Analysis of the Impact of Mining Activities on Flooding in Pangkalpinang City

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ABSTRACT

Flooding is one of the problems in Pangkal Pinang City. Tin mining activities in the districts around Pangkal Pinang City have triggered flooding in Pangkal Pinang City Apart from that, the reduction in catchment areas and sub-optimal polder system infrastructure affect the height and duration of flood inundation in Pangkal Pinang City. Flood management is currently still partial, so it is necessary to carry out integrated coordination between agencies and institutions to review the master plan for flood management in Pangkal Pinang City. To prevent flooding, it is necessary to review the things that cause flooding, so research needs to be carried out to analyze these things. This research aims to determine and analyze the influence of mining activity factors, catchment areas, polder systems and coordination on flood conditions in Pangkal Pinang City. This research uses a multiple linear regression analysis model with supporting data from historical data on the height and average duration of flood inundation in Pangkal Pinang City. The research results showed that the model equation Y = 3.216 + 0.484X1 – 0.396X2 – 0.412X3 – 0.480X4. Based on the results of data analysis using SPSS, the results showed that mining activity factors, catchment areas, polder systems and coordination had an influence on flood conditions in Pangkal Pinang City with an influence contribution of 85.0% with the most dominant variable ranking influencing flooding, namely mining activity. The regression coefficient value for the mining activity variable has a positive value of 0.484. This shows that if mining activity increases by 1%, then the height and duration of flooding as a flood indicator will increase by 0.484 times assuming other independent variables are considered constant. This model is used to project future floods. With this modeling, it is hoped that it can be used to overcome flooding in Pangkal Pinang City.

Keywords: floods, mining, activities, polder systems, coordination.

INTRODUCTION

Tin is the main commodity of the Bangka Belitung Islands Province. Tin exploitation is based on public policy in the mining sector based on the 1945 Constitution which states that "The land and water and the natural resources contained therein are controlled by the State and used as much as possible for the prosperity of the people". The level of environmental damage on Bangka Island is very worrying [1].

Large-scale tin mining exploitation activities have caused environmental problems that have an impact on the decline in environmental quality. The increasing population and the high price of tin minerals have caused many people to convert agricultural land into mining areas where exploitation does not pay attention to land conversion and the environment.

Tin mining activities carried out conventionally and unconventionally have a significant impact on the environment, one of which is the expansion of critical land. Based on the Decree of the Director General of Watershed Management and Forest Rehabilitation of the Ministry of Environment and Forestry [2] concerning the Determination of National Critical Land Maps and Data in 2022, the area of critical land in the Bangka Belitung Islands Province increased to 167,104 Ha. Critical land in Bangka Regency and Central Bangka Regency triggered flooding to Pangkal Pinang City. This is supported by topographic conditions that have a flat contour and tend to be concave (-0.6 to 3 meters above sea level) compared to the surrounding districts, so that Pangkal Pinang City is downstream from the upstream in Bangka Regency and Central Bangka Regency.

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It is regulated that the proportion of green open space in the city area is at least 30% of the area. Based on data from the Pangkal Pinang City Environmental Service in 2024, the function of green open space as a city catchment area has not been fulfilled, because it only meets 21.225% of the minimum green open space area requirements.

Tin mining waste from Bangka and Central Bangka Regencies carried by water currents to Pangkal Pinang City can cause sedimentation in the Polder System. Currently there are 2 ponds operating as a polder system in Pangkal Pinang City, namely the Kacang Pedang Retention Pond and the Rangkui PDAM Pond. Sediment contained in the Kacang Pedang Retention Pond Polder System and the PDAM Pond can cause changes in channel dimensions, reduce channel capacity and cause shallowing, so that the ability to drain water is reduced, causing flooding problems in residential areas. In addition, inadequate city drainage infrastructure is the main cause of the large number of puddles in several points in Pangkalpinang City during the rainy season. Many drains are clogged due to the large amount of garbage and high sedimentation. Lack of public awareness of environmental cleanliness such as throwing garbage into rivers or gutters and closing drainage channels for personal interests are the causes of flooding and puddles in Pangkalpinang City.

Mining

Quoting the press release of the Ministry of Energy and Mineral Resources, entitled Mining Management Must Consider Environmental Aspects, it is stated that "mining activities are the process of extracting and processing minerals, metals, coal, and other natural resources from beneath the earth's surface or from open natural resources such as open pit mines. Mining activities involve a series of steps, including exploration, mining, processing, and marketing of mining products [3]. Mining activities do not always cause environmental damage if they are implemented in accordance with good mining practices". Research conducted by Bayu states that mining activities result in land damage [4].

Tin mining is indicated to have various implications including land disturbances that lead to environmental damage, many mining areas have the potential for abrasion and ecosystem damage that has the potential to cause drought and landslides [5]. In addition, mining land openings can increase flood runoff and sedimentation [6].

Water Catchment Area

A water catchment area is an area where water enters from the ground surface into the water-saturated zone so that it forms a groundwater flow that flows to lower areas.

The function of the water catchment area is to accommodate the discharge of rainwater that falls in the area. Indirectly, the water catchment area plays an important role in controlling the occurrence of stagnant water because the area that functions as a water catchment will absorb rainwater into the ground and prevent drought in the dry season in the area below.

Stated that the condition of a good water catchment area can be seen from the results of its infiltration conditions. The better the infiltration in an area, the better the resulting absorption conditions. Infiltration in water absorption is divided into six categories, namely: good conditions, natural normal conditions, starting critical conditions, slightly critical conditions, critical conditions, very critical conditions.

Water Absorption Area Indicators

Here are some aspects for assessing water absorption areas [7]:

1. Harmonious hydrogeological aspects, including the direction of groundwater flow, the presence of water-bearing layers, the condition of the cover soil and rainfall;
2. Morphological aspects, the higher and flatter the land, the better it is as a water catchment area and;
3. Land use aspects, land covered by plants is better for the water catchment process.

The indicators for assessing water catchment areas are land use, namely the area of built-up land (%) and the area of green open space (%).

Make the determinants of water catchment areas land use, rainfall, land slope and soil texture. Water catchment areas are able to accommodate the discharge of rainwater that falls. In addition to having a direct impact on flood control, catchment areas can also be water reserves in the dry season and water supply for areas below. This is because rainwater does not fall to lower areas but is absorbed as groundwater [7].

One way to overcome the problem of flooding is to make biopore infiltration holes. Biopore infiltration holes are part of eco-drainage or environmentally friendly drainage with the basic principle of controlling excess surface water in such a way that runoff can flow in a controlled manner and have more opportunity to seep into the soil. Therefore, to overcome flooding, biopore infiltration holes need to be made.

Polder System

The Polder System is a system that is hydrologically separated from its surroundings, either naturally or artificially, which is equipped with embankments, internal drainage systems, pumps and/or reservoirs, and water gates.

A polder is a collection of lowlands that form an artificial hydrological unit surrounded by embankments. The addition of a polder system can lower the average water level compared to without a polder system. With good planning, the polder system can be used to overcome flooding [8].

The polder system consists of several components that form a unit that supports the success of the drainage system. The development of the polder system must consider aspects of safety, sustainability, and flexibility in accordance with the polder concept developed in the Netherlands as one of the countries with the best polder systems in the world [9]. The research revealed that the existence of a pump house is very important to overcome flooding. However, it must be accompanied by the implementation of the Standard Operating Procedure (SOP). The operational procedure is in the form of the number of pump units that are run. The following image shows the components of the polder system [9].

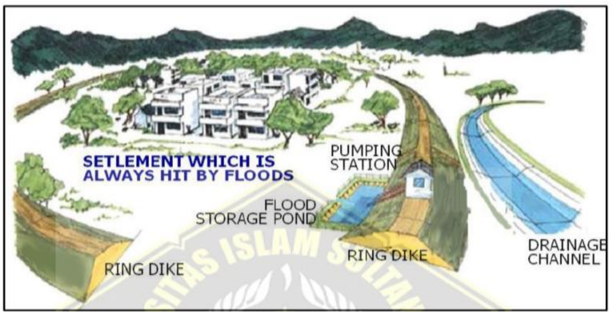

Figure 1. Polder System Components [9]

The elements of the polder system consist of a drainage network, embankment, retention pond and pump body. The following are the four elements of the polder system that must be planned integrally, so that they can work optimally [10], [11].

Drainage Network

Drainage is a term used for a system for handling excess water. Specifically for the term urban drainage, the excess water in question is water that comes from rainwater. Excess rainwater in an area can cause problems, namely stagnant water or puddles, so a drainage channel is needed that functions to accommodate rainwater and then drain the rainwater to the reservoir. From the reservoir, to control the water level elevation, the excess water must be discharged through pumping.

Definition of Coordination

Coordination is a process of leadership developing a regular group effort system among subordinates and ensuring unity of action in achieving common goals. In other words, the form of a cooperation

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system in the division of tasks and functions and responsibilities in each different unit in the agency. The implementation of leadership coordination in a command agency is called structural coordination, which means that the implementation of this coordination is carried out because it has a work unit under the same leadership. Structural coordination can be described as a leader who has the responsibility and authority to direct his subordinates who are under his leadership.

Flood

Flood is a river overflow that inundates the surface land. The research stated that changes in land cover can affect flood discharge [8]. The causes of flooding in urban areas are generally lack of water absorption, poor spatial planning systems, water inflow from other areas, large amounts of waste in drainage channels, and high rainfall. In addition, mining land openings can also affect flood runoff discharge. Other factors identified as causes of flooding are the amount of waste production, the number of settlements on riverbanks, and the number of slopes [12].

Flooding in Pangkal Pinang City

Flooding is a problem that often hits Pangkalpinang City. History shows that Pangkalpinang City experienced a major flood. This flood occurred around the riverbanks or the Pintu Air Dam. This inflow flood occurred because the upstream land received heavy rain that flowed to the downstream area. Thus, the flow exceeded the capacity of the water channel. Floods submerged 3,112 houses and 2,316 residents were evacuated to 16 locations spread across Pangkalpinang City [13].
The topographic conditions of Pangkalpinang City, which have a flat contour and tend to be concave (-0.6 to 3 meters above sea level) compared to the surrounding districts, are one of the causes of flooding in Pangkalpinang City.
Judging from the hydrological conditions, Pangkal Pinang City is influenced by several rivers, including the Rangkui River, Pedindang River, and Baturusa River. These rivers function as the main channels for draining the city's rainwater, as well as river transportation infrastructure from the market to the Baturusa River and then to the sea.

RESEARCH METHODS

This study uses a quantitative descriptive research method, and the quantitative research method in its implementation identifies existing facts and symptoms and conducts research to find factual information. The data obtained will be used as research variables. The next process is to measure the relationship or correlation and influence between two or more variables. This method also involves evaluation and comparison of what has been done in dealing with similar situations and problems, and the results can be used in preparing plans/solutions for future decision making [14]. The following is a research flowchart.

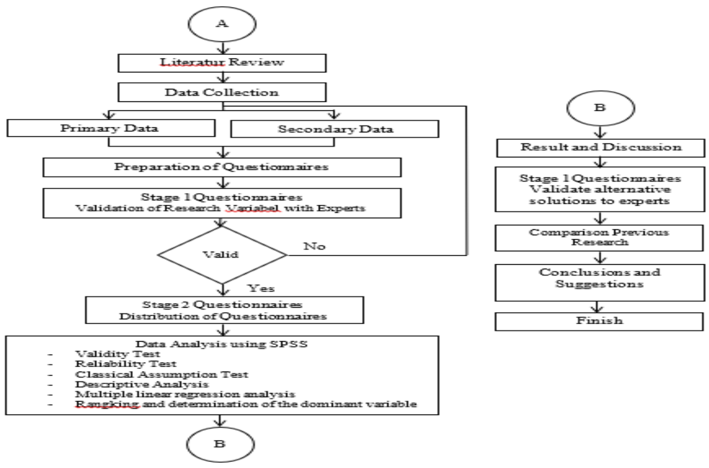

Figure 1. Research Flowchart

Population and Sampling Method

A population is a generalization area consisting of objects or subjects that have certain qualities and characteristics that are determined by researchers to be studied and then conclusions are drawn.
To calculate the number of samples from a certain population, sampling uses the Slovin Formula with the following formula:
$n=N/(1+N e^2)$
Description:
n: sample size
N: population size
e: percentage of inaccuracy due to sampling errors that are still tolerable or desired [15].

Research Variables & Hypotheses

A variable is a characteristic or attribute of an individual or organization that can be measured or observed that has certain variations determined by researchers to be used as lessons and then conclusions are drawn. In this study, flooding is the dependent variable (Y) because it is the object that is affected. While the influencing/causing variable is the independent variable (X), namely the factors that influence flooding. The relationship between the independent (X) and dependent (Y) variables in this study can be modeled [15].

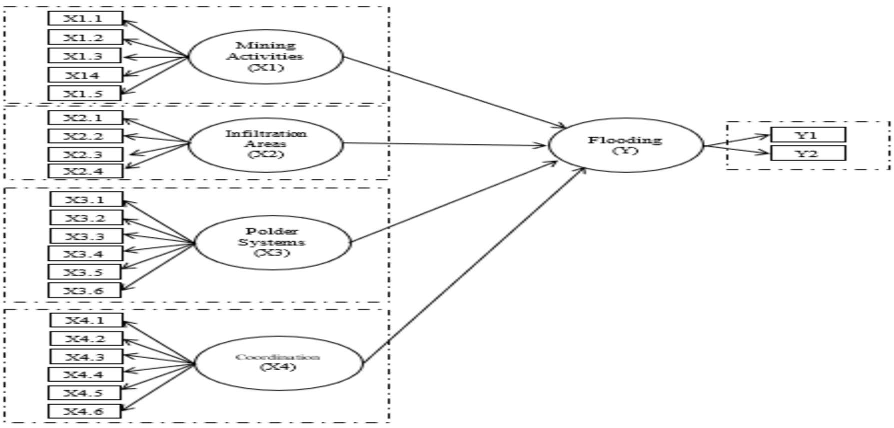

Figure 2. Research variables and hypotheses

Application & Use of Statistical Product and Service Solutions (SPSS)

SPSS software has the advantage of more informative data display, more accurate information by providing reason codes if data errors occur. SPSS is the most widely used software because its display is easy for users to understand and can be accessed in various available formats, such as dBase, Lotus, Text files.

Validity Test

A validity test is needed to determine whether or not the statement items of a questionnaire are valid. Validity is the degree of accuracy between the data that actually occurs in the object and the data collected by the researcher. The correlation method used to test validity is the Pearson product moment correlation with the following formula [15],
$r_{xy}=(n\Sigma x_i y_i-(\Sigma x_i).(\Sigma y_i))/\sqrt{([n\Sigma x_i^2-(\Sigma x_i)^2][n\Sigma y_i^2-(\Sigma y_i)^2])}$
Where:
rxy: Product moment correlation coefficient
n: Number of subjects in the instrument test
Σx_i: Number of observations of variable x
Σy_i: Number of observations of variable y
$\Sigma x_i y_{}$: Sum of the results of the multiplication of observations of variable x and variable y
Σ xi2: Sum of squares on each x score
Σ yi2: Sum of squares on each y score

Reliability Test

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Reliability test is the extent to which measurement results using the same object will produce the same data.
Reliability is determined by the cronbach's alpha value (α), namely:

$$\alpha = [N / (N-1)][1 - (\Sigma\sigma^2 \text{ items}) / (\sigma^2 \text{ total})]$$

Explanation of the cronbach's alpha formula above:
α : cronbach's alpha
N : number of questions
σ 2 items : variance of question items
σ 2 total : variance of total score [15]

Multiple Linear Regression Analysis

Regression analysis is a structural model that aims to test the amount of contribution indicated by the path coefficient in each path diagram of the causal relationship of the independent variable (X) to the variable (Y). States that multiple linear regression analysis is an analytical tool used to predict changes in the value of the dependent variable if the value of the independent variable is increased or decreased [15].

RESULTS AND DISCUSSION

Overview of Research Object

The research review area is in the Bangka Belitung Islands Province, precisely in Pangkal Pinang City. Pangkal Pinang City is an autonomous region as well as the capital of the Bangka Belitung Islands Province. The Bangka Belitung Islands Province is divided into 7 regencies/cities, including West Bangka Regency, Bangka Regency, Central Bangka Regency, South Bangka Regency, Pangkal Pinang City, Belitung Regency, and East Belitung Regency. Pangkal Pinang City is divided into 7 sub-districts and has 42 villages. The list of sub-districts in Pangkal Pinang City includes Gerunggang, Gabek, Girimaya, Pangkalbalam, Rangkui, Bukit Intan, and Taman Sari Districts [16]. The Administrative Map of the Bangka Belitung Islands Province can be seen in the following image.

Figure 3. Map of the Bangka Belitung Islands Province

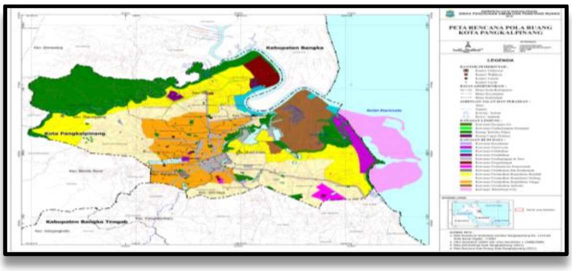

Figure 3. Map of Pangkal Pinang City RTRW

The Polder System used as the object of research is: Kacang Pedang Retention Pond, Rangkui PDAM Pond, Jl. Boga Pump House, Bintang Village, Rangkui Water Gate along with its drainage network which will be shown in the following image:

Figure 4. Jalan Boga Pump House, Bintang Village

Next, the experts validated the variables in the questionnaire in the form of statements of agreement or disagreement. The validation data from the first questionnaire results, namely in the form of statements of agreement or disagreement from the experts, as well as additional suggestions for variable indicators from the experts, were then processed with parameters if the answers from the experts were greater than 50% who agreed, then the variable would be used in the next questionnaire, while if the answers from the experts were less than 50% who agreed, then the variable would be eliminated and would not be used in the next questionnaire.

The following are the research variables from expert validation results that will then be used in the next questionnaire.

Table 2. Research Variables from Expert Validation Results

No	Variable	Dimension	Indicator code	Indicator Variable
1.	Mining Activity (X1)	Environmental Damage	X1.3	Critical land due to mining activities is expanding.
			X1.4	Former mining pits have the potential to cause landslides and erosion.
			X1.5	Increasing forest and land damage.
		Environmental Quality	X1.6	The quality of the environment in the Bangka Belitung Islands Province has decreased.
		Location	X1.7	The mining location is in a water catchment area.
		Waste	X1.8	Mining waste damages the environmental ecosystem.
		Waste	X1.9	The source of raw water in the former tin mining pit contains heavy metals.
		Technology	X1.10	Mining technology is still conventional.
		Mineral Resource Potential	X1.11	The amount of mineral and geological resources in the Bangka Belitung Islands Province is abundant.
			X1.12	Information regarding the geological potential in the Bangka Belitung Islands Province is not yet optimal.
		Land Conversion	X1.13	Many plantation areas have been turned into mining areas.
		Law	X1.14	The rise in community mining (tin mining without a permit).
			X1.15	The government has not taken firm action against illegal miners.
		Policy System	X1.16	Good maintenance practice activities have not been running well.
			X1.17	There are obstacles in land reclamation.
			X1.18	The land rehabilitation budget is not optimal.
2.	Catchment Area (X2)	Land use conditions	X2.1	The development of settlements in built-up areas takes into account water catchment areas. Green Open Space (RTH) in Pangkal Pinang City and its surrounding districts is not sufficient to

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No	Variable	Dimension	Indicator code	Indicator Variable
				accommodate the discharge of rainwater that falls.
			X2.5	As an infiltration area, the elevation conditions of Pangkal Pinang City which are flat and tend to be concave have been planted with the right types of vegetation, such as bamboo and banyan.
		Topographic conditions	X2.3	The number of biopore holes is not evenly distributed throughout Pangkal Pinang City.
		Biopore holes	X2.6	The government has built infiltration wells.
		Infiltration wells	X2.7	Drainage channels are routinely dredged by related agencies.
3.	Polder System (X3)	Drainage conditions	X3.2	The current capacity of the drainage channels is not yet able to accommodate the volume of flooding that occurs.
			X3.7	The water level is always monitored routinely by related agencies to detect potential flooding or drought early.
		Pump operational conditions	X3.3	The pump house is currently operating optimally.
			X3.8	The government has prepared a handling strategy to reduce sedimentation in retention ponds along with its budget plan.
		Retention pond conditions	X3.5	Normalization of retention ponds is carried out routinely by related agencies.
			X3.6	The budget in agencies to support flood control programs/activities includes the budget for personnel in the field.
4.	Coordination	Unity of Action	X4.2	The program/activity in the Engineering Service Project for Bangka Island Flood Management in Bangka Belitung Province has not been realized according to plan.
			X4.7	Frequency of internal communication related to flood control programs/activities > 3 times a month.
		Communication	X4.3	Frequency of external communication with agencies/departments related to flood control > 3 times a month.
			X4.4	The implementation of tasks between fields has been synergized through joint seminars related to the duties and programs of the agency.
		Division of Labor	X4.5	Availability of SOPs in the implementation of work in agencies that minimize the involvement of leaders in carrying out daily tasks.
		Discipline	X4.6	Based on observations of floods in Pangkal Pinang City, the average inundation time is 30-60 minutes.
5.	Flood	Inundation	Y1	Based on observations of floods in Pangkal Pinang City, the average inundation height is 15-25 cm.
			Y2	Critical land due to mining activities is expanding.

Source: Researcher Processing, 2024

Respondent Overview

Respondents in this study were employees at agencies and departments in Pangkal Pinang City, agencies and departments in bordering regencies/cities, as well as other agencies and departments that have experience and knowledge about flood infrastructure development and handling of former mining areas.

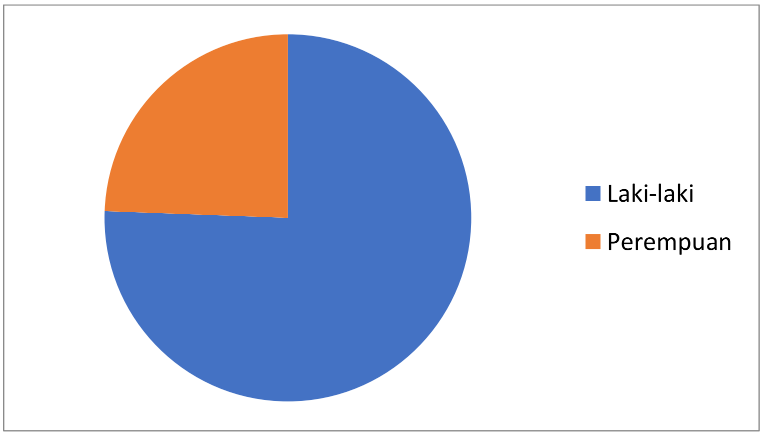

Figure 5. Respondent Characteristics Based on Source: Researcher Processing (2024)

Based on gender characteristics in this study, of the 86 respondents, 65 (75.6%) were male and 21 (24.4%) were female.

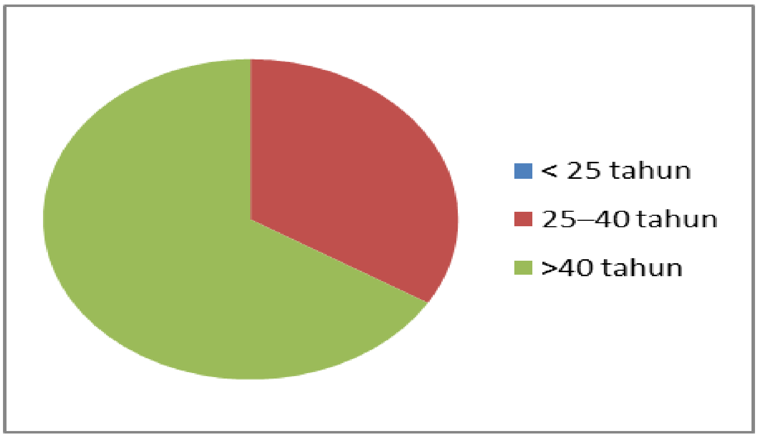

Figure 6. Respondent Characteristics Based on Age Source: Researcher Processing (2024)

Based on the age characteristics in this study, of the 86 respondents, 29 (33.7%) were aged 25–40 years and 57 (66.3%) were over 40 years old and none were under 25 years old.

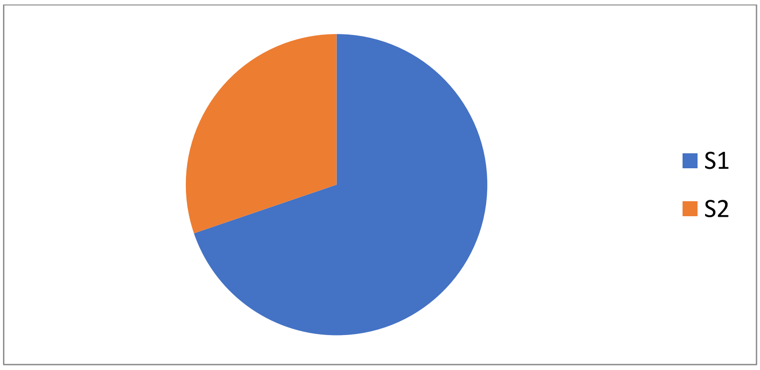

Figure 7. Respondent Characteristics Based on Last Education Source: Researcher Processing (2024)

Based on the characteristics of the last education in this study, of the 86 respondents, 60 (69.8%) had a bachelor's degree, and 26 (30.2%) had a master's degree.

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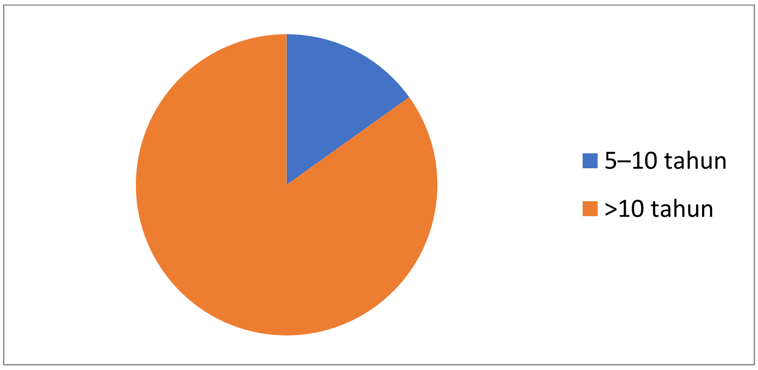

Figure 8. Respondent Characteristics Based on Work Experience Source: Researcher Processing (2024)

Based on the characteristics of work experience in this study, of the 86 respondents, 13 (15.1%) had 5-10 years of work experience and 73 (84.9%) had more than 10 years of work experience.

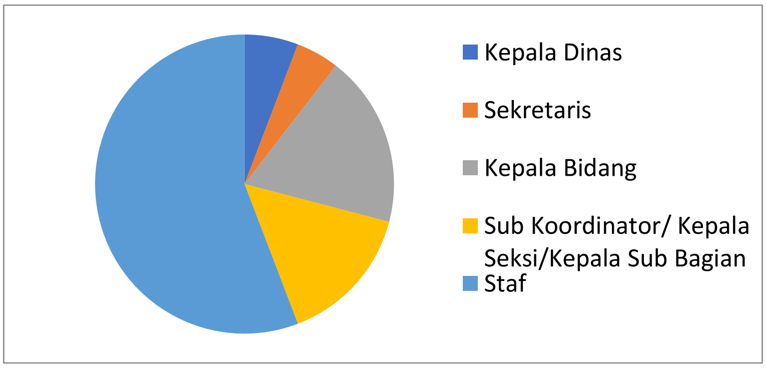

Figure 9. Respondent Characteristics Based on Position Source: Researcher Processing (2024)

Based on the characteristics of the positions in this study, out of 86 respondents, 7 (13.2%) had the position of head of department, 38 (71.7%) had the position of secretary, 38 (71.7%) had the position of head of division, 38 (71.7%) had the position of sub-coordinator/section head/sub-section head and 3 (5.7%) had the position of staff.

Descriptive Analysis of Mining Activities (X1)

The mining activity variable in this study was measured through 16 indicators with a total of 86 respondents as follows:

Table 3. Respondents' Responses Regarding Mining Activities

No	Statement	STS	%	TS	%	N	%	S	%	SS	%	Weight	Maximum value	%
1	X1.3	0	0%	0	0%	8	9%	49	57%	29	34%	365	425	86%
2	X1.4	29	34%	23	27%	5	6%	17	20%	12	14%	218	425	51%
3	X1.5	23	27%	28	33%	1	1%	21	24%	13	15%	231	425	54%
4	X1.6	0	0%	0	0%	11	13%	54	63%	21	24%	354	425	83%
5	X1.7	10	12%	39	45%	17	20%	16	19%	4	5%	223	425	52%
6	X1.8	8	9%	27	31%	21	24%	25	29%	5	6%	250	425	59%
7	X1.9	8	9%	30	35%	18	21%	26	30%	4	5%	246	425	58%
8	X1.10	8	9%	38	44%	16	19%	19	22%	5	6%	233	425	55%
9	X1.11	6	7%	35	41%	29	34%	12	14%	4	5%	231	425	54%
10	X1.12	0	0%	7	8%	15	17%	42	49%	22	26%	337	425	79%
11	X1.13	0	0%	13	15%	19	22%	41	48%	13	15%	312	425	73%
12	X1.14	0	0%	2	2%	15	17%	53	62%	16	19%	341	425	80%
13	X1.15	0	0%	7	8%	17	20%	39	45%	23	27%	336	425	79%
14	X1.16	3	3%	8	9%	13	15%	49	57%	13	15%	319	425	75%
15	X1.17	4	5%	5	6%	20	23%	48	56%	9	10%	311	425	73%

16	X1.18	4	5%	8	9%	12	14%	49	57%	13	15%	317	425	75%
Jumlah		103	7%	270	20%	237	17%	560	41%	206	15%	4624	6800	68%

Source: Researcher Processing 2024

Based on Table 3 above, it can be explained that of the 16 statement items submitted, 15% of respondents answered strongly agree, 41% of respondents answered agree, 17% of respondents answered Neutral, 20% of respondents answered disagree and 7% strongly disagree.

Descriptive Analysis of Infiltration Areas (X2)

The infiltration area variable in this study was measured through 5 indicators with a total of 86 respondents as follows:

Table 4. Respondents' Responses Regarding Infiltration Areas

No	Statement	STS	%	TS	%	N	%	S	%	SS	%	Weight	Maximum value	%
1	X2.1	0	0%	0	0%	1	1%	48	56%	37	43%	380	425	89%
2	X2.3	35	41%	21	24%	1	1%	16	19%	13	15%	209	425	49%
3	X2.5	0	0%	0	0%	2	2%	45	52%	39	45%	381	425	90%
4	X2.6	23	27%	29	34%	1	1%	20	23%	13	15%	229	425	54%
5	X2.7	0	0%	0	0%	3	3%	48	56%	35	41%	376	425	88%
Total		58	13%	50	12%	8	2%	177	41%	137	32%	1575	2125	74%

Source: Researcher Processing 2024

Based on Table 4 above, it can be explained that of the 5 statement items submitted, 32% of respondents answered strongly agree, 41% of respondents answered agree, 2% of respondents answered Neutral, 12% of respondents answered disagree and 13% strongly disagree.

Descriptive Analysis of the Polder System (X3)

The polder system variable in this study was measured through 6 indicators with a total of 86 respondents as follows:

Table 5. Respondents' Responses Regarding the Polder System

No	Statement	STS	%	TS	%	N	%	S	%	SS	%	Weight	Maximum value	%
1	X3.2	33	38%	43	50%	10	12%	0	0%	0	0%	149	425	35%
2	X3.3	30	35%	42	49%	13	15%	1	1%	0	0%	157	425	37%
3	X3.5	38	44%	30	35%	18	21%	0	0%	0	0%	152	425	36%
4	X3.6	39	45%	36	42%	10	12%	1	1%	0	0%	145	425	34%
5	X3.7	4	5%	28	33%	30	35%	24	28%	0	0%	246	425	58%
6	X3.8	32	37%	39	45%	15	17%	0	0%	0	0%	155	425	36%
Total		176	34%	218	42%	96	19%	26	5%	0	0%	1004	2550	39%

Source: Researcher Processing 2024

Based on Table 5 above, it can be explained that of the 6 statement items submitted, 0% of respondents answered strongly agree, 5% of respondents answered agree, 19% of respondents answered Neutral, 42% of respondents answered disagree and 34% strongly disagree.

Descriptive Analysis of Coordination (X4)

The coordination variable in this study was measured through 6 indicators with a total of 86 respondents as follows

Table 6. Respondents' Responses Regarding Coordination

No	Statement	STS	%	TS	%	N	%	S	%	SS	%	Weight	Maximum value	%
1	X4.2	2	2%	10	12%	16	19%	38	44%	20	23%	322	425	76%
2	X4.3	0	0%	13	15%	18	21%	39	45%	16	19%	316	425	74%
3	X4.4	3	3%	5	6%	16	19%	43	50%	19	22%	328	425	77%
4	X4.5	13	15%	44	51%	17	20%	10	12%	2	2%	202	425	48%
5	X4.6	0	0%	3	3%	17	20%	49	57%	17	20%	338	425	80%
6	X4.7	14	16%	40	47%	11	13%	16	19%	4	5%	214	425	50%
Total		32	6,2%	115	22,3%	95	18,4%	195	37,9%	78	15,1%	1720	2125	81%

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Source: Researcher Processing 2024

Based on Table 6 above, it can be explained that of the 6 statement items submitted, 15.1% of respondents answered strongly agree, 37.9% of respondents answered agree, 18.4% of respondents answered Neutral, 22.3% of respondents answered disagree and 6.2% strongly disagree.

Descriptive Analysis of Floods (Y)

The flood variable in this study was measured through 5 indicators with a total of 86 respondents as follows:

Table 7. Respondents' Responses Regarding Floods

No	Statement	STS	%	TS	%	N	%	S	%	SS	%	∑	%	
1	Y1	6	7%	5	6%	19	22%	45	52%	11	13%	308	425	72%
2	Y2	6	7%	7	8%	13	15%	49	57%	11	13%	310	425	73%
Total		12	7%	12	7%	32	19%	94	55%	22	13%	172	100%	73%

Source: Researcher Processing 2024

Based on Table 7 above, it can be explained that of the 2 statement items submitted, 13% of respondents answered strongly agree, 55% of respondents answered agree, 19% of respondents answered Neutral, 7% of respondents answered disagree and 7% strongly disagree.

Multiple Linear Regression Analysis

The multiple linear regression equation is obtained by looking at the results of the Unstandardized coefficients value in the SPSS output. The Unstandardized coefficients value is usually used to predict independent variables against dependent variables, so that a picture of the future is obtained with past data. The following is a table of the results of the multiple linear regression analysis:

Table 8. Results of Multiple Linear Regression Analysis

Coefficients[a]								
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	3.216	.642		5.010	.000		
	Mining_activity	.484	.023	1.919	20.848	.000	.218	4.577
	Reach_area	-.396	.032	-.766	-12.379	.000	.484	2.066
	Polder_system	-.412	.048	-.553	-8.589	.000	.446	2.240
	Coordination	-.480	.036	-.901	-13.366	.000	.407	2.454
a. Dependent Variable: Flood								

Source: SPSS Results, 2024

From the results of the regression analysis calculations, the Unstandardized Coefficients value for the mining activity variable (X1) was 0.484, the infiltration area variable (X2) was -0.396, the polder system variable (X3) was -0.412, and the coordination variable (X4) was -0.480.

Based on the table, the multiple linear regression equation can be described as follows:

$Y = \alpha + \beta 1X1 + \beta 2X2 + \beta 3X3 + \beta 4X4 + e$

$Y = 3.216 + 0.484X1 – 0.396X2 – 0.412X3 – 0.480X4$

Determination Analysis (R Square)

Determination analysis is a measure of how much the X variable contributes to the Y variable. This analysis is used to determine the magnitude of the contribution of the simultaneous influence of independent variables on the dependent variable. The magnitude of the contribution of the simultaneous influence of the variables of mining activities (X1), infiltration areas (X2), polder systems (X3) and coordination (X4) on the flood variable (Y) is 85.0%. The remaining 15.0% is influenced by other factors outside this study, such as weather, garbage, the number of settlements on riverbanks, and slope gradients.

Table 9. Results of Determination Analysis (R Square).

Model Summary[b]				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.922[a]	.850	.843	.778
a. Predictors: (Constant), Coordination, Catchment area, Polder system, Mining activity				
b. Dependent Variable: Flood				

Source: SPSS Results, 2024

Ranking and Determination of Dominant Variables

Ranking and determination of dominant variables are done by looking at the Standardized coefficients beta value. Standardized Coefficients Beta is usually used to determine the magnitude of the influence and effective contribution of independent variables to dependent variables, but only applies at that time and in that sample.

The results of data processing using SPSS obtained the Standardized Coefficients Beta values as follows:

Table 10. Zero-order Test Results

Model		Standardized Coefficients	Correlations		
		Beta	Zero-order	Partial	Part
1	(Constant)				
	Mining_activity	1.919	.566	.918	.897
	Reach_area	-.766	.166	-.809	-.533
	Polder_system	-.553	.147	-.690	-.370
	Coordination	-.901	.031	-.829	-.575

Source: SPSS Results, 2024

Discussion of Research Findings

Based on the research results, the variables of mining activity (X1), infiltration areas (X2), polder systems (X3) and coordination (X4) have a significant effect on the flood variable (Y).

Mining Activity Factors

Tin mining is indicated to have various implications including land disturbances that lead to environmental damage, many mining areas have the potential for abrasion and ecosystem damage that has the potential to cause drought and landslides [17]-[19]. This is in line with the results of the respondent assessment of the mining activity variable indicators that 86% of respondents stated that critical land due to mining activities is expanding and 83% stated that the quality of the environment in the Bangka Belitung Islands Province has decreased, and 51% stated that former mining holes have the potential to cause slope landslides and erosion. Research conducted by [4] also stated that mining activities cause landslides. This is supported by data from the Ministry of Environment and Forestry in 2022 that critical land due to mining activities in Bangka Regency increased to 24,463 Ha and in Central Bangka Regency to 30,948 Ha. According to Ibrahim, Dwi & Nanang in their book entitled Ecological Politics and Lessons from the Bangka Belitung, the urgency of natural resources needs to be understood not only at the level of economic interests, let alone mere politics. The continuous mining exploitation process has caused increasingly severe environmental conditions. The general characteristics of ex-mining land are severely damaged land that causes changes to the land, such as damaged soil structure layers and irregular land surfaces, loss of vegetation on the surface accompanied by damage to the soil layer structure is a driving factor for increased erosion which results in the loss of humus soil, so that the land becomes barren, and the formation of holes/holes from former mining excavations. Data from the Central Statistics Agency of Bangka Belitung in 2020, there were 2,356 holes/pits from former tin mining with a total area of around 4,010 hectares, with the following details:

1. Bangka Regency: 1044 pits (1,656 hectares)
2. West Bangka Regency: 344 pits (541 hectares)
3. South Bangka Regency: 232 pits (351 hectares)
4. Central Bangka Regency: 541 pits (831 hectares)
5. Belitung Regency: 195 pits (312 hectares)

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In 2003, the number of former tin mining pits in the Bangka Belitung Islands Province was only 887 pits with an area of 1,712.65 Ha. The number of pits has increased quite significantly. Currently, many plantation areas have been converted into mining areas. This is due to the suboptimal spatial planning of the region. Environmental damage due to tin mining activities in Bangka and Central Bangka Regencies can be seen from the environmental quality index which has experienced a downward trend from 2021-2022. This can be seen in the following graph:

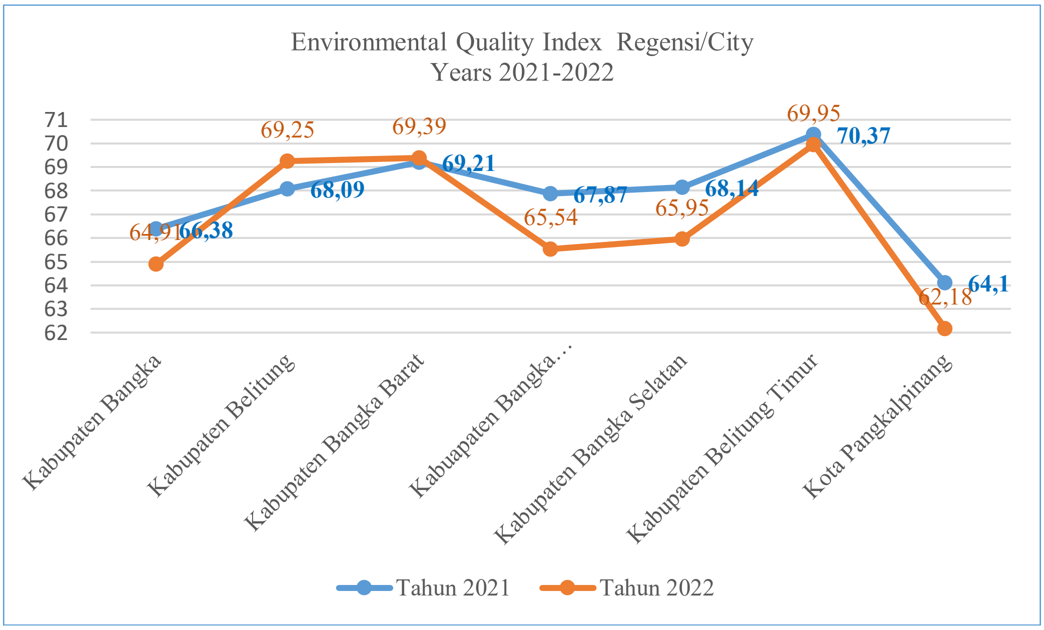

Figure 10. Regency/City Environmental Quality Index [20]

Judging from the graphic pattern, it can be concluded that the environmental quality in Bangka Regency and Central Bangka Regency has decreased from 2021-2022. The causes of the decline in environmental quality are generally caused by 2 factors, namely natural factors and human factors. Examples of natural factors include tornadoes, earthquakes, landslides and tsunamis. Meanwhile, the decline in environmental quality caused by human activities includes mining activities, logging, and forest fires. In addition to being seen from the environmental quality index, the water quality index value can also be used as a benchmark for the cause of flooding. The water quality index in the Bangka Belitung Islands Province in 2020-2022 can be seen in the following graphic image.

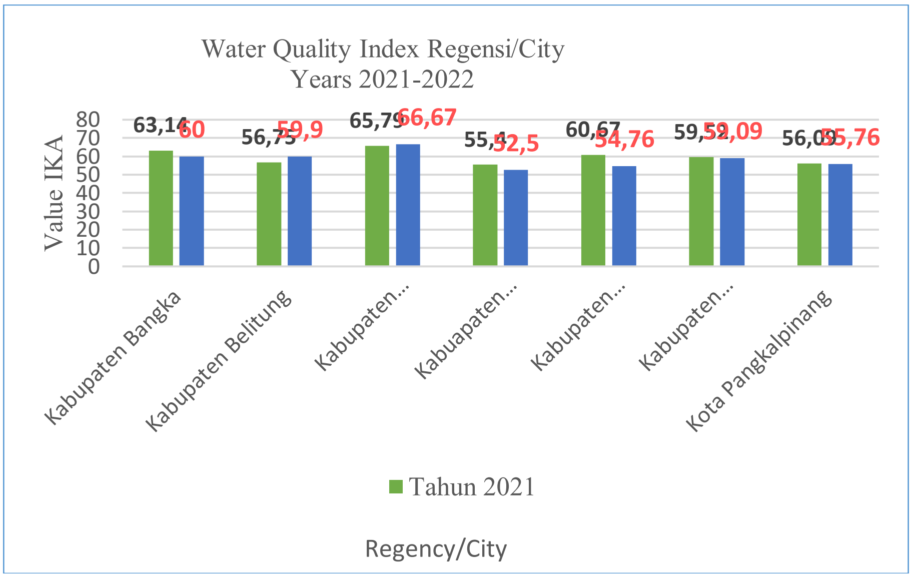

Figure 11. Water Quality Index of Bangka Belitung Islands Province [20]

Judging from the graphic pattern, it can be concluded that water quality in Bangka Regency and Central Bangka Regency has decreased from 2021-2022.

Waste from tin mining activities from Bangka and Central Bangka Regencies carried by water currents to Pangkal Pinang City can cause sedimentation in the Polder System. Sediment contained in the Kacang Pedang Retention Pond Polder System and PDAM Pond can cause changes in channel dimensions, reduce channel capacity and cause shallowing, so that the ability to drain water is reduced, causing flooding problems in residential areas. Referring to the results of the analysis, it was found that the influence of environmental damage, environmental quality, mining locations, mining waste, technology, mineral resource potential, land conversion, laws, and mining policies as indicators of mining activity on the height of inundation and duration of inundation as flood indicators obtained a regression coefficient value of 0.484. In line with the results of the study by [6] that mining land openings can increase flood runoff discharge and sedimentation [21]-[24].

Alternative Solution X1

The following is a table of alternative solutions for handling tin mining activities in Bangka and Central Bangka Regencies:

Table 11. Alternative Solutions for Mining Activity Variables (X1)

No	Indicators code	Indicator Variable	Alternative Solution
1.	X1.3	Critical land due to mining activities is expanding. Holes from mining excavations have the potential to cause landslides and erosion.	1. Reclaiming critical land by returning the land to its original form.
			2. Planting plants according to its vegetation (land/basin).
			3. Planting cover crops on critical land.
			4. Increasing public awareness of the impact of critical land due to mining activities.
2.	X1.4	Increasing forest and land damage.	1. Refilling former mining holes with stable soil.
			2. Planting strong and deep vegetation to maintain slope stability.
3.	X1.5	The quality of the environment in the Bangka Belitung Islands Province has decreased. The mining location is in a water catchment area. Mining waste damages the environmental ecosystem.	1. Reforesting damaged forest and land areas.
			2. Increasing supervision and law enforcement against illegal logging and forest burning activities.
			3. Increasing public awareness of the importance of preserving forests and land.
4.	X1.6	The source of raw water in the former tin mining pit contains heavy metals.	Create clear and firm environmental regulations to protect the environment.

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5.	X1.7	Mining technology is still conventional.	Conduct strict supervision and management of mining activities in catchment areas because they can affect the availability of groundwater.
6.	X1.8	The amount of mineral and geological resources in the Bangka Belitung Islands Province is abundant.	Set environmental standards that must be met by mining companies so that the impact of environmental damage due to mining activities can be minimized.
7.	X1.9	Information regarding the geological potential in the Bangka Belitung Islands Province is not yet optimal.	Use water treatment technology to treat water affected by mining.
8.	X1.10	Many plantation areas have been turned into mining areas.	Implement the concept of environmentally friendly mining (green mining).
9.	X1.11	The rise in community mining (tin mining without a permit).	Manage mineral and geological resources in a sustainable manner so that they can be utilized in the long term.
10.	X1.12	The government has not taken firm action against illegal mining actors.	Develop an integrated and comprehensive geological information system.
11.	X1.13	Good management practice activities have not been running well.	Make effective spatial planning to avoid conversion of forest and plantation land into mining land.
12.	X1.14	There are obstacles in land reclamation.	Regulate mining permits strictly and ensure that only companies that meet environmental standards can mine.
13.	X1.15	The land rehabilitation budget is not optimal.	Conduct supervision and take action against illegal mining actors.
14.	X1.16	Critical land due to mining activities is expanding.	The need for integrated and continuous guidance and supervision of mining actors related to good maining practices.
15.	X1.17		The need for guidance, increased awareness and community participation in the implementation of land reclamation to reduce concerns that land will be taken after reclamation.
16.	X1.18	Holes from mining excavations have the potential to cause landslides and erosion.	Allocate sufficient budget to support forest and land management efforts.

Source: Researcher Processing, 2024

Reach Area Factors

According to the Regulation of the Minister of Environment and Forestry Number 10 of 2022, a water catchment area is an area where water enters from the ground surface into the water-saturated zone, forming a groundwater flow that flows to a lower area.

Based on the survey results, 90% of respondents stated that the Green Open Space (RTH) in Pangkal Pinang City and surrounding districts was not sufficient to accommodate the discharge of rainwater that fell. This is in line with data from the Pangkal Pinang City Environmental Service in 2024 that the area of RTH in Pangkal Pinang City as a city catchment area does not meet the minimum RTH area requirements because it only meets 21.225% of the 30% minimum requirements for Urban RTH.

The change in land into built-up land in the catchment area causes the land to be unproductive in the absorption process. The lack of land conservation in the absorption area causes the land to become critical.

Based on data from the PUPR Service of Pangkal Pinang City in 2024, the built-up land area was 8,434.35 Ha from a total area of 10,455.65 Ha or 80.67%. The built-up land area must still pay attention to the infiltration area. Because increasing the built-up land area that does not consider the infiltration area will have an impact on increasing flooding in Pangkal Pinang City.

The results of the regression coefficient analysis showed that the influence of land use conditions, topographic conditions, biopore holes, and infiltration wells as indicators of infiltration area variables was -0.396. This value shows a negative influence (in the opposite direction) between the infiltration area and flood variables. This means that if the infiltration area variable increases by 1%, then conversely the height and duration of inundation as indicators of the flood variable will decrease by 0.396 times. Assuming that other variables remain constant. That changes in land cover greatly affect the flood discharge return period at a certain time.

One way to overcome the problem of flooding is to make biopore infiltration holes. Biopore infiltration holes are part of eco-drainage or environmentally friendly drainage with the basic principle of controlling excess surface water in such a way that runoff water can flow in a controlled manner and has more opportunity to seep into the ground. Therefore, to overcome inundation flooding, biopore infiltration holes need to be made. Alternative solution X2

Table 12. Alternative Solution of Resorption Area Variable (X2)

No	Indicators code	Indicator Variable	Alternative Solution
1.	X2.1	The development of settlements in built-up areas takes into account water catchment areas.	There needs to be an increase in public understanding regarding the development of settlements in built-up areas that pay attention to infiltration areas such as environmentally friendly building concepts
2.	X2.3	As a catchment area, the elevation conditions of the flat and concave Pangkal Pinang City area have been planted with the right types of vegetation, such as bamboo and banyan.	Encouraging the community to participate in planting vegetation can help the water absorption process.
3.	X2.5	Green Open Spaces (RTH) in Pangkal Pinang City and the surrounding districts are not sufficient to accommodate the amount of rainwater that falls.	There needs to be supervision regarding the use of public and private Green Open Spaces (RTH) located in residential and community housing areas.
4.	X2.6	The number of biopore holes is not evenly distributed throughout Pangkal Pinang City.	Making strategic location planning for the placement of biopore holes.
5.	X2.7	The government has built infiltration wells.	There needs to be an increase in the number of infiltration wells.

Source: Researcher Processed 2024

Polder System Factors

A Polder System is a system that is hydrologically separated from its surroundings, either naturally or artificially, equipped with embankments, internal drainage systems, pumps and/or reservoirs, and water gates [25]. The polder system consists of several components that form a unit that supports the success of the drainage system. The development of the polder system must consider aspects of safety, sustainability, and flexibility in accordance with the polder concept developed in the Netherlands as one of the countries with the best polder systems in the world. The research revealed that the existence of a pump house is very important to overcome flooding. However, it must be accompanied by the implementation of the Standard Operating Procedure (SOP). The operational procedure is in the form of the number of pump units that are run. Data on the Number of Polder Systems in Pangkal Pinang City are as follows:

Table 13. Data on Polder Systems in Pangkal Pinang City.

No.	Polder System Elements	Number	Location
1.	Reservoir	3	Sword Bean Retention Pond
			PDAM Rangkui Pond
			Rice Warehouse Pond
3.	Water Gate	2	Rangkui River
			Gateway River
4.	Pump House	1	Jl. Boga, Bintang Village

Source: Researcher Processing, 2024

From the table above, the number of polder system components in Pangkal Pinang City is still very minimal compared to the polder system in big cities in Java. The addition of a polder system can lower the average water level compared to without a polder system. With good planning, the polder system can be used to overcome flooding [8].

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Figure 12. Condition of the Kacang Pedang Water Gate Source: Researcher Documentation, 2024

Figure 13. Sedimentation Conditions of the Sword Bean Retention Pond Source: Researcher Documentation, 2024

Analysis Results and Discussion

Referring to the analysis results, the influence of drainage conditions, pump operational conditions, and retention pond conditions as indicators of the polder system on the height of inundation and duration of inundation as indicators of flooding was obtained by a regression coefficient value of -0.412. This value shows a negative influence (in the opposite direction) between the polder system and flood variables. This means that if the polder system variable increases by 1%, then conversely the height and duration of inundation as indicators of flooding will decrease by 0.412 times. Assuming that other variables are considered constant. States that flooding can be caused by a lack of existing channel capacity, area contours, garbage and sediment at the bottom of the channel.
Alternative solutions for polder systems (X3)
The following are alternative solutions for improving the quality of polder systems in Pangkal Pinang City:

Table 14. Alternative Solutions for Polder System Variables (X3)

No	Indicators code	Indicator Variable	Alternative Solution
1.	X3.2	Drainage channels are routinely dredged by related agencies.	Increase the frequency of drainage dredging.
2.	X3.3	The water level is always monitored routinely by related agencies to detect potential flooding or drought early.	Develop an early warning system for monitoring water levels.
3.	X3.5	The government has prepared a handling strategy to reduce sedimentation of retention ponds along with a budget plan.	Develop a sedimentation management strategy through the construction of sediment traps.
4.	X3.6	Normalization of retention ponds is carried out routinely by related agencies.	Conduct routine budgeting for retention pond normalization.
5.	X3.7	The current capacity of drainage channels is not yet able to accommodate the volume of flooding that occurs.	Conduct routine drainage normalization.
			Increase drainage capacity through the construction and improvement of drainage infrastructure.

6.	X3.8	The pump house is currently operating optimally.	Add pump house units in areas identified as flood-prone.

Source: Researcher Processed 2024

Coordination Factor

Coordination in the government system is the arrangement of working relationships between government officials, government institutions, and different work units. Coordination in handling floods in Pangkal Pinang City is still not optimal because it still prioritizes sectoral egos.
The results of the regression coefficient value analysis obtained the influence of unity of action, communication, division of labor, and discipline as indicators of the coordination variable, which is -0.480. This value shows a negative influence (in the opposite direction) between the coordination variable and flooding. This means that if the coordination variable increases by 1%, then conversely the height and duration of inundation as indicators of the flood variable will decrease by 0.480 times. Assuming that other variables are considered constant. This result is directly proportional to the research results of which states that the institutional aspect variables consisting of communication frequency, facility maintenance, and institutional conditions have a significant effect on the height of inundation and the duration of inundation. This coordination model is considered the most effective for improving coordination between agencies/institutions, namely between the Pangkal Pinang City Government and the surrounding Regency Governments:

Table 15. Alternative Solutions for Coordination Variables (X4)

No	Indicators code	Indicator Variable	Alternative Solution
1.	X4.2	The budget in the agency to support flood control programs/activities includes the budget for personnel in the field.	Conduct routine budgeting related to personnel budget in the field to support flood control in Pangkal Pinang City.
2.	X4.3	Frequency of internal communication related to flood control programs/activities > 3 times a month.	Increase the intensity of routine meetings between internal stakeholders in supporting flood control in Pangkal Pinang City.
3.	X4.4	Frequency of external communication with agencies/departments related to flood control > 3 times a month.	Increase the intensity of routine meetings between external stakeholders in supporting flood control in Pangkal Pinang City.
4.	X4.5	The implementation of tasks between fields has been synergized through joint seminars related to the agency's duties and programs.	Conducting effective communication to ensure alignment and agreement in program implementation.
5.	X4.6	Availability of SOPs in implementing work in agencies that minimize the involvement of leaders in carrying out daily tasks.	Improving the quality of human resources through training implementation.
6.	X4.7	The activity program in the Engineering Service Project for Bangka Island Flood Management in Bangka Belitung Province has not been realized according to plan.	Conduct further evaluation of the Engineering Service Project for Bangka Island Flood Management in Bangka Belitung Province using the Dynamic Performance Management model (Carmine Bianci, 2018) related to the number of policy makers, managed variables, priority scale, diversity of problems that cause delays, relevance that affects results, the number of policies to sacrifice something to get something else, and external factors that influence policy makers.

Source: Researcher Processing 2024

Questionnaire Stage 3 (Expert Validation of Research Results)

The research results obtained were then validated by 5 experts with the following profiles:

Table 16. Research Expert Profile

No	Code	Job Title	Education	Work experience
1.	P1	Head of Service	Strata 1 (S-1)	Over 20 Years
2.	P2	Head of Service	Strata 1 (S-1)	Over 20 Years
3.	P3	Head of Center	Strata 2 (S-2)	Over 20 Years
4.	P4	Head of Service	Strata 2 (S-2)	Over 20 Years
5.	P5	Head of Service	Strata 2 (S-2)	Over 20 Years

Source: Researcher Processing 2024
The validation data of the questionnaire results are in the form of statements of agreement or disagreement from the five experts regarding the alternative research solutions.

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Discussion of research results

Based on the results of data analysis using SPSS, it was found that the factors of mining activity, infiltration areas, polder systems and coordination had an effect on flood conditions in Pangkal Pinang City with a contribution of 85.0% with the most dominant variable ranking influencing flooding being mining activities. Institutional aspect variables consisting of communication frequency, facility maintenance, and institutional conditions had a significant effect on the height of inundation and duration of inundation. Alternative solutions to significantly reduce flooding in Pangkal Pinang City were carried out on mining activity variables as the most dominant variable influencing flooding in Pangkal Pinang City.

CONCLUSION

Based on the results of data analysis and discussion that have been described in the previous chapter, the conclusions in this study are: 1) Based on the results of data analysis using SPSS, it was found that the factors of mining activity, infiltration areas, polder systems and coordination had an effect on flood conditions in Pangkal Pinang City with a contribution of 85.0% with the most dominant variable ranking influencing flooding being mining activities. 2) Mining land openings affect flood runoff and sedimentation, changes in land cover greatly affect the flood discharge return period at a certain time. Flooding is caused by the lack of existing channel capacity, regional contours, garbage and sediment at the bottom of the channel. Institutional aspect variables consisting of communication frequency, facility maintenance, and institutional conditions have a significant effect on the height of inundation and the duration of inundation. 3) Alternative solutions to significantly reduce flooding in Pangkal Pinang City are carried out on mining activity variables as the most dominant variables affecting flooding in Pangkal Pinang City.

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