

## Slope analysis and occupational health and safety risks for watershed rehabilitation supervisors in Southeast Sulawesi, Indonesia

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### Abstract

**Background:** Supervisors who are in charge of monitoring and assessing DASD rehabilitation activities in areas with high slopes, have potential occupational health and safety (OHS) risks that need serious attention such as slipping or falling, which is one of the main causes of injuries to workers in locations exposed to heavy terrain. In addition, health risks are also related to the physical condition of supervisors who are exposed to strenuous physical activity, extreme weather, and exposure to various diseases that can develop in the rehabilitation area.

**Method:** The research is observational descriptive research carried out in two districts in Southeast Sulawesi Province, namely North Kolaka Regency and Central Buton Regency. Slope data was obtained from DEMNAS DATA combined with route results data from the field PIC team. The slope class is generated from DEMNAS derivative analysis using the Slope function in the Geographic Information System (GIS). The value of the slope is expressed in percent (%) or degrees (°). For the purposes of national mapping and risk analysis, classification from BIG and FAO is generally used which consists of Flat, Sloping, Slightly Steep, Steep, Very Steep.

**Results:** The distribution of the wide proportion (%) of each block based on five slope classes, namely flat (0–8%), sloping (8–15%), slightly steep (15–25%), steep (25–45%), and very steep (>45%). The results of the following analysis provide an overview of the characteristics of the topography and its implications for the potential land use in each block. Overall, the distribution of slope classes in this region shows a dominance in the sloping and slightly steep categories, which indicates a weak to moderate undulating geomorphological character. Blocks such as Wadiabero I and II have great potential for intensive development and agricultural activities, while blocks such as Pasampang, Watumotaha I, and Nimbuneha are more suitable for land conservation functions to maintain environmental stability and reduce erosion risk.

**Keywords:** Slope; Occupational Health and Safety; Watershed Rehabilitation; Supervisors

### 1. Introduction

Occupational health and safety is a crucial aspect of any rehabilitation activity, especially in high-risk areas. Research by Pramudya et al. emphasizes the importance of implementing OHS to anticipate the possibility of accidents in the work environment [1]. Watershed rehabilitation carried out in steep areas requires strict OHS procedures to protect workers from the risk of injury from falls or other accidents. However, applying the principles of OHS in a rehabilitation

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environment may be different from its application in hospitals, which are more unique and require a specific approach, for example, from research by Eviarista and Handayani [2].

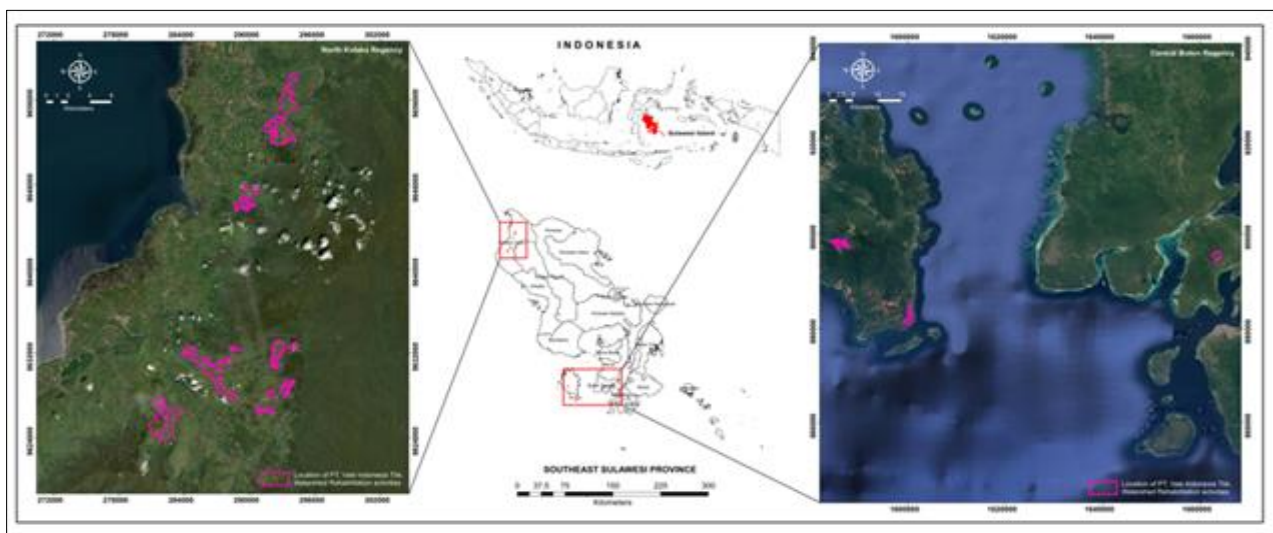
In order to carry out rehabilitation safely, supervisors and other workers must be trained in identifying existing risks. The results of a study by Kabul et al. revealed that proper management of the OHS system is necessary to ensure the safety of the workforce and reduce the likelihood of work accidents [3]. Therefore, the responsible supervisor in watershed rehabilitation areas must develop and follow comprehensive risk management procedures, including hazard assessments and risk control as described in the publication by Herlina et al. that show the importance of strengthening OHS management to improve safety and productivity in the workplace [4].

Watershed rehabilitation on steep slopes creates its own challenges in terms of OHS. Supervisors conducting monitoring must be prepared for risks associated with unstable physical conditions and work environments that are often affected by extreme weather. The concepts put forward by Montrose et al. can be applied to understand and mitigate potential hazards within rehabilitation projects, especially related to environmental factors that affect safety [5]. However, research on environmental risks in the workplace as a whole remains to be considered [6].

One of the important steps in reducing the risk of CSH is adequate training for all parties involved. According to research by Rahim et al., safety management practices and safety culture are essential in improving safety performance in the workplace [7]. Education and training on OHS will reduce the likelihood of accidents by increasing individual awareness of hazards and good safety practices.

## 2. Material and methods

The research is an observational descriptive research with geospatial analysis (Geographic Information System/GIS). This research was carried out in two districts in Southeast Sulawesi Province, namely North Kolaka Regency and Central Buton Regency. North Kolaka Regency consists of the Lengkong Batu Block, Bukit Baru Block, Pasampang Block, Nimbuneha Block, Parutellang Block I, Parutellang Block II, Parutellang Block III, Parutellang Block IV, Parutellang Block V, Parutellang Block VI, Watumotaha Block I, and Watumotaha II Block. Central Buton Regency consists of Wadiabero Block I, Wadiabero Block II, and Wuu Block.



**Figure 1** Location of Supervision

## 2.1. Sampling Techniques

The slope class is generated from DEMNAS derivative analysis using the Slope function in the Geographic Information System (GIS). The value of the slope is expressed in percent (%) or degrees (°). For the purposes of national mapping and risk analysis, the following classifications from BIG and FAO are generally used:

**Table 1** Classification of slope slopes from BIG and FAO

Slope Class	Slope (°)	Slope (%)	Topographic Description	Interpretation of Terrain Risk
Flat	0 – 2°	0 – 3%	Almost flat surface, alluvial plains or beaches	Very low risk; Easy to reach
Sloping	>2 – 8°	3 – 15%	Low slopes, generally soft hilly areas	Low risk; still easily accessible
A bit steep	>8 – 15°	15 – 30%	Moderate slopes, there is a potential for erosion	Moderate risk; Requires operational caution
Steep	>15 – 25°	30 – 45%	The slopes are clearly visible; difficult for heavy vehicles	High risk; Landslide potential increases
Very Steep	>25°	>45%	Steep slopes, mountains or rock cliffs	The risk is very high; need access restrictions

## 2.2. Data Collection

Slope slope data was obtained from DEMNAS DATA combined with route results data from the field PIC team. This approach results in spatial mapping that not only depicts the topographic contours, but also shows the level of operational risk per activity block, such as the Parutellang I–VI, Wadiabero I–II, Watumotaha I–II, and Nimbuneha areas. Thus, the use of DEMNAS allows the identification of areas with high terrain hazard potential, supports the development of spatial-based occupational safety strategies, and increases the effectiveness of risk management in the field. The geospatial analysis is carried out through the creation of a Slope Slope Map. The OHS analysis was carried out through the classification of OHS risks based on the slope category.

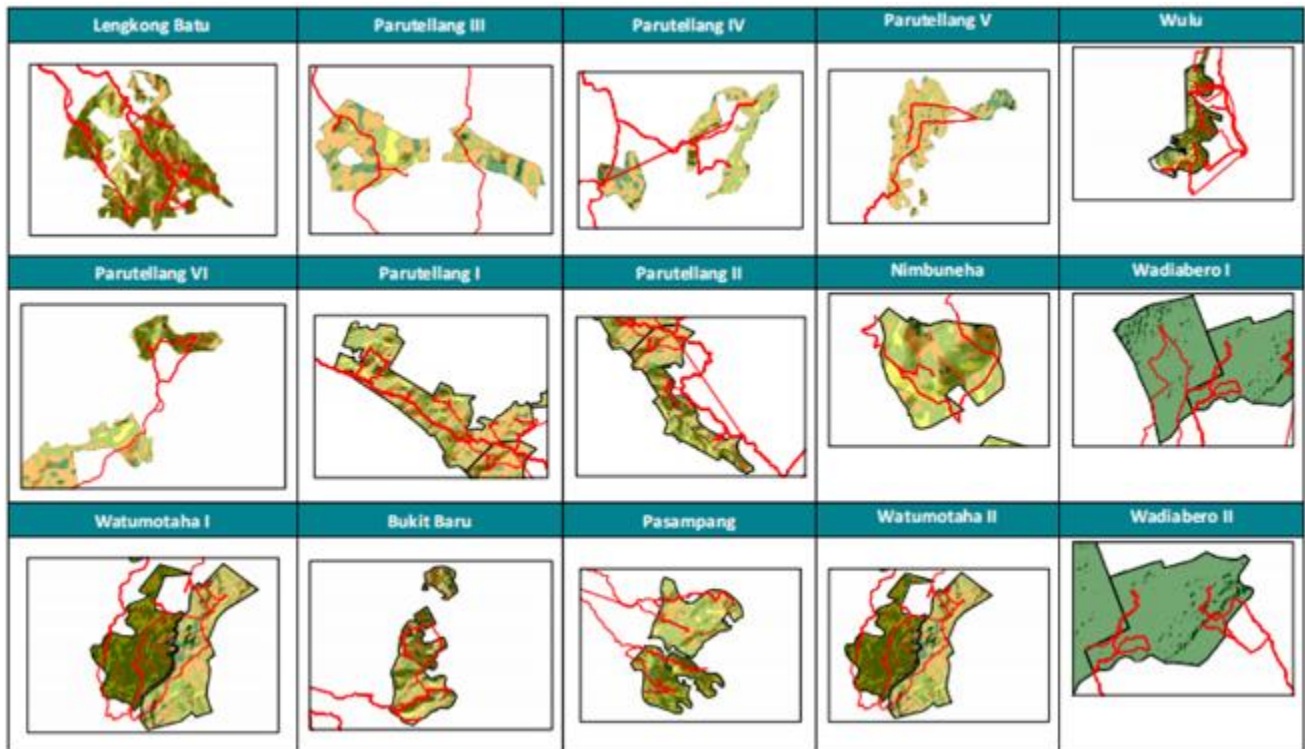
## 3. Results

### 3.1. Analysis of the proportion of slope classes in each block of the region

The slope slope affects the level of erosion, drainage, and land suitability for various space use activities. The data in Table 1 shows the distribution of the wide proportion (%) of each block based on five slope classes, namely flat (0–8%), sloping (8–15%), slightly steep (15–25%), steep (25–45%), and very steep (>45%). The results of the following analysis provide an overview of the characteristics of the topography and its implications for the potential land use in each block.

The map visualization provides a clear spatial representation of the topographic diversity at watershed rehabilitation sites. In general, the map shows a significant contrast between blocks dominated by sloping/flat slopes (represented by light green/pale colors), such as Wadiabero I and II, and blocks dominated by steep slopes (represented by yellow, brown, and dark red), such as Watumotaha I, Pasampang, and Nimbuneha. This map visually confirms the previously analyzed proportional data, where areas rich in steep colors directly correlate with the classification of Very High OHS Risk.

The red line that crosses each block represents the route taken by the PIC Team. The integration of this route data is key, as it shows that in many high-risk blocks (e.g., Lengkong Batu, Watumotaha I, and Wulu), the Supervisor is forced to operate and carry out documentation through or around very steep zones. The limitations of avoiding these steep zones directly validate the need for a tailored OHS Standard Operating Procedure (SOP) and the use of fall protection special PPE along the red route line, especially in the segments that cross yellow to dark brown, in accordance with the mitigation recommendations that have been discussed.



Source: DENMAS data combined with data from the PIC TEAM route results in the field

**Figure 2** Analysis of the proportion of slope classes in each block of the region

**Table 2** Analysis of the Proportion of Slope Classes in Each Region Block

Block Name	Slope and Classification (Proportion %)					Area, Proportion, %	OHS Risk Classification	OHS Notes
	(0 - 8 Flat)	(8 - 15 Slopes)	(15 - 25 A Bit Steep)	(25 - 45 Steep)	(> 45 Very Steep)			
Lengkong Batu	5	36.43	48.19	9.51	0.46	100	Height	The potential for slipping and heavy equipment accidents, it is necessary to secure the work line.
Parutellang III	21.50	47.66	25.31	5.53	0.00	100	Medium	Relatively safe conditions, need maintenance of the work line.
Parutellang IV	26.44	41.61	28.67	3.29	0.00	100	Height	Need an SOP for work on the slope.
Watumotaha II	17.71	42.29	34.71	5.29	0.00	100	Medium-High	A large area on the slopes; risk of slipping and the machine rolling.

Parutellang V	21.35	56.90	20.97	0.77	0.00	100	Medium	Drainage control is needed.
Parutellang VI	8.67	42.14	41.84	7.35	0.00	100	Height	SOP for medium slope work.
Parutellang I	6.69	44.68	41.86	6.66	0.11	100	Height	A large area with a significant slope.
Parutellang II	13.00	49.92	31.22	5.87	0.00	100	Medium	Relatively safe with regular supervision.
Squirrelly	4.57	29.72	50.05	15.66	0,00	100	Height	Potential falls in small cliff areas.
Timeline I	2.90	19.46	47.63	28.98	1.03	100	Very High	Activities need to be limited and SOPs are specific.
Wadiabero I	100.00	0.00	0.00	0.00	0.00	100	Low	Safe for mechanization.
Bukit Baru	15.94	48.13	32.57	3.28	0.07	100	Medium	Potential for local landslides.
São Paulo	2.05	19.97	54.78	20.96	2.24	100	Height	Large area on a medium slope.
Wadiabero II	99.92	0.08	0.00	0.00	0.00	100	Low	Safe.
Wool	14.25	25.33	44.08	16.32	0.02	100	Height	The risk of slipping is moderate.

The slope affects the level of erosion, drainage, and land suitability for various space use activities. The data in Table 2 shows the distribution of the wide proportion (%) of each block based on five slope classes, namely flat (0–8%), sloping (8–15%), slightly steep (15–25%), steep (25–45%), and very steep (>45%). The results of the following analysis provide an overview of the characteristics of the topography and its implications for the potential land use in each block.

- Lengkong Batu: This block is dominated by a slightly steep class of 48.19% and a slope of 36.43%. This condition indicates an area with moderate to sloping topography, which describes the transition area between the foot of the slope and the middle slope. The potential for surface flow is moderate, so it is still possible for cultivation activities with the application of good soil conservation.
- Parutellang III: Most areas are included in the sloping (47.66%) and flat (21.50%) categories. This indicates a relatively stable morphology with a low erosion rate, making it suitable for agricultural and residential activities.
- Parutellang IV: It has a proportion of sloping slopes of 41.61% and a slightly steep 28.67%, showing topographic variations from flat to undulating. This area has a balance between stable areas and areas with the potential for moderate erosion.
- Watumotaha II: The proportions of sloping (42.29%) and slightly steep (34.71%) are almost balanced, indicating the morphological conditions of the low hills that still have potential for land development with proper vegetation and water management.
- Parutellang V: Dominated by sloping slopes of 56.90% and flat 21.35%. This topography shows an area with a low slope, suitable for intensive agriculture and other productive land uses.
- Parutellang VI: Slightly steep (41.84%) and sloping (42.14%) classes dominate this block, indicating low hills with moderate potential water runoff. Land use requires the application of conservation techniques such as terraces and erosion-resistant vegetation.
- Parutellang I: The proportion of slightly steep (41.86%) and sloping (44.68%) slopes depicts undulating slopes with moderate stability. Soil conservation is important to prevent land degradation.
- Parutellang II: This area has a sloping proportion of 49.92% and a slightly steep 31.22%, which is still quite potential for cultivation activities with good erosion management in sloping areas.

- Nimbuneha: This block is dominated by a slightly steep slope (50.05%), indicating slope conditions with high erosion potential. Therefore, it is recommended for the use of permanent vegetation such as perennials or secondary forests.
- Watumotaha I: Dominated by slightly steep (47.63%) and steep (28.98%) classes, depicting undulating to steep topography. This area is less suitable for wetland farming, and is more suitable for conservation or agroforestry areas.
- Wadiabero I: Has 100% flat conditions, indicating very stable land with a very low risk of erosion. Potential for intensive agriculture and infrastructure development.
- Bukit Baru: This block has a sloping class of 48.13% and a slightly steep 32.57%, describing a low-hilly area with medium to high cultivation potential if the drainage system is managed properly.
- Pasampang: Dominated by slightly steep (54.78%) and steep (20.96%) slopes, showing a steep slope with high erosion potential. This area should be directed to the conservation of soil and permanent vegetation.
- Wadiabero II: It has an almost perfect flat topography (99.92%), ideal for agriculture and settlements with very little risk of erosion.
- Wulu: It has a slightly steep proportion of 44.08% and a slope of 25.33%, describing topographical conditions varying from sloping to sloping. Land use should be directed to conservative agricultural systems or agroforestry.
- Overall, the distribution of slope classes in this region shows a dominance in the sloping and slightly steep categories, which indicates a weak to moderate undulating geomorphological character. Blocks such as Wadiabero I and II have great potential for intensive development and agricultural activities, while blocks such as Pasampang, Watumotaha I, and Nimbuneha are more suitable for land conservation functions to maintain environmental stability and reduce erosion risk.

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## 4. Discussion

### 4.1. Implications of Slope Slope on Supervisory OHS

Integrated geospatial analysis (DENMAS) showed that the classified blocks had a High OHS Risk, such as Lengkong Batu (48.19% Somewhat Steep) and Nimbuneha (50.05% Somewhat Steep), driven by the dominance of the proportion of slopes of the Somewhat Steep class (15%–25%). The risk of collapse of a soil mass is closely related to the geographical and geological conditions of a place that affect worker mobility, as well as how the work environment can contribute to ergonomic injuries [8]. Research shows that uneven and sloping terrain not only increases metabolic load on workers but also increases the risk of falls and slips [9]. The cause of on-site injuries depends on the complex interaction between environmental conditions and worker actions, which suggests that exposure is not only related to worker density but also to tool mastery and understanding of occupational safety [4].

The most obvious risk correlation was seen in the presence of Steep (25%–45%) and Very Steep (>45%) slopes. The Watumotaha I Block, with a Steep proportion of 28.98% and Very Steep 1.03%, is classified as having a Very High risk. OHS recommends securing work paths as an important step to minimize these risks. This includes training and use of personal protective equipment (PPE) as well as the installation of appropriate safety signs to help workers be more aware of potential hazards [9]. Thus, various measures to improve safety at the site such as the installation of warning signs, the provision of personal protective equipment, and the implementation of standard operating procedures (SOPs) are indispensable to reduce the likelihood of incidents [10].

The data show a shift in the focus of OHS risk on blocks with a high proportion of Sloping slopes (8%–15%) that integrate with Slightly Steep, such as Lengkong Batu, which record the risk of heavy equipment accidents. Although the Ramp class (such as Wadiabero I and II) is classified Low and safe for mechanization, the transition to the Relatively Steep class (15%–25%) drastically changes the risk profile of the machine.

The findings that are differentiated across the block from Low Risk in Wadiabero to Very High in Watumotaha I demand the implementation of *Risk-Based Standard Operating Procedures* (R-BSOP). Based on the Risk Matrix developed from this data, blocks with a predominance of Somewhat Steep (High Risk), such as Parutellang VI, must implement a POS that emphasizes *fatigue* management and PPE checks that focus on *slip-resistant footwear*, while the Very High block must implement a POS oriented towards specialist OHS supervision and work permit procedures at heights (PTW). The implementation of training programs that focus on mastering ergonomics and occupational safety is crucial in reducing incidents caused by external factors. According to research by Nugroho et al., the implementation of risk analysis through a combination of safety awareness training is very effective in preventing work accidents caused by fatigue or work stress [11]. Increased knowledge and compliance with safe work procedures at every level has a significant positive impact [12].

The importance of safeguarding in the work environment in locations with the risk of collapse of soil masses, especially on land categorized as Somewhat Steep, cannot be ignored. Although in absolute terms the risk of this zone is lower compared to the Very Steep zone, increased exposure can potentially lead to incidents related to mobility and ergonomics [13]. Effective supervision of these risks so that they do not become a bigger problem is very important, especially in the field of Occupational Health and Safety (OHS). Therefore, it is recommended that the OHS training of Watershed Rehabilitation Supervisors in South Sulawesi includes basic topographic map literacy modules and visual slope stability analysis, which allows Supervisors in the Pasampang block (20.96% Steep) to conduct a *quick risk assessment* before starting work, especially after extreme weather conditions.

#### 4.2. Recommended OHS Risk Mitigation Strategies

The main mitigation strategy recommended is the development of OHS Standard Operating Procedures (POS) which are no longer general, but are explicitly adapted to slope zoning. For predominantly Slightly Steep areas (15%–25%) classified as High Risk (e.g., Nimbuneha and Lengkong Batu), POS should emphasize work path safety procedures, including clearing of loose materials, routing of access, and implementing buddy systems with safe distances to mitigate the risk of slips and falls. In contrast, POS for Very Steep (>45%) and Significant Steep areas (such as Watumotaha I) should include more restrictive measures, namely mandatory Work Permit at Height (PTW) procedures and visual slope stability analysis by the Supervisor before work begins.

Recommendations for the need for Personal Protective Equipment (PPE) for Supervisors must be differentiated according to the risk profile of each block. Given the predominance of biomechanical (slipping) risks on Ramp to Slightly Steep slopes, Supervisors should be required to wear boots with anti-slip soles and ankle support that have a high-performance rating against slip hazards, exceeding general PPE standards. Meanwhile, for work on Steep and Very Steep slopes (Watumotaha I), PPE must be upgraded to a complete Personal Fall Arrest System (PFAS), including full body harness, shock-absorbing lanyard, and vertical safety line, accompanied by training on anchor point installation in accordance with work guidelines at height. In the context of Occupational Health and Safety (OHS), strengthening the use of personal protective equipment (PPE) is very important, especially for workers who carry out activities at heights. The necessity for upgrading Personal Protective Equipment (PPE) to include a complete Personal Fall Arrest System (PFAS) is underscored by the high incidence of fall-related injuries in construction and other high-risk environments. A PFAS includes critical components such as a full-body harness, shock-absorbing lanyard, and vertical safety lines, which are specifically designed to prevent injury in the event of a fall. Recent research emphasizes that not only the right equipment but also effective training is essential to mitigate fall risks effectively [14,15].

PFAS is classified as a secondary protection measure designed to minimize the impact of a fall when primary protections, such as guardrails and safety nets, fail [16]. While PFAS cannot completely prevent falls from heights, their proper use significantly reduces the severity of injuries sustained during such accidents. A key feature of PFAS is the shock-absorbing lanyard that mitigates the force experienced during a fall, allowing for safer recovery and stabilization post-fall [17,18].

Training is crucial in this context, as studies have demonstrated that the efficacy of harness use improves significantly with repeated practice and instruction (Bunney et al., 2021; . Workers who are not adequately trained in the use of PFAS may not connect their equipment properly or may fail to utilize it effectively during a fall, which greatly undermines its intended protective capabilities (Bunney et al., 2021; Korkmaz, 2023). Furthermore, the OSHA guidelines establish the fundamental need for such training, highlighting that effective worker education on safety protocols is vital for reducing fall-related incidents [19,20].

OSHA mandates that employers ensure their workers utilize fall protection systems when working at elevations that pose potential fall hazards [15,21]. This regulation permits the use of various fall protection systems, including PFAS, provided they are compliant with OSHA standards. In other regions, like South Korea and China, regulatory frameworks can be even more stringent, often requiring mandatory use of fall arrest equipment in any circumstance involving elevation greater than two meters [21]. This demonstrates a global recognition of the importance of PFAS in occupational safety.

The implementation of a comprehensive safety culture is essential, which encompasses risk assessment and hazard identification related to fall hazards [15,19]. Proper training, recognized and enforced through OSHA guidelines, helps ensure that workers not only understand the risks associated with their tasks but are also trained in the correct usage of PFAS to minimize those risks effectively. This dual approach of providing both proper equipment and necessary training can significantly enhance workplace safety [19,20].

The development of a training program must also consider evidence-based approaches that underline the relationship between effective safety interventions and accident prevention. Research highlights that interventions based on empirical data tend to yield more substantial improvements in safety outcomes [21,22]. An example includes utilizing virtual and augmented reality technologies to simulate hazardous situations, allowing workers to engage with their training dynamically [23,24].

Continuous training and feedback mechanisms are pivotal in maintaining a high safety standard. Regular updates to training content, informed by the latest safety research and technological advancements, help ensure that workers stay apprised of best practices [25][26]. Implementing feedback loops through evaluation metrics and performance assessments allows for continual improvement of training effectiveness [27].

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## 5. Conclusion

The risk of the Supervisor's OHS is directly proportional to the proportion of Somewhat Steep to Very Steep land in each block; The dominance of Slightly Steep areas (15%–25%) increases the risk of slipping/fatigue, while a small percentage of Steep slopes (>25%) triggers a Very High risk of falling from heights and heavy equipment accidents. Therefore, it is recommended that the Watershed Center immediately implement a Topographic Zoning-Based Mitigation Strategy, including the development of slope-specific OHS POS, procurement of PFAS PPE, and geospatial competency training for Supervisors, in order to create a predictive and safe work environment. We would like to express our gratitude to the administrative team and PIC for Watershed Rehabilitation at PT. Vale Indonesia in Southeast Sulawesi: M. Reza Setiawan, Alan Saputra, Hasrudin Hayat, Simaali, Sijebir, Wahyu Syahputra, Muhammad Fatwa Jumain, La Hamrun, Dedi Darmawan, Hermansyah, Danar, Septian Anakia Fitrah, and Siti Nurdianti, who were very helpful throughout the data collection and field documentation processes.

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## Compliance with ethical standards

### *Disclosure of conflict of interest*

No conflict of interest to be disclosed.

### *Statement of informed consent*

Informed consent was obtained from all individual participants included in the study.

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