, 2005) risk assessment approach is a legislative requirement and is not specific to abandoned mines; rather it applies to any contaminated area. It adopts a tiered approach to the investigation, prioritisation and remediation of sites, considering human health, controlled waters and other receptors. The risk assessment for metal mines involves using guideline or "trigger" values for contaminants to assess the possibility of harm to humans or the environment.

RISK ASSESSMENT—SYDNEY DRINKING WATER CATCHMENT AREA

Background

Coffey (2001) conducted a coarse screening to reduce 891 mine sites to 499, which were subsequently reduced to 124 derelict mine sites. These 124 sites were then ranked using the scoring system presented in Table 1. Once the scores were assigned, a weighting was applied to Questions 1 and 2 before the scores were summed. The principal objective of the ranking was to order the list of 124 sites from the highest to the lowest risk of impact on water quality. It should be noted, however, that the ranks are relative, indicating whether a site ranks higher or lower than others in the list. A particular score does not necessarily indicate a 'significant risk to water quality' since that can only be determined by a visual site inspection.

Following the initial desk-based ranking process, 21 sites (Figure 1) were chosen for field assessment. The majority of these sites were field-assessed using ten environmental factors (Coffey, 2001)—(i) surface water contamination, (ii) erosion and sedimentation, (iii) groundwater contamination, (iv) physical safety of the site to humans and fauna, (v) chemical safety of the site to humans and fauna, (vi) potential heritage value, (vii) vegetation impacts on the sites, (viii) fauna habitat impacts on the site, (ix) potential to generate dust and (x) visual aspect of the site.

A score of one-to-five was assigned to each factor and a total score was then calculated for each mine. Sites were then re-evaluated for water quality risk according to distance to watercourse, number of watercourses before storage/abstraction, and distance to storage/abstraction points. Remediation options for each of the field-assessed 21 mines were considered and the sites that posed a higher risk to water quality and/or the environment were selected for rehabilitation. These sites were prioritised and remediation options were recommended for seven sites scattered across the catchment. The seven sites prioritised for rehabilitation were (a) The Joadja Complex (2 sites), (b) Mulloon Copper Mine, (c) Hartley Vale Shale Mine, (d) Tolwong Mines, (e) Tuglow Copper Mine, (f) Black Bob's Creek Mine and (g) Nattai Shale Mine. Information on water quality/environmental hazards and potential impacts for the seven prioritised sites are presented in Table 2.

Table 1: Scoring System Used for Ranking (Coffey, 2001)

	Question	*Score 1*	*Score 2*	*Score 3*	*Score 4*	*Score 5*
1.	How far is the site from a water supply storage/ abstraction point?	> 40 km	30–40 km	20–30 km	10–20 km	< 10 km
2.	How many water courses prior to reaching storage?	drains to more than three water courses before storage	drains to three water courses before storage	drains to two water courses before storage	Drains to a single water course before storage	drains direct to storage
3.	How much land cover and how different is the site to its surroundings?	no discernable land cover pattern	class 12–19 surrounded by class >19 (yes or probably)	class 4–11 surrounded by class >11 (probably)	class 4–11 surrounded by class >11 (yes)	class 1–3 (yes or probably)
4.	How steep is the terrain?	flat terrain	n/a	moderate terrain	n/a	steep terrain

Notes:

Question 1 refers to the distance along watercourses, measured using a Global Positioning System (GPS). It is a broad assessment of potential for contamination to reach a water supply storage or abstraction point.

Question 2 was determined using GPS, by counting the number of water courses prior to storage. It is a broad assessment of potential for sediment transfer towards storages.

Question 3 includes 'probably' options to allow judgement to be used where a plotted mine location appears that it may be slightly inaccurate on the basis of land-cover mapping. It is a broad assessment of whether land contamination at the site may be significant enough to affect vegetation cover.

Question 4 is determined on the basis of contour spacing. It is a broad assessment of potential erosion and sedimentation issues.

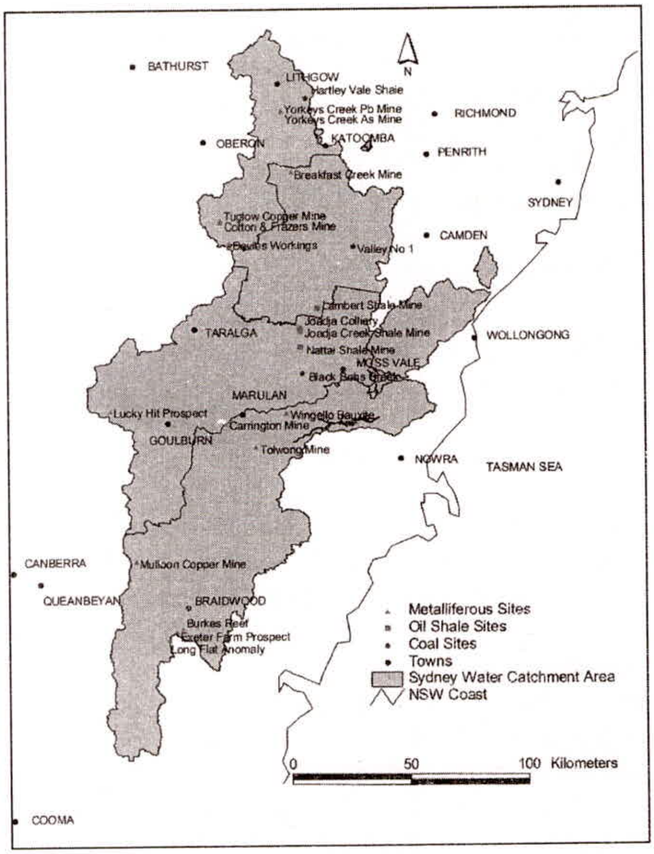

Fig. 1: Field Assessed Sites (Coffey, 2001)

Limitations

The major limitations of the Coffey (2001) recommendations stem from the lack of reliability of data used to identify and assess the sites. In addition, the preliminary screening process excluded a number of sites of potential concern. It is also important to note that the rankings were relative; therefore, a particular score did not necessarily indicate a 'significant risk to water quality'. Furthermore, the ranking was based on the four generic questions (Table 1), which might have resulted in rankings that were not a true representation of the water quality risk posed by some mines in the catchment. It was also found that the main focus of the rehabilitation options appeared to be on safety, rather than water quality.

Follow-up on Coffey Recommendations

Shea (2004) reviewed the prioritisation methods employed by Coffey and URS and argued that the main issue was not whether applying the URS methodology would reorder the Coffey defined top-21 priority list, but whether the initial culling process included all derelict mines that should be prioritised. It was concluded that the Coffey methodology was adequate and that it could be used to prioritise sites for

Table 2: Site Summary—Prioritised Mines (Coffey, 2001)

Rank	*Site*	*Commodity*	*Water Quality/Environmental Hazards*	*Potential Impacts*
1.	Joadja Creek Shale Mine and Joadja Colliery	Oil shale	Tar and ash deposits from refinery and tar pit Contaminated runoff from site	Groundwater hydrocarbon contamination Surface water contamination
2.	Mulloon Copper Mine	Copper, zinc, lead (minor gold and silver)	Contaminated runoff from sulphidic mullock (acid drainage, heavy metals, sulphate)	Surface water contamination
3.	Hartley Vale Shale Mine	Oil shale, coal	Poor revegetation of waste dumps leading to contaminated runoff	Increased runoff and surface water contamination
4.	Tolwong Mine	Copper, tin, arsenic (minor zinc, lead and silver)	Elevated arsenic in waste heaps in processing area and in Tolwong Creek sediment High levels of mineralisation in Tolwong Creek	Arsenic contamination in Shoalhaven River Acid drainage in creek
5.	Tuglow Copper Mine	Copper, lead, zinc, silver and gold	Saline/acidic soil conditions preventing regeneration of vegetation cover	Increased runoff and surface water contamination
6.	Black Bob's Creek Mine	Coal	Erosion of coal waste material into Black Bob's Creek Acid drainage into Creek	Surface water contamination Water quality affected in Creek
7.	Nattai Shale Mine	Oil shale	Acid seepage from adit Possible presence of hydrocarbons (not tested)	Low water quality effect in Jackey Jackeys Creek Surface or groundwater contamination

remediation, provided it was cross-checked against Catchment Officers' knowledge of alternative sites of concern. Catchment Officers' response to the findings and recommendations to Coffey (2001) were generally positive, with most agreeing with the findings. They also agreed that any remediation works completed would not significantly improve catchment water quality, but would have localised benefits. There was some debate, however, as to the omission of some sites deemed to have water quality risks.

STAGES OF INVESTIGATION

Introduction

The practical component of the project involved the prioritisation of selected derelict mine sites, an investigation into suitable rehabilitation options (with the emphasis on protecting water quality) and the development of a draft rehabilitation plan for a selected derelict mine site. The seven sites identified by Coffey (2001) for rehabilitation were further investigated through additional desk-top studies and site visits. Additional interviews were also conducted with Catchment Officers and other stakeholders (e.g., land owners).

Desk-Top Study

Additional desk-top studies involved the collection of additional information through various sources, including SCA catchment officers, the NSW Environment Protection Authority (EPA) and the Department of Primary Industry (DPI). It also looked into possible rehabilitation options for selected sites, focussing on the water quality aspect. In addition, the desk-top study involved application of the risk assessment and rehabilitation plans used for Yerranderie (Coffey, 2004a, b; CH2MHILL, 2001; EES, 2003) and Mt Waratah Coal Stockpile (Geoterra, 2004).

Site Inspections

In order to further prioritise (with respect to water quality) the sites identified by Coffey (2001), it was necessary to conduct site inspections of the identified derelict mine sites. The main purpose of the site inspections was to provide important visual information on site conditions that could not be determined from the Coffey Report. Site inspections were carried out at the seven sites identified for rehabilitation by Coffey (2001), to determine the environmental and/or water quality hazards and the potential impacts of those hazards at each of the sites.

The site inspections included taking photographs and notes of features at the sites, as well as using Global Positioning System (GPS) coordinates to verify site locations. This information was used to assist in the prioritisation of sites and selection of the site for the rehabilitation plan.

Prioritisation of Sites

The prioritisation of selected mine sites was one of the most important components of this study. It draws on the risk assessment methodology, environmental and/or water quality hazards presented (and their potential impacts) and the rehabilitation requirements of each mine. The prioritisation process involved looking into all information available on selected sites and developing a list that can be used by the SCA to allocate future resources to derelict mine rehabilitation projects.

The prioritisation of mines basically follows the recommendations of Coffey (2001), using the seven mines identified for rehabilitation as the base for the prioritisation process. In addition to the Coffey risk assessment, additional factors were taken into account following the site inspections, as a number of issues were identified during these visits that were not raised in the 2001 report. The same risk assessment technique was used. However, some of the scores allocated for the water quality factors were changed to reflect the current situation observed at the sites during the site inspections.

Table 3 presents the results of the risk assessment used to prioritise the selected derelict mines. The risk assessment considered water quality, safety and environmental factors at each of the sites and the distance to watercourses and storage/abstraction points. The seven sites were each assigned a score and listed in order from highest to lowest risk to water quality.

A brief description of the water quality and/or environmental hazards, potential impacts and rehabilitation issues presented by each of the sites are presented below.

Mulloon Copper Mine

Mulloon Copper Mine was ranked highest in the priority list as the (three) mining areas at the site are located on steep slopes, within close proximity to Mulloon Creek (<50 m). The original field assessment, conducted by Coffey (2001), missed one of the three mining areas and therefore the risk to water quality and safety has increased as a result of this additional mining area.

Table 3: Risk Assessment and Priority List

		Water Quality Factors			*Safety Factors*		*Environmental Factors*						*Consequence Factors*			
Priority	Derelict Mine	(a) Surface water contamination	(b) Erosion and Sedimentation	(c) Groundwater contamination	(d) Physical Safety	(e) Chemical Safety	(f) Heritage	(f) Vegetation	(h) Fauna	(i) Dust	(j) Visual	Total WQ related (a+b+c)	(X) Distance to watercourse	(Y) Directness of access to watercourse	(Z) Distance to storage/ abstraction	Total ranking (axbxcxXxYxZ)
1.	Mulloon	4	4	3	5	2	4	3	3	1	1	11	5	3	1	720
2.	Tolwong	3	3	2	5	2	4	2	2	1	3	8	5	2	4	720
3.	Black Bobs	4	4	2	2	2	2	3	2	1	1	10	5	2	1	320
4.	Joadja	4	2	5	5	2	5	2	3	1	4	11	4	2	1	320
5.	Hartley	4	2	5	5	2	4	3	2	1	4	11	3	2	1	240
6.	Tuglow	3	3	2	4	1	2	3	3	2	2	8	5	2	1	180
7.	Nattai	1	2	3	4	2	2	1	1	1	1	6	3	1	1	18

Note: Tolwong, Hartley Vale and Joadja processing areas were assessed, not mine sites themselves

All three mining areas are predominantly devoid of vegetation and, therefore, the risk of water pollution at the site is very high due to surface water runoff and erosion issues. The main water quality/environmental hazard at the site is the contaminated runoff from sulphidic mullock in the mining areas. The potential impact is surface water contamination in Mulloon Creek due to acid drainage, heavy metals and sulphate.

Tolwong Mine

Tolwong Mine (processing area) was ranked second on the priority list, mainly due to its proximity to the Shoalhaven River (<50 m) and a water storage/ abstraction point (Lake Yarrunga). The main water quality/environmental hazard at the site is the elevated arsenic levels in the waste heaps in the processing area. The potential impact is arsenic contamination in the Shoalhaven River.

Note: The mine itself was not assessed as the processing area was considered to be the main water quality risk and access to the mine was extremely difficult due to the steep terrain. Coffey assessed the mine in 2001 and identified acid mine drainage from the adits and arsenic contamination in Tolwong Creek as the main water quality issues.

Black Bob's Creek Mine

Black Bob's Creek Mine was ranked third on the priority list, mainly due to its proximity to the creek (< 20 m) and the surface water contamination and erosion issues at the site. The main water quality/ environmental hazards at the site are the erosion of coal waste material and acid drainage into the creek. The potential impacts are surface water contamination and reduced water quality in the creek.

There were no significant issues preventing the development of a rehabilitation plan for Black Bob's Creek Mine.

Joadja Oil Shale Mine

Joadja Oil Shale Mine (processing area) was ranked fourth on the priority list, mainly due to its proximity to Joadja Creek and the issue of surface and ground water contamination at the site. The main water quality/environmental hazards at the site are tar and ash deposits from the refinery and tar pit and contaminated runoff from the site into Joadja Creek. The potential impacts are surface and ground water contamination.

Joadja Oil Shale Mine is listed on the NSW EPA Contaminated Sites Register and the NSW Heritage Register. A remediation order was issued to the property owner in 1997 and a subsequent groundwater contamination study was completed to determine the extent of groundwater contamination from the site. Any rehabilitation plan developed for the site would need to satisfy the requirements of the EPA and NSW Heritage Office.

Note: The mine itself was not assessed as the processing area was considered to be the main water quality risk. Coffey assessed the mine in 2001 and identified acid mine drainage from the adits as a water quality issue.

Hartley Vale Shale Mine

The Hartley Vale Shale Mine (processing area) was ranked fifth on the priority list, mainly due to issues relating to surface and ground water contamination at the site. The site is also located within 100 m of Kerosene Creek. The main water quality/environmental hazards at the site are tar and ash deposits from the refinery area and contaminated runoff from the site into the creek. The potential impacts are surface and ground water contamination.

The Hartley Vale Shale Mine processing area is listed on the NSW EPA Contaminated Sites Register and the NSW Heritage Register. The EPA recently commissioned GHD to conduct a groundwater investigation at the site to determine the extent of groundwater contamination in the area. Following the investigation, GHD will also develop a Remedial Action Plan (RAP) for the site. Following the results of the investigation, archaeological studies (Heritage listed site) and acceptance of the RAP, remedial works will be conducted at the site.

Note: The mine itself was not assessed as the processing area was considered to be the main water quality risk. Coffey assessed the mine in 2001 and identified acid mine drainage from the adits as a water quality issue. The GHD RAP does not address any issues related to the mine itself.

Tuglow Copper Mine

The Tuglow Copper Mine (mullock area) ranked sixth on the priority list, mainly due to its proximity to Chimney Creek (<200 m) and issues relating to surface water contamination and erosion at the site. The main water quality/environmental hazards at the site are saline/acidic soil conditions preventing regeneration of vegetation cover on the mullock heaps. The potential impacts are increased runoff and surface water contamination in Chimney Creek.

The Tuglow Copper Mine mullock area is located on private property in the middle of a crop paddock. The potential for surface water contamination in the creek is minimal as runoff from the mullock is mainly captured in a small farm dam in the drainage line.

Note: The mine itself was not assessed as it was located on a neighbouring property and not at the location given in the Coffey Report. The location given was the mullock area which was considered to be the main water quality risk. Coffey assessed the mine in 2001 and identified no water quality issue.

Nattai Shale Mine

The Nattai Shale Mine was the lowest ranked mine on the priority list. Coffey identified acid seepage coming from the adit in 2001; however, no seepage was observed during the recent site inspection.

No significant water quality issues were identified during the site inspection. There is a minor issue relating to ash deposits, however the most obvious issue is the safety issue associated with the unsealed adit. No remediation is required (from a water quality perspective).

CONCLUSION AND RECOMMENDATION

Following the prioritisation process, Black Bob's Creek Mine was chosen for rehabilitation. It was the third on the priority list, after Mulloon Copper Mine and Tolwong Mine. Both Mulloon Copper mine and Tolwong mine have issues with access and require considerable planning for rehabilitation. It was estimated that the potential for water quality improvement in Black Bob's Creek is significantly high. In addition, the site is accessible, the plan is practical and 'do-able' in the short-term, the main stakeholder's are co-operative and the estimated project cost is within available means. Another attraction was the potential funding from the NSW Department of Mineral Resources Derelict Mines Program.

A rehabilitation plan for Black Bob's Creek Mine has since then been prepared.

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