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Research Paper

Sedimentation Analysis and Control Prioritization Using Meyer-Peter Müller and AHP: Evidence from the Ati River, West Papua, Indonesia

Hans Bano[1], Nusa Sebayang[2], Erni Yulianti[3*]
[1,2,3] *(Post Graduate Program of Civil Engineering, Institut Teknologi Nasional, Malang, Indonesia)*
Corresponding Author: Erni Yulianti

ABSTRACT: *The Ati River in Teluk Wondama Regency is affected by sedimentation that can reduce channel capacity and increase flood exposure. This study integrates Meyer-Peter Müller (MPM) bed-load analysis with the Analytical Hierarchy Process (AHP) to quantify sediment-transport intensity, identify the most critical river segment, and prioritize sediment-control measures from a construction-management perspective. An applied descriptive-quantitative design, supported by field observation and stakeholder judgment, was implemented along a 0.70 km reach at STA 3+700 (upstream), STA 3+350 (middle), and STA 3+000 (downstream). Twenty-two purposively selected respondents evaluated three alternatives - Sabo Dam, gabion groyne, and river normalization - against six criteria. The computed maximum bed-load transport was 4,560,005.563 tons/day upstream, 5,177,410.863 tons/day in the middle segment, and 5,136,194.854 tons/day downstream; therefore, the middle segment was identified as the most critical. AHP assigned the highest global priority to Sabo Dam (0.4454), followed by river normalization (0.3294) and gabion groyne (0.2252), with all pairwise matrices meeting CR <= 0.10. The recommended implementation sequence combines immediate normalization and maintenance, medium-term construction of priority control works, and long-term watershed rehabilitation, monitoring, and sustainable infrastructure management. The findings provide a structured basis for linking sediment hydraulics to staged investment decisions, while remaining limited to an empirical three-station study without numerical morphodynamic modeling or detailed structural design.*

KEYWORDS: *Sedimentation, Meyer-Peter Muller, analytical hierarchy process, river normalization, construction management.*

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I. INTRODUCTION

Sedimentation is a continuous component of river morphology in which eroded material is transported and deposited as flow energy changes. Its magnitude is controlled by watershed characteristics, rainfall, sediment properties, channel geometry, discharge, velocity, bed slope, and hydraulic resistance [1-5,13]. In managed river corridors, persistent deposition can reduce effective conveyance, alter channel form, and increase the probability that high flows exceed the available section capacity. These effects are especially important where river infrastructure serves settlements, roads, public facilities, and local economic activities.

The Ati River in Rasiei District, Teluk Wondama Regency, West Papua, drains terrain characterized in the thesis by steep upstream slopes, sandy-stony soil, and high annual rainfall. Recurrent flood events and visible deposition motivated a focused analysis of a 700 m river reach. Previous sedimentation studies have commonly examined erosion, transport rates, numerical river behavior, or individual control structures [2,4,5,8,12]. Structural measures such as Sabo Dams and gabion work, together with operational measures such as channel normalization, are widely considered for sediment and river-control programs [6-9,11,12].

A key problem is that a technically severe sediment condition does not by itself determine which intervention should be implemented first. Decision makers must also consider flood risk, exposure of settlements and infrastructure, ease of construction, and treatment cost. The source thesis therefore identifies a research gap in studies that integrate an empirical bed-load calculation with a multicriteria decision method in a construction-management framework. Its novelty lies in combining MPM-derived sediment information with AHP-based prioritization rather than selecting a control structure before the assessment.

This article converts the thesis into an international-journal format and concentrates on its quantitatively supported findings. The objectives are to: (1) estimate and compare bed-load transport at the upstream, middle, and downstream stations; (2) identify the critical sedimentation segment; (3) determine the relative importance of six decision criteria and rank three sediment-control alternatives using AHP; and (4) translate the results into short-, medium-, and long-term management priorities for the Ati River.

II. LITERATURE REVIEW

2.1. Sedimentation and Bed-Load Transport

River sediment transport reflects the interaction between sediment supply and hydraulic capacity. Material derived from erosion may move as suspended load or as bed load through rolling, sliding, and saltation. Bed-load behavior is particularly sensitive to the shear exerted by the flow, sediment size, density, channel slope, and hydraulic geometry [1,3,13]. Changes in discharge and velocity may consequently produce substantial variation in sediment mobility and deposition along a river reach.

The thesis adopts the Meyer-Peter Müller empirical approach to estimate bed-load transport from measured and derived hydraulic parameters, including wetted area, hydraulic radius, flow velocity, discharge, bed slope, shear stress, and median sediment size (D50). Similar sedimentation studies emphasize that spatial variation in channel morphology and flow conditions should be assessed by segment because a single river-average value can mask local critical zones [2,4,5].

2.2. Sediment-Control Alternatives

Sediment-control programs can combine structural and operational interventions. A Sabo Dam is intended to intercept and regulate sediment movement from upstream, whereas gabion works are commonly used to protect banks, reduce local scour, and stabilize river sections. River normalization restores conveyance through dredging, removal of obstructing material, and improvement of the channel section [6-9,12]. The effectiveness and implementation burden of these alternatives differ, making direct comparison necessary before investment decisions are made.

For the Ati River, the thesis evaluates Sabo Dam, gabion groyne (Krib Bronjong), and river normalization as competing but potentially complementary alternatives. The purpose is not to treat the highest-ranked option as the only intervention. Instead, the ranking is used to structure a staged strategy in which rapid operational actions can precede more complex structural works and long-term watershed measures.

2.3. AHP and Construction-Management Prioritization

The Analytical Hierarchy Process decomposes a decision problem into a goal, criteria, and alternatives, then derives relative priorities from pairwise comparisons [10]. In the Ati River study, the criteria are sedimentation level, flood risk, threat to settlements, threat to infrastructure, ease of implementation, and treatment cost. Expert and stakeholder judgments are aggregated and tested for consistency, with a Consistency Ratio of 0.10 or less treated as acceptable.

Integrating AHP with sediment analysis gives construction management a transparent basis for sequencing work. Technical severity can be weighed together with social exposure, constructability, and cost, while the final priority can be converted into scheduling, budgeting, quality control, risk management, operation and maintenance, and asset-management actions. This integration is the central decision framework applied in the study.

III. RESEARCH METHOD

3.1. Research Design and Study Context

The study is an applied research project using a descriptive quantitative approach supported by qualitative field information. The study area covers approximately 0.70 km of the Ati River in Rasiei District, from STA 3+000 to STA 3+700. Three stations represent downstream (STA 3+000), middle (STA 3+350), and upstream (STA 3+700) conditions. The middle station lies at a change in channel direction, while the three stations jointly provide the hydraulic and sediment data used for segment comparison.

Primary data consist of channel geometry, flow velocity, field observations of bed material and deposition, interviews, and AHP questionnaires. Secondary data include watershed maps and topography, D50 sediment information, rainfall, supporting hydraulic records, and flood-event information. Field measurements were undertaken during the rainy season to capture representative flow and sediment conditions within the available study period.

3.2. Respondents and AHP Data Collection

AHP respondents were selected purposively on the basis of competence, experience, involvement in river management, or direct knowledge of the Ati River. The sample comprises 22 respondents: four from the Teluk Wondama Regency Public Works agency, two from the River Basin organization, two from the West Papua provincial Public Works agency, three consultants, four disaster-management representatives, three river-work contractors, and four community leaders or affected residents. Pairwise judgments were combined using a geometric mean before priority calculation.

3.3. Analytical Procedure

The analysis proceeds in two linked stages. First, hydraulic parameters are processed and bed-load transport is estimated with the MPM method for each station; the computed Qb values are then compared to identify the most critical segment. Second, AHP evaluates three alternatives against six criteria. Criteria and local-alternative weights are synthesized into global priorities, and every pairwise matrix is checked using the Consistency Index and Consistency Ratio. Only results with CR <= 0.10 are accepted for decision synthesis [10]. Table 1 summarizes the research framework.

Table 1. Research framework and analytical outputs

Element	Application in the Study	Main Output
Study reach	STA 3+000-STA 3+700; three representative stations	Upstream, middle, downstream comparison
Hydraulic assessment	Geometry, velocity, discharge, slope, hydraulic radius and shear-related parameters	Input for MPM analysis
Sediment assessment	MPM bed-load calculation using available field and secondary data	Qb by station and critical-segment identification
AHP assessment	22 purposively selected respondents; six criteria; three alternatives	Criteria weights and local priorities
Decision synthesis	Weighted AHP aggregation with CR <= 0.10	Global alternative ranking
Management translation	Construction-management interpretation of technical and AHP results	Short-, medium-, and long-term strategy

IV. RESULT AND DISCUSSION

4.1. Sediment-Transport Profile and Critical Segment

The MPM calculations show a strong difference in computed bed-load transport among the three stations. Maximum Qb is 4,560,005.563 tons/day at the upstream station, 5,177,410.863 tons/day at the middle station, and 5,136,194.854 tons/day at the downstream station. The thesis classifies the middle station as very high and identifies it as the most critical segment because it has the greatest computed transport capacity. The downstream station is only slightly lower, indicating that sediment management cannot focus exclusively on a single point.

The location-specific result is consistent with the study premise that sediment behavior varies with hydraulic and morphological conditions rather than following a uniform downstream pattern. The middle station is situated around a change in channel direction, while the downstream reach receives material transported from upstream. This spatial variation supports segment-based monitoring and targeted intervention instead of applying the same treatment intensity along the entire reach [2,5,8].

Table 2. Maximum computed bed-load transport and criticality by river segment

Segment	STA	Qb max. (tons/day)	Class	Rank	Interpretation
Upstream	3+700	4,560,005.563	High	3	High transport, below middle and downstream
Middle	3+350	5,177,410.863	Very High	1	Highest Qb; identified as the most critical segment
Downstream	3+000	5,136,194.854	Moderately High	2	Very high transport with deposition potential in lower-velocity zones

4.2. AHP Criteria Priorities

AHP gives the greatest weight to Sedimentation Level (TS = 0.3730), followed by Flood Risk (RB = 0.2325). Threat to Settlements (AP) and Threat to Infrastructure (AI) each receive 0.1339, while Ease of Implementation (KP) receives 0.0778 and Treatment Cost (BP) 0.0489. The consistency test for the six-criterion matrix yields CR = 0.0179, well below the 0.10 threshold. This weighting indicates that the respondent group prioritizes technical sediment severity and flood reduction over constructability and cost when selecting the principal control measure.

Local priorities differ by criterion. Sabo Dam leads under Sedimentation Level and Flood Risk; river normalization leads under threats to settlements and infrastructure; and gabion groyne leads under ease of implementation and cost. This pattern is important for management because it shows that no alternative dominates every decision dimension. The final ranking therefore reflects an explicit trade-off across technical, social, implementation, and economic considerations rather than a one-factor selection.

Table 3. AHP criteria weights, local priorities, and consistency

Criterion	Weight	Sabo Dam	Gabion Groyne	Normalization	CR	Leading Alternative
TS - Sedimentation level	0.3730	0.6515	0.1185	0.2300	0.0104	Sabo Dam
RB - Flood risk	0.2325	0.6325	0.1298	0.2377	0.0240	Sabo Dam
AP - Threat to settlements	0.1339	0.1539	0.2923	0.5538	0.0148	River normalization
AI - Threat to infrastructure	0.1339	0.1539	0.2923	0.5538	0.0148	River normalization
KP - Ease of implementation	0.0778	0.1169	0.5704	0.3128	0.0240	Gabion groyne
BP - Treatment cost	0.0489	0.1023	0.5769	0.3208	0.0279	Gabion groyne

The high combined weight of sedimentation level and flood risk explains why Sabo Dam receives the strongest global score even though it is not the preferred option for ease of implementation or treatment cost. This result should be interpreted as a planning priority rather than a final design decision. The thesis explicitly limits its scope before detailed structural design, geotechnical verification, and project-level cost estimation, so implementation of a Sabo Dam requires subsequent feasibility and engineering studies [6,7,9,12].

4.3. Global Alternative Ranking

Global synthesis ranks Sabo Dam first with a score of 0.4454, river normalization second with 0.3294, and gabion groyne third with 0.2252. All alternative comparison matrices have CR <= 0.10, so the source study treats the judgments as consistent. The ranking supports Sabo Dam as the principal medium-term structural option, while the strengths of normalization and gabion work justify their continued use as operational and localized measures.

The result also illustrates the value of integrating MPM and AHP. MPM identifies where sediment transport is most critical, whereas AHP addresses what type of intervention should receive priority after considering additional risks and implementation constraints. In this way, the hydraulic analysis and the management decision are connected without assuming that the highest Qb automatically dictates a single construction solution.

4.4. Construction-Management Strategy

The thesis translates the ranking into a staged implementation strategy. Short-term actions (0-2 years) emphasize measures that can quickly restore conveyance and strengthen routine control; medium-term actions (2-5 years) focus on priority sediment-control construction and formal project controls; and long-term actions (more than 5 years) address watershed sources, monitoring, institutional coordination, and infrastructure asset management. This sequence allows urgent operational needs to be treated while more complex capital works are designed and funded.

This staging resolves an apparent difference between the global AHP rank and immediate implementation needs. Sabo Dam is the highest-priority alternative in the multicriteria synthesis, but the thesis recommends normalization and maintenance first because they are faster to mobilize and can provide direct short-term benefit while design, budgeting, and construction preparation for the principal structure are completed. Gabion works remain appropriate for localized bank protection, particularly at erosion-prone outer bends.

Table 4. Staged sediment-control strategy in a construction-management framework

Horizon	Management Objective	Priority Actions
Short term (0-2 years)	Recover channel function and reduce immediate flood exposure.	Normalize priority reaches; remove deposited sediment and obstructing vegetation; repair existing gabions; establish routine O&M; monitor discharge, bed elevation, and cross-section change.
Medium term (2-5 years)	Implement priority structural control with formal project management.	Develop Sabo Dam as the principal AHP-ranked option subject to feasibility and detailed design; strengthen vulnerable banks; improve connected drainage; control schedule, cost, quality, risk, and supervision; evaluate structure performance.

Horizon	Management Objective	Priority Actions
Long term (>5 years)	Reduce sediment supply and sustain infrastructure performance.	Rehabilitate the watershed through reforestation and erosion control; develop data-based sediment monitoring; prepare a sediment-control master plan; strengthen institutional coordination; update strategies using monitoring and asset-performance results.

4.5. Managerial Implications and Limitations

For infrastructure management, the results can guide priority investment, operation and maintenance, risk control, and coordination among the Teluk Wondama Regency Government, river-basin authorities, disaster-management agencies, contractors, consultants, and communities. The combined framework makes the logic of prioritization visible: segment severity is quantified first, decision criteria are weighted second, and implementation is then phased according to urgency and project readiness.

The study is bounded by the available source data. It evaluates only a 0.70 km reach and three stations; it applies an empirical MPM calculation rather than a numerical hydraulic or morphodynamic model; and it does not include detailed structural design, stability analysis, or construction cost calculation. The AHP component also depends on purposive judgments from 22 respondents. These limitations mean that the ranking should support planning and feasibility analysis rather than substitute for detailed engineering.

Future work should extend the hydraulic observation period, incorporate numerical sediment and channel-morphology simulation, test alternative structure locations, and develop detailed Sabo Dam design, geotechnical assessment, scheduling, cost estimation, and cost-benefit analysis. Broader watershed and climate variables can also be integrated to examine how changing land use and rainfall may alter sediment supply and flood risk over the infrastructure life cycle.

V. CONCLUSION

The Ati River assessment integrates bed-load analysis and multicriteria decision making to connect sediment severity with construction-management priorities. The maximum computed Qb is 4,560,005.563 tons/day at STA 3+700, 5,177,410.863 tons/day at STA 3+350, and 5,136,194.854 tons/day at STA 3+000. The middle segment therefore has the highest computed sediment transport and is identified as the most critical reach within the study area.

AHP ranks Sabo Dam first (0.4454), river normalization second (0.3294), and gabion groyne third (0.2252). Sedimentation level and flood risk are the dominant criteria, while normalization performs most strongly for settlement and infrastructure exposure and gabion groyne performs most strongly for implementation ease and cost. All reported comparison matrices meet CR <= 0.10.

The most practical implication is a phased strategy: immediate normalization, maintenance, and monitoring; medium-term development of priority control structures subject to feasibility and detailed design; and long-term watershed rehabilitation, monitoring systems, institutional coordination, and asset management. Because the analysis is limited to three stations and does not include numerical morphodynamic modeling or detailed engineering, the results should be used as a transparent prioritization basis for the next stage of river-control planning.

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