Safe Road System: Maintenance Road Watering Improvement Process.

Presenter: **David Tulloch**
Authors: **David Tulloch**
RoadSafety Training Services Pty Ltd

David Stocker
Crash Analysis & Training Consultants Pty Ltd

Abstract

Maintenance Watering of Mine Roads is the conundrum of managing risk on the road network; it reduces one hazard and increases another. This paper is an examination of that procedure and the development of an improved and safer operational process.

Road Material Audit

- ➢ Determine appropriate water application rates for at risk road materials

Water Truck Audit

- ➢ Can the water truck deliver required water application rate and appropriate watering method at relevant speeds?
- ➢ Water delivery system features:
  - Adjustments and modifications
  - Spray settings, pump settings and automated pulse values

Road Watering Audit

- ➢ Can the operator deliver the required water application rate & appropriate watering method on at risk road materials?
- ➢ Operator training and awareness of:
  - Water delivery system and water application rates
  - Watering methods and road materials

Safe Road System

- ➢ Is the road network maintaining a competent level of friction supply through appropriate water application rate and watering method?
- ➢ Regular monitoring and continual improvement risk management triggers:
  - New road materials
  - New water trucks
  - New operators
  - Repairs and modifications to the water truck fleet

1. Background

Uncontrolled vehicle movements account for a notable proportion of safety related reportable mine incidents and uncontrolled movements due to deficient surface friction.

[1]*Analysis of reported incidents and observations by inspectors during follow-up inspections has shown:*

- *Most of the incidents (59%) took place on ramps*
- ***Watering or excessive watering was identified as the primary cause of such incidents (46%)***
- *Wet road conditions due to rain has been a causal factor in (8%) of incidents*

The challenge confronting surface mining operators is the inherent conflict of dust management without compromising safe road surface friction levels. This situation is exacerbated by demanding and changing road geometry, construction limitations and water sensitive friction properties of substandard competent material type.

A Safe Road System can be established where the available friction supply exceeds normal vehicle operation friction demand and provides a measurable '*factor of safety'* margin for safer operation of mine vehicles.

2. The Safe Road System Model

The *Safe Road System Model* was developed for mine road networks to address the correlation between the three foremost road safety critical elements. This paper has a focus on the road water application component of the model.

Assessment Tools

1. **Road Material Audit**
2. **Road Watering Audit**
   - *Water Truck Audit*
   - *Operational Road Watering Audit*
3. **Road Geometry Audit**

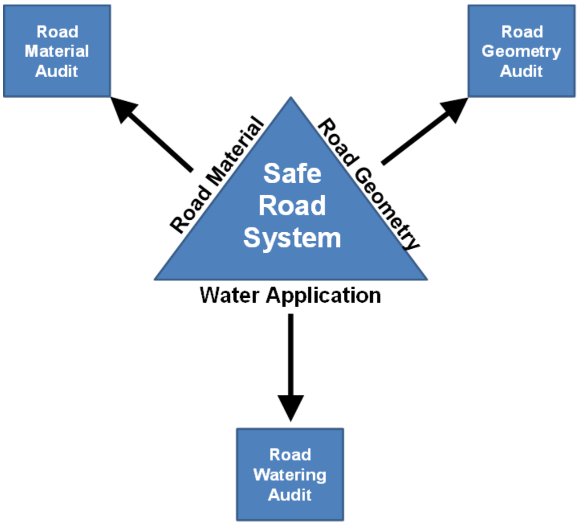


Figure 2. Safe Road System Model

[1] Safety bulletin no. 99 (Version 1) 23 August 2010

2.1 Mine Road Watering Improvement Process

The watering improvement process displayed in *Figure 2A* integrates an auditing methodology that utilises the safe road system principal branches in a continual improvement risk management procedure.

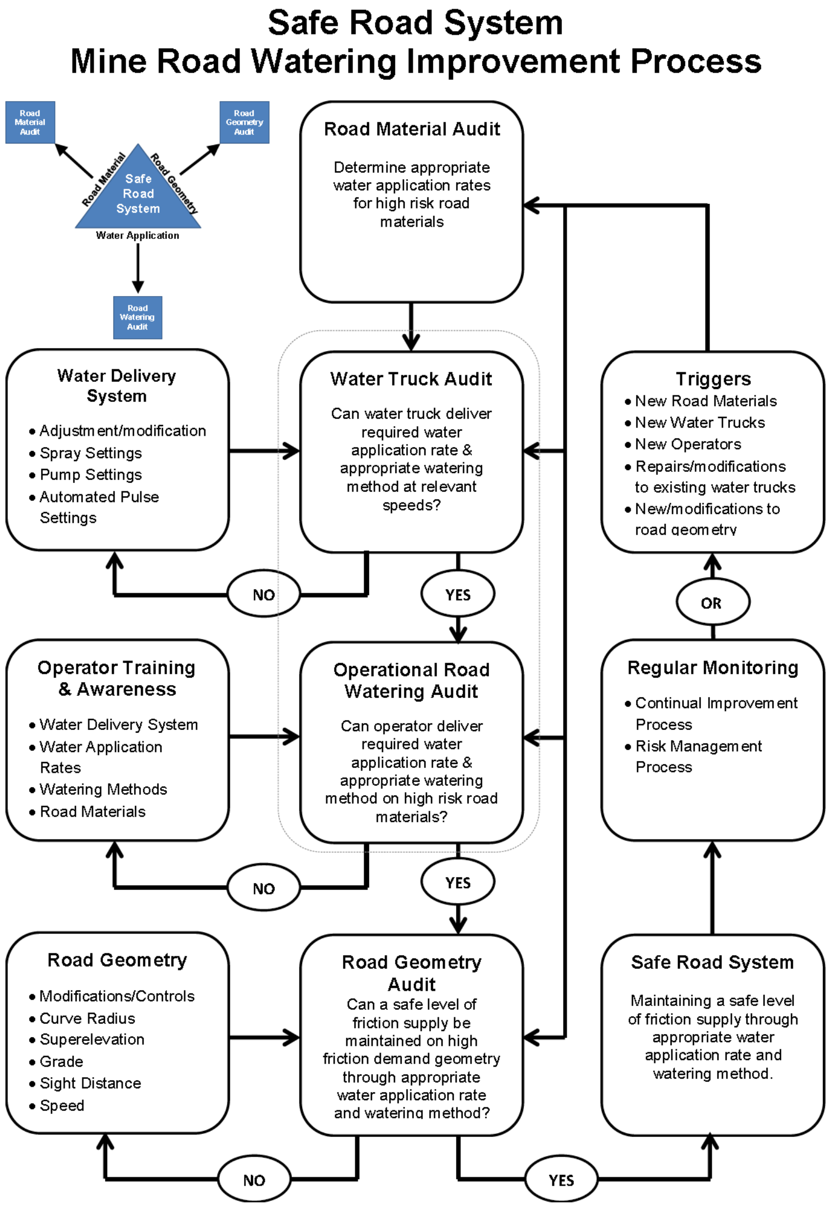


Figure 2A. Tulloch/Stocker Process flowchart

The above process expanded on in subsequent pages; begins with a *Road Material Audit* to identify higher risk roads and determine appropriate water applications rates. This is followed by a *Road Watering Audit* consisting of a *Water Truck Audit* and an *Operational Road Watering Audit*.

The *Water Truck Audit* determines whether water trucks can deliver the required application rate and appropriate water application method. The *Operational Road Watering Audit* concludes whether the operators control or determine the situational awareness of changing conditions and appropriate watering method on at risk roads.

The final procedure in the process is *the Road Geometry Audit* which governs whether a safe operating level of friction supply can be maintained on high friction demand geometry such as ramps, curves and intersections through appropriate water application rate and watering method.

3. Road Material Audit (Higher Risk Roads)

The Road Material Audit identifies the higher risk water sensitive road materials and determines the appropriate water application rates to maintain a safe operating level of friction supply. The model illustrated in *figure 3* provides a guide to operating levels of friction for mine vehicles, including haul trucks, founded on extensive field research and development conducted by the authors of this paper.

Normal	0.45	Level 1	0.35	Level 2	0.25	Level 3
Level Surface Friction above 0.45		Level Surface Friction between 0.45 – 0.35		Level Surface Friction between 0.35 – 0.25		Level Surface Friction below 0.25
Safe Operations for All Vehicles		Caution for Haul Trucks		Potentially Hazardous for Haul Trucks & Caution for Light Vehicles		Hazardous for Haul Trucks & Potentially Hazardous for Light Vehicles
		OCE/Supervisor to Determine Operational Restrictions		OCE/Supervisor to Determine Operational Restrictions		OCE/Supervisor to Determine Operational Restrictions

Figure 3. Tulloch/Stocker Global Road Friction Risk Model

The Road Material Audit is completed by performing a series of *Mine Friction Tests* on the mine road network firstly under dry conditions and then followed by a measured water application rate of 0.3mm per square metre of road surface. This procedure measures the available friction supply and allows the road material to be firstly classified and then identified as a higher risk road using the above *Friction Guide.*

The *Mine Friction Test* involves driving a mine ABS equipped light vehicle at ~35km/h across the subject road material and applying emergency ABS braking until the vehicle comes to a complete stop. The available friction supply is measured using a portable accelerometer based device fitted to the interior of the vehicle that displays the test results in real time.

A mine road material audit does not require an exhaustive test regime. The audit process to classify an individual wearing course material risk profile using a typical mine light vehicle takes about 5 minutes using a calibrated water truck; with no interference to mining activities or operational road safety.

With a focus on the higher risk classified road surfaces, a safe application rate[2] can be determined taking into account the effect of seasonal and ambient mine conditions at any particular time during day or night time operations.

[2] Water application methodology such as spot or strip watering, not examined in this paper, forms part of safe watering procedures.

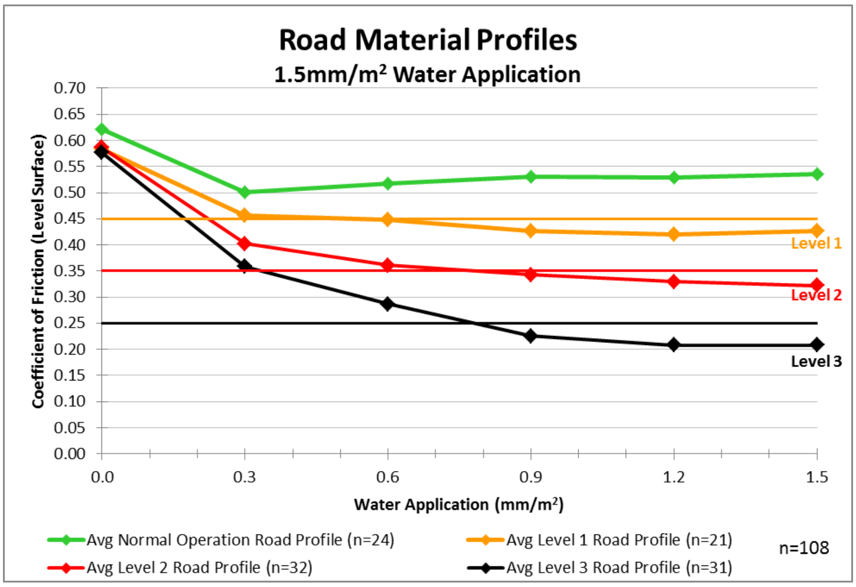


Figure 3A. Mine Road Friction Performance Profiles (Global Data)

3.1 Safe Water Application (Higher Risk Roads)

The measured data displayed in *figure 3*A represents thousands of individual field tests on 108 diverse road wearing course surface profiles at 18 operational mine sites throughout Queensland.

Real world watering application to ground rates from these operational mines was measured at between 0.15-1.2mm/m² with an observed mean most commonly in a range of 0.3-0.6mm/m².

The safe road system model defines the importance of classifying mine roads to determine road risk profiles on the network. High friction performing roads displayed in *figure 3A* as normal operations (green) and Level 1 (amber) are relatively friction insensitive surfaces and consequently represent a low risk to water application rate anomalies during mining operations.

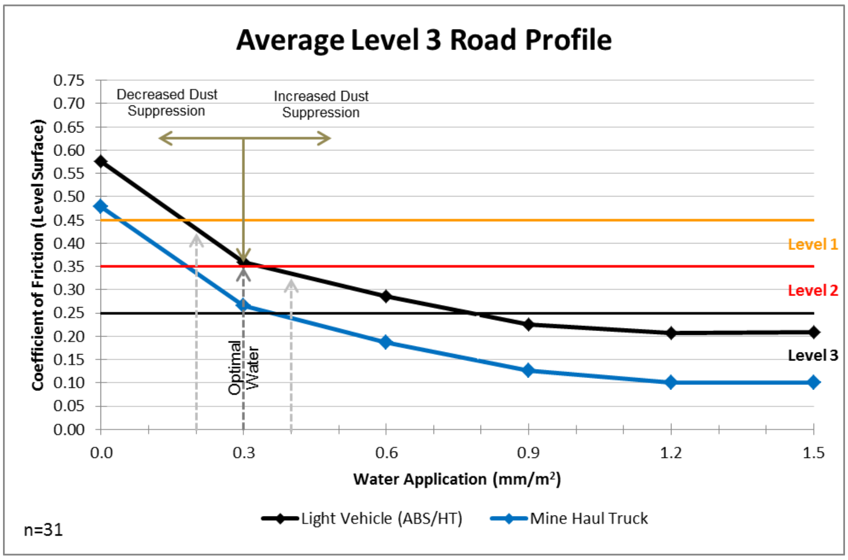


Figure 3B. High Risk Road Profile (Global Data)

A road wearing course surface classified at Level 3 (black), requires significant compromise between adequate dust suppression and safe operating friction values if remedial treatment such as road surface sheeting is not a viable option. An optimal water application to ground rate range is depicted in *figure 3B*, subject to seasonal and other site specific conditions.

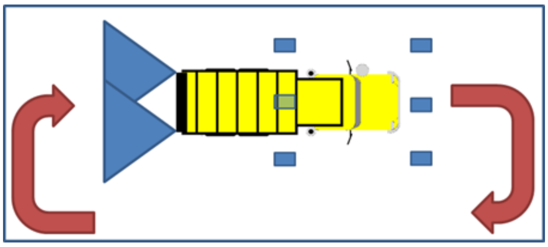
4. Water Truck Audits

The *Water Truck Audit* was developed to determine whether water trucks could actually deliver the required water application rate and appropriate watering method on high risk road materials at the relevant operational speeds particularly on ramps, curves and main haul roads.

Visits to some 18 mine sites has resulted in detailed measurements of application rates, operational observation and interviews with about 40 water truck operators. This extensive research has provided a solid basis to provide valid commentary on current industry practices and existing operational water truck fleet capacity.

The water truck audit examines current practices for each water truck delivery system. The purpose is to benchmark and improve upon current road watering practices. The wide variety of water trucks and delivery systems currently in use provides an imperative that any prescribed water truck audit is straightforward and sufficiently robust to accurately measure any unit used in field operations.

Figure 4. Water Truck Audit (Calibration) in Progress



$$A_W = \frac{V}{(A_S \times n)}$$

Aw = $Water\ Application\ Rate\ (mm/m^2)$
V = $Volume\ of\ Water\ Captured\ (litres)$
As = $Surface\ Area\ of\ Containers\ (m^2)$
n = $Number\ of\ Passes\ in\ Water\ Truck$

Figure 4A. Calibration procedure diagram & water application rate formula

Water truck calibration procedure:

- Locate a suitable large flat area or section of haul road where water saturation does not affect mining operations or general vehicle movement safety.
- Set out a minimum of 6 identical containers in a grid pattern allowing sufficient clearance for the wheel track of the water truck. Drive the water truck through the containers a minimum of 4 times at the same speed and direction, spray nozzle selection and pump settings.
- Measure the volume of water captured in the containers using a graduated measuring cylinder. Evaluate the spray water delivery to ground rate bias; measuring separately left, centre & right water tray collection. Calculate the average water application rate over the entire spray width in total litres per square metre.

4.1 Water delivery system and application method

The *Water Truck Audit* identifies the capabilities of the water delivery system and any issues that can and should be addressed with the spray and/or pump settings through adjustment, modifications or upgrade.

Water Truck Summary Sheet			
Mine		**Date**	
Truck No	**WC1**	**WC2**	**WC3**
Make & Model	Cat 777C	Cat 773D	Cat 769D
Pump Settings	4	Nil	Nil
Automated Pulse/Spot	Manual	Manual	Manual
Spray Configuration	6 Sprays	4 Sprays	4 Sprays
	L C R (Hi & Lo)	L CL CR R	L CL CR R
Speed Regulated	No	No	No
Water Application Rates	General settings as nominated by operators		
Up 10% Ramp	**0.17 mm/m^2**	**0.17 mm/m^2**	**0.94 mm/m^2**
	Spot	Spot	Spot
	1 Spray (Lo)	1 Spray	1 Spray
	Pump @ 4	-	-
	2nd Gear	2nd Gear	1st Gear
Down 10% Ramp	**0.16 mm/m^2**	**0.26 mm/m^2**	**0.54 mm/m^2**
	Spot	Spot	Spot
	3 Sprays (Lo)	1 to 2 Sprays	2 Sprays
	Pump @ 4	-	-
	3rd Gear	3rd Gear	4th Gear
Level Haul Road	**0.14 mm/m^2**	**0.15 mm/m^2**	**0.50 mm/m^2**
	Spot	Spot	Spot
	3 Sprays (Hi)	4 Sprays	2 Sprays
	Pump @ 1	-	-
	5th Gear	5th Gear	5th Gear
Comments:			
Testing with WC1 indicates that pump setting switch not operating. Output from WC3 is too high with uneven spray distribution resulting in overwatering.			

Figure 4B. Example of a water truck audit summary

Figures 4A & 4B provide a simple reliable method to measure water to ground application rates at nominated water truck speeds, nozzle spray selection and pump settings. A competent water truck operator no matter how experienced and skilled cannot deliver the required water application rate and appropriate watering method if the water delivery system is incapable.

Observed legacy water delivery systems on certain operational water trucks have limited capacity to deliver safe water application rates, particularly up ramps when speed is mechanically restricted and overwatering risk increased. Water trucks with inadequate delivery systems continue to be useful when competently assessed with regard to their current and future operational capacity.

Water delivery automation systems can reduce human operated inconsistency, although, it was observed that water truck setup parameters and operational implementation with new delivery systems remain challenging in practice.

5. Operational Road Watering Audit

The *Operational Road Watering Audit* determines whether water truck operators can deliver the required water application rate and appropriate watering method on high risk roads. Due to the implicit variables of water trucks, water delivery systems and application methods, a robust and efficient practice was required to conduct on-site operational road watering audits.

This requirement prompted the development of an operational audit procedure that is effective, uncomplicated and provides real time feedback to water truck operators by trained supervisors and safety personnel conducting the audit.

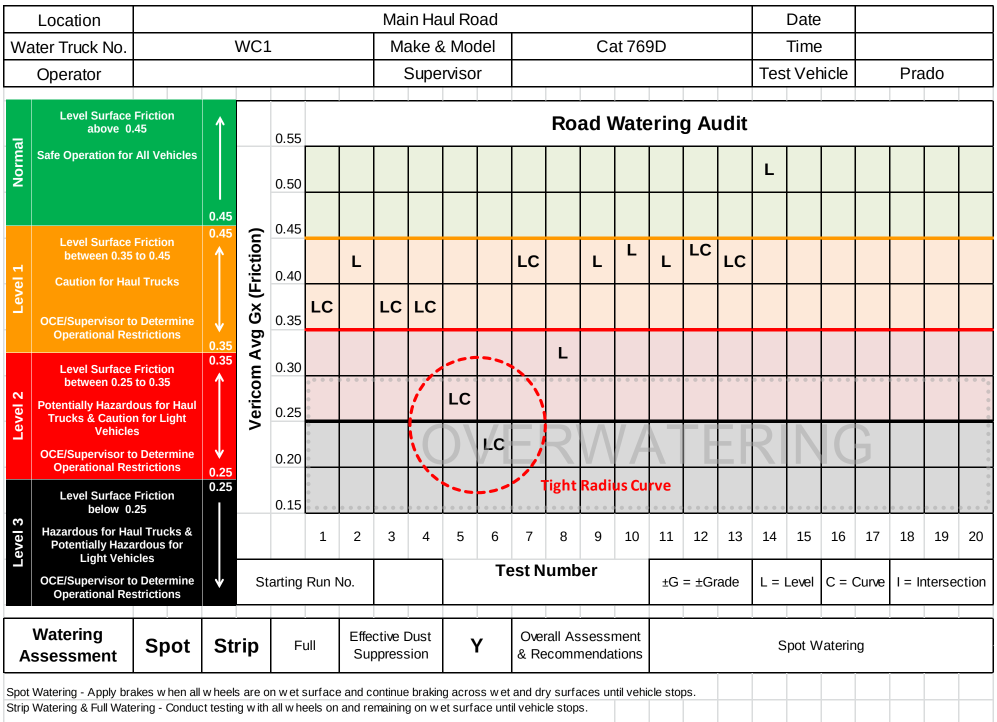


Figure 5. Example of a live road watering audit record

The audit sheet depicted in *figure 5* is that of a main haul road circuit operational audit and highlights a location where road friction levels were reduced to unsafe levels when the water truck slowed for demanding road geometry while maintaining a constant water delivery rate.

5.1 Operator Training and Awareness

Operational mine policy was found to be inconsistent with regard to water truck operations; certain mines used their experienced operators while others utilised their more junior personnel for water truck duty tasks, some mines had no specific policy in terms of operator selection.

General training and awareness observations at the visited mines indicated overall competent truck operating (driving) skills; however, water application rates and application methods among operators were variable, ad hoc and their awareness of water delivery system setups incomplete.

Mine water application policies were normally limited to when and where to use a strip watering method as opposed to spot watering or full watering application. Manual spot watering length for example, appeared to be mainly at operator discretion as were pump settings and spray nozzle selections that commonly caused spray bias and overwatering with observed and measured water to ground application rates.

Almost all water truck operators and other related management and safety personnel expressed a need for greater training in and understanding of the mine road safety content, subject of the research and development outlined in this paper.

6. Road Geometry Audit

The *Road Geometry Audit* is the final process in the *Safe Road System*. With severe geometry comes higher friction demand particularly on ramps, curves and intersections. The Road Geometry Audit determines whether a sufficient *factor of safety* can be maintained between friction demand and supply on challenging geometry through appropriate water application rate and watering method alone.

The *Road Geometry Audit* is an operational audit completed by fitting a portable accelerometer based device to the interior of a light vehicle, mine haul truck or any chosen vehicle being driven around the road network under normal operation. The instrument runs in the background mapping friction demand from the vehicle as it negotiates the mine circuit curves, ramps and intersections.

This process provides a benchmark or friction demand map of the mine road network under normal operations. The circuit friction demand map can then be compared directly to the road friction supply level determined from the *Road Material Audit* and *Road Watering Audit* consequently calculating a factor of safety margin.

In cases where the factor of safety is still insufficient even after optimal watering practices, modifications to geometry in terms of curve radius, superelevation, grade and sight distance may be considered. The audit can assist with appropriate selection of speed and other traffic management controls in locations that don't meet best practice geometric standards or subject to a changing operational environment.

7. Process Monitoring and Triggers

Any safety and risk mitigation process requires regular monitoring to flag system or potential systemic weakness. The operational mine conditions that may warrant process reviews are:

1. New road materials where friction sensitivity to water application is unknown or compaction is insufficient in the pavement strata.
2. This can be addressed by conducting a road material audit.
3. New water trucks where water application rates or spray bias is not quantified. A water truck audit will address this risk.
4. A new water truck or inexperienced water truck operators. Training and awareness sessions of the road watering improvement process and specific mine policy may mitigate this condition.
5. Modifications and repairs to the current water truck fleet in particular those that change or potentially change water application rates, spray bias and water delivery system outputs. A water truck audit will alleviate these risks.
6. Changed road geometric features including ramp grades, intersection layouts and curve radii influence vehicle friction demand and operator interaction with the road environment. A geometry audit will highlight potential safety margin issues.

8. Safer Road System Process

The safe road system road watering improvement concept follows a logical path[3] to apply a rigorous risk mitigation process to this critical mining practice. The purpose is to provide a safe level of road wearing course friction while maintaining adequate dust suppression for a safer road operating environment.

9. References

Queensland Mining Industry Health & Safety Conference Innovation Awards 2012
http://www.qrc.org.au/conference/_dbase_upl/RoadSurfaceFrictionRisk.pdf
DNRM: Coal Mine Road Network Surface Friction Report 2011
http://mines.industry.qld.gov.au/assets/mines-safety-health/Coal-Mine-Road-Network-Surface-Friction-Report-2011.pdf
Mines Inspectorate Safety bulletin 99 Published 23 August 2010
http://mines.industry.qld.gov.au/safety-and-health/mining-safety-health.htm

[3] See *figure 2A flowchart* page 3.