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Analysis of the Determination of Irrigation System Maintenance Activities at Subantoro, Mojokerto

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Abstract:- Subantoro irrigation area which located at the province of Jawa Timur expands as much as 515 Ha. That large area is divided into two sections in which located in Kabupaten Mojokerto and Kota Mojokerto by 416 Ha and 99 Ha of area respectively. The water is supplied from Kintelan River through Subantoro dam. There are 3 secondary channel with 9.298 metres of total length consisting of Subantoro, Kedung Pring, and Ngrayung. Currently, There are lots of damage in the channel system and other diversion structure hence quite amount of water losses occurred. Budget limitation was suspected to be the cause of incomplete maintenance.

This study was conducted to recalculate maintenance costs of irrigation system so that optimal function can be achieved. Mixed integer program was utilized to maximize water saving and to optimize maintenance costs.

The results indicate as much as 222.28 L/Sec of water loss was caused by unmaintained infrastructure. Maintenance costs of Rp.100,000,000 was projected to be able to save 106.90 L/Sec of water. The largest savings were estimated in Kedung Pring Channel KP5 – KP6 and diversion structure BSB 1 by 36.07 L/Sec and 18.98 L/Sec respectively. It was recommended to prioritize the maintenance on channel and diversion structure which loss the most amount of water.

Keywords:- *Maintenance, Water Loss, Mixed Integer Program*

I. INTRODUCTION

Irrigation is one of many important factors in agriculture industry and its development hence reliable infrastructure is required to keep the water be sufficiently supplied. As the demand for water increase and the supporting facilities were restricted in number, the irrigation system has to be more effective and efficient.

Subantoro irrigation area which located at the province of Jawa Timur expands as much as 515 Ha. That large area is divided into two sections in which located in Kabupaten Mojokerto and Kota Mojokerto by 416 Ha and 99 Ha of area respectively. The water is supplied from Kintelan River through Subantoro dam.

There are degradation in function and performance of irrigation system along time which cause the water to be insufficiently supplied. The breakdown that occurred in the channel system and diversion structure was strongly suspected to be the cause of severe headloss thus affect the supply in downstream during dry season. According to irrigation engineering standard (KP-3), the current average efficiency for Subantoro was 71.88%, which less than the ideal number of 90% for both primary and secondary system and 80% for the tertiary.

Budget limitation in maintenance makes maintenance for all infrastructures not feasible. Referring to the problem, analysis on maintenance framework is required to get the optimum results despite being restricted in budget. The optimum results mentioned are including minimum loss of water thus planting intensity on agriculture industry follows.

II. STUDY OF LITERATURE

A. Assets Management

Assets management is a process of preserving and making use of public investation in order to promote an effective and efficient government by maintaining its properties (Muchtar Hidayat, 2012).

B. Maintenance of Irrigation System

According to Peraturan Menteri Pekerjaan Umum dan Perumahan Rakyat No. 12 tahun 2015 on utilization and preservation of irrigation system, it was stated that the preservation of irrigation system was being implemented to keep its optimal function and sustainability. Inventory result indicates problem identification survey, participative preservation, and well-structured action plan were required. Essentially, delayed maintenance of irrigation system will likely be the cause of severe degradation which lead to costly rehabilitation in the end.

C. Water Losses

According to Kartasapoetra and Sutedjo (1994) the occurrence of leakage on irrigation systems are commonly found where there is no shield or layer that protects the channel. The efficiency and loss of water were being analyzed on each sector in certain length (Wilhelmus, 2013).

The best method to discover the amount of water leakage is to calculate the difference between inflow and outflow, that way the interference on lengthy channel system can be eliminated (Sumandiyono, 2012).

D. Mixed Integer Program

Integer Programming is a variation of linier programming where one or few completion vectors were having integer value. Integer programming that partially limits decision variables are known as Mixed Integer Programming (Susi, Astuti H. 1999).

According to Smith (2007), the creation of Mixed Integer Program can be done in three stages as follows:

- To define variables
- To define the Constraint
- To set the objectives

The mathematical model of Mixed Integer Programming:

❖ *Objective Function*

Zmax = C1X1 + C2X2 + C3X3 + ……..+ CnXn

Constraint

a11X1 + a12X2 + a13X3 +……+ a1nXn > b1
a21X1 + a22X2 + a23X3 +……+ a2nXn > b2
am1X1 + am2X2 + am3X3 +……+ amnXn > bm

❖ *Explanation:*

- Objectives : C1X1 + C2X2 + C3X3 + …….. + CnXn
- There are two types of constraints;
- Functional Constraint
  ai1X1+ ai2X2 +ai3X3 + ……+ ainXn
- Non-Negatif-Constraint which stated as (X1, X2, ..., Xm ≥ 0 and integer, X6, X7, ... Xn = 0 or 1)

- Decision Variable or Xj Variables.
- Constant Input or Model Parameter (aij, bi, dan cj).

III. DATA AND METHODOLOGY

A. Data Collection

There are two types of data in which divided into primary data and secondary data. Primary data were obtained by measuring both inflow and outflow to check the amount of water loss. The data which categorized as primary were water losses in channel system and water losses in diversion structure, both measured in Litre/Second (L/Sec). Secondary data were obtained from Dinas PU Sumber Daya Air Jawa Timur, UPT PSDA Surabaya, Dinas PU Kabupaten Mojokerto, and other related institution. Total irrigation area, irrigation topography, irrigation network chart, inventory of damaged facilities, and maintenance cost of channel system were secondary data that were required.

B. Testing Methodology

Mixed integer programming used in this study consists of specific component and characteristic. The volume and part of the system to be fixed as well as how much saving can be achieved can be discovered by the model of mixed integer programming (Sitorus, 2012). Model component were including decision, objectives, and constraint. The equation is as follows :

➢ *Objectives :*

The objective of this study is to maximize the efficiency of maintenance hence more saving can be achieved.

Z = C1X1 + C2X2 + C3X3 + C4X4 + C5X5 + C6X6 + C7X7 + C8X8 + C9X9 + C10X10 + C11X11 + C12X12 + C13X13 + C14X14 + C15X15 + C16X16 + C17X17 + C18X18 (1)

Z : Maximize Water Saving (Lt/dt)
X1-X14 : Damage channel Length (m)
X14-X18 : Damage diversion structure Volume (unit)
C1-C14 : Water Loss from damage channel System ((Lt/dt)/m)
C15-C18 : Water Loss from damaged diversion structure (Lt/dt)

➢ *Constraint :*

- *Maintenance Costs*

Maintenance costs are including channel system and diversion structure maintenance cost which calculated based on the length and units that are being maintenance for both respectively. Total allocation for maintenance work is as much as one hundred million rupiah.

B1X1 + B2X2 + B3X3 + B4X4 + B5X5 + B6X6 + B7X7 + B8X8 + B9X9 + B10X10 + B11X11 + B12X12 + B13X13 + B14X14 + B15X15 + B16X16 + B17X17 + B18X18 ≤ A (2)

- *Decision* : X1 - X14 ≤ Damage channel Length (m)
X15 – X18 ≤ Damage diversion structure Volume (unit)

- *Non Negativity* : X1, X2, ..., X14 ≥ 0; X15, X16, ... X18 = 0/1

X1-X14 : Damage channel Length (m)
X14-X18 : Damage diversion structure Volume (unit)
B1-B14 : Cost/1 metre (Rp).
B15-B18 : Cost/unit (Rp).
A : Maintenance Costs (Rp).

IV. RESULTS AND DISCUSSIONS

Subantoro irrigation area consisting of 3 secondary channel including Subantoro, Kedung Pring, and Ngrayung. There are lots of damage on the channel system and diversion structure which cause quite amount of water loss. According to the observation, total damage approximately as long as 3,171 metre of channel system and 4 units of diversion structure with Rp.3,522,488,713 of total cost of maintenance. The damage cause 222.28 L/sec of water loss with 198.86 L/sec and 23.42 L/sec from channel system and diversion structure respectively. Detailed calculations displayed on Table 1 and Table 2 below:

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No	Section	Decision Variable	Water Loss (Δ Q) (Lt/dt)	Damage Length (m')	Δ Q/L (Lt/dt) / m	Cost / m' (Rp)	Maintenance Cost (Rp)
Kedung Pring							
1	KP0 - KP1	X1	14.65	80.00	0.183	907,972	72,637,770
2	KP1 - KP2	X2	9.00	20.00	0.450	907,972	18,159,443
3	KP2 - KP3	X3	0.06	4.00	0.015	1,124,146	4,496,585
4	KP3 - KP4	X4	26.52	30.00	0.884	691,798	20,753,943
5	KP5 - KP6	X5	36.07	55.00	0.656	907,972	49,938,467
Ngrayung							
No	**Section**	**Decision Variable**	**Water Loss (Δ Q) (Lt/dt)**	**Damage Length (m')**	**Δ Q/L (Lt/dt) / m**	**Cost / m' (Rp)**	**Maintenance Cost (Rp)**
6	NY0 - NY1	X6	9.22	20.00	0.461	691,798	13,835,962
7	NY1 - NY2	X7	5.91	10.00	0.591	907,972	9,079,721
8	NY2 - NY3	X8	7.15	10.00	0.715	691,798	6,917,981
9	NY3 - NY4	X9	23.20	1562.00	0.015	1,124,146	1,755,916,318
10	NY4 - NY5	X10	7.66	10.00	0.766	1,124,146	11,241,462
11	NY6 - NY7	X11	11.02	416.00	0.026	1,124,146	467,644,807
12	NY7 - NY8	X12	9.51	50.00	0.190	1,124,146	56,207,309
13	NY8 - NY9	X13	28.43	893.00	0.032	1,124,146	1,003,862,530
Subantoro							
No	**Section**	**Decision Variable**	**Water Loss (Δ Q) (Lt/dt)**	**Damage Length (m')**	**Δ Q/L (Lt/dt) / m**	**Cost / m' (Rp)**	**Maintenance Cost (Rp)**
14	SB0 - SB1	X14	10.45	11.00	0.950	691,798	7,609,779
	Total		198.86	3171.00			3,498,302,074

Table 1:- Water Loss in Channel System

No	Diversion Structure	Decision Variable	Water Loss (Lt/dt)	Damage Volume (m3)	Cost / m3 (Rp)	Maintenance Cost (Rp)
1	BSB 1	X15	18.98	3.4	1,010,298	3,435,013
2	BKP 1	X16	0.91	11.5	1,010,298	11,618,428
3	BNY 1	X17	2.67	7.15	1,010,298	7,223,631
4	BNY 2	X18	0.86	1.9	1,010,298	1,919,566
	Total		23.42			24,196,639

Table 2:- Water Loss in Diversion Structure

The length of channel system and units of diversion structure need to be maintenanced were calculated by Mixed Integer Program.

Mathematical Model of Mixed Integer Program :

➢ *Objectives :*

Z = 0.183X1 + 0.450X2 + 0.015X3 + 0.884X4 + 0.656X5 + 0.461X6 + 0.591X7 + 0.715X8 + 0.015X9 + 0.766X10 + 0.026X11 + 0.190X12 + 0.032X13 + 0.950X14 + 18.98X15 + 0.91X16 + 2.67X17 + 0.86X18

➢ *Constraint Function:*

- *Cost Limitation*

907,972 X1 + 907,972 X2 + 1,124,146 X3 + 691,798 X4 + 907,972 X5 + 691,798 X6 + 907,972 X7 + 691,798 X8 + 1,124,146 X9 + 1,124,146 X10 + 1,124,146 X11 + 1,124,146 X12 + 1,124,146 X13 + 691,798 X14 + 3,435,013 X15 + 11,618,428 X16 + 7,223,631 X17 + 1,919,566 X18 ≤ Rp 100,000,000

- *Decision :*

X1 ≤ 80, X2 ≤ 20, X3 ≤ 4, X4 ≤ 30, X5 ≤ 55, X6 ≤ 20, X7 ≤ 10, X8 ≤ 10, X9 ≤ 1562, X10 ≤ 10, X11 ≤ 416, X12 ≤ 50, X13 ≤ 893, X14 ≤ 11, X15 ≤ 1, X16 ≤ 1, X17 ≤ 1, X18 ≤ 1

- *Non Negativity* : X1, X2, ..., X14 ≥ 0 and integer, X15, X16, ... X18 = 0 or 1

With total maintenance budget allocated Rp. 100.000.000 which calculated by a mixed integer program, 6 sections including KP3-KP4; KP5-KP6; NY0-NY1; NY2-NY3; NY4-NY5 and SB0-SB1 with the length of 30 m; 55 m; 0.15 m; 10 m; 10 m; and 11 m respectively. As for diversion structure, BSB 1 was prioritized.

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V. CONCLUSION

It is recommended to prioritize the maintenance on channel system and diversion structure which loss the most amount of water. Allocated budget which calculated by mixed integer program is as much as Rp.100,000,000 and projected to be used for maintenance on channel and diversion structure. The project including maintenance of 116.15 m length of channel and 1 diversion structure that help saving 106.90 L/Sec of water.

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