Evaluation of Deposition Pattern of Wonogiri Reservoir Sedimentation

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***Abstract*-- The Wonogiri Reservoir problem is not only rapid decreasing in the reservoir capacity, but also spatial sedimentation problems. Regular sediment monitoring or measurements need to be performed for determining the pattern and estimating the rate of sedimentation. An evaluation of reservoir sediment inflow and spatial reservoir sedimentation is required when the sedimentation rate exceeds the rate of sedimentation plans. Therefore the objective of this study is to evaluate the deposition pattern of Wonogiri Reservoir due to spatial sedimentation problems by using monitoring of reservoir bottom elevation. This study used the monitoring of reservoir bottom elevation of Wonogiri Reservoir year 1980, 1993, 2004, 2005 and 2011 base on measurement by *Balai Besar Wilayah Sungai Bengawan Solo*, JICA and *Perum Jasa Tirta* I. Deposition pattern of Wonogiri Reservoir sedimentation evaluates and discusses. Base on the result, Wonogiri Reservoir is a unique reservoir, because the reservoir water inflow came from river mouths that located around the reservoir. Therefore, sediment input will deposit at the river mouth around the reservoir and the deepest part of the reservoir at the center. Intake location occupies the deposition area with a high rate.**

***Index Term*-- reservoir sedimentation, deposition pattern, Wonogiri Reservoir.**

INTRODUCTION

The Wonogiri Reservoir is located in the Southeast part of the Central Java province of Indonesia (Figure 1). Location of the reservoir is on a mountainous area, since it is the Upper part of the Bengawan Solo river basin. Area of reservoir watershed is 1,305 km^2 consists of eight sub watersheds. The Wonogiri dam was constructed in 1980 and Impoundment December 1981. The reservoir began operation in November 1982. The purposes of reservoir are for flood control, water supply for industrial and drinking water, irrigation, hydropower, fisheries and tourism and maintenance of minimum flow the Bengawan Solo River. Reservoir design life is 100 years, with original total storage of 730 MMC. 220 MMC of the reservoir storage at the elevation +135.3 m up to +138.3 m is allocated for flood control and 440 MMC of the reservoir water for water supply at the elevation of +127m up to +136 m. 120 MMC of the reservoir storage is purposed as the dead storage at elevation below +127 m.

Most of reservoirs in Java Island have sedimentation rate higher than estimated sediment rate, so that the reservoir storage capacity decrease faster than planed capacity (Hastowo, 2003). It also occurs in Wonogiri Reservoir. Sedimentation leads to reduction of the reservoir's economic life, disruption of operations due to intake clogging from The Keduang River debris and a decrease in the water reservation ability, especially during the dry season (JICA, 2007). Base on Wulandari et al. (2014) up to the year 2011 remaining of total reservoir capacity is only 67% and remaining of dead storage capacity is only 50%. Effective storage capacity and flood storage capacity also decreased, their remaining capacity are 69 % and 57 %, respectively. The Wonogiri Reservoir problem is not only rapid decreasing in the reservoir capacity, but also spatial sedimentation problems such as sedimentation in the front of reservoir intake.

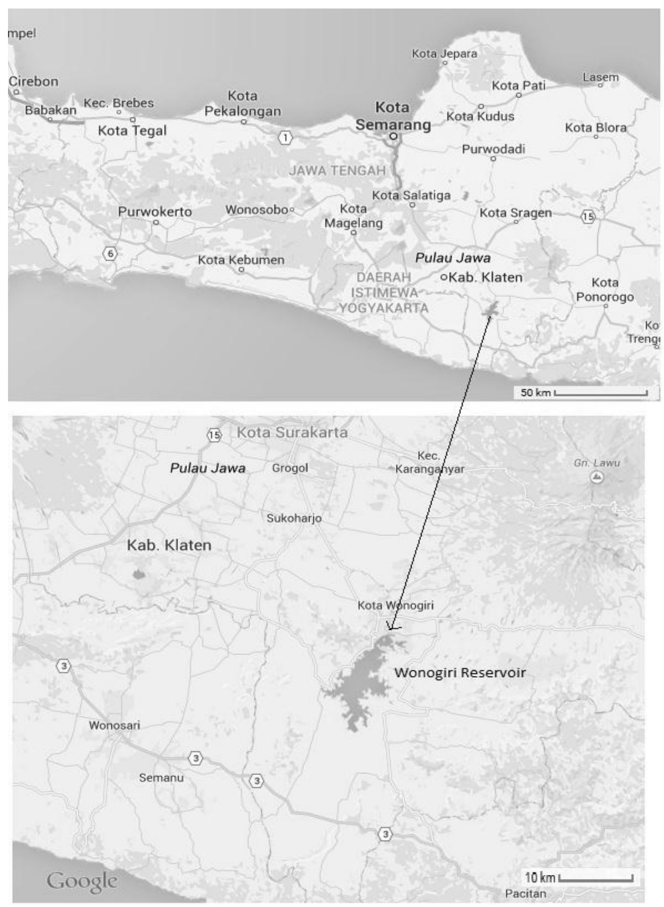


Fig. 1. Map of the Wonogiri Reservoir (Google Map, 2015)

Reservoir sedimentation in the reservoir dead storage is one aspect for determining economic life of reservoir. If the capacity of dead storage is full then the efficiency of reservoir operation will be disrupted and eventually ended reservoir function. In reality, not all the sediment settles in the dead storage. Sediment that settles over the dead storage will reduce the effective storage. So the sediment deposition pattern is necessary to know distribution of sediment and fluctuation of the sediment volume that settles in the reservoir, either in dead storage or effective storage. Sediment deposition pattern are different and naturally very complex due to differences in hydrologic conditions, sediment characteristics, reservoir geometry and reservoir operations (Morris & Fan, 1997). Regular sediment monitoring or measurements need to be performed for determining the pattern and estimating the rate of sedimentation. An evaluation of reservoir sediment inflow and spatial reservoir sedimentation is required when the sedimentation rate exceeds the rate of sedimentation plans.

The biggest challenge in reservoir operation is to study the sedimentation rate, volume and pattern of the sediment deposition (Garg and Jothiprakash, 2013). Some studies related to the distribution of reservoir sedimentation have been conducted by several researchers. Hassanzadeh (2004) developed a mathematical model to describe the purpose of longitudinal profile and sediment transport variations as a function of time and hydraulic flow conditions. Effler et al. (2006) examined the impact of runoff events in the external suspended solids are transported to the Schoharie Reservoir and assess the pattern of light scattering and sedimentation in reservoirs. ELCI et al. (2007) investigated the influence of stratification and shoreline erosion reservoir to the reservoir sedimentation patterns. Lu et al. (2010) examined the erosion and deposition in the upper reaches of the reservoir which is always influenced by backwater fluctuations. Dufresne et al. (2010) make a physical model to investigate the deposition that occurs due to the main flow patterns and the influence of the main flow pattern of the trap efficiency in shallow reservoirs. Habili & Heidarpour (2010) developed a new empirical method for predicting the distribution of sediments in the reservoir. Rahmanian and Banihashemi (2012) developed an empirical method to predict the distribution of reservoir sedimentation based on reservoir geometry.

Widely used conventional methods for reservoir sedimentation assessment are reservoir capacity surveys (Range and Contour surveys). These methods are considered to be most accurate though time consuming and very expensive (Garg and Jothiprakash, 2013).Therefore the objective of this study is to evaluate the deposition pattern of Wonogiri Reservoir due to spatial sedimentation problems by using monitoring of reservoir bottom elevation.

Methods

This study used the monitoring of reservoir bottom elevation of Wonogiri Reservoir year 1980, 1993, 2004, 2005 and 2011 base on measurement by *Balai Besar Wilayah Sungai Bengawan Solo*, JICA and *Perum Jasa Tirta* I. The monitoring of reservoir bottom elevation data were processed using ArcView GIS. Then deposition pattern of Wonogiri Reservoir sedimentation evaluates and discusses.

Results and Discussion

Figure 2 shows the H-V curve and the H-A curve of Wonogiri Reservoir in periods 1980 - 2011. Based on Fig. 2 it can be seen the storage and the reservoir surface area decreases from time to time. The sediment inflow are not only settle in the dead storage, the sediment inflow settles on the entire surface of the reservoir bed. Sediment that settles on effective storage and flood storage will reduce capacity of the effective storage and the flood storage, respectively. Figure 3 shows the sediment deposition in each zone. Negative values indicate that in the zone occurs bed surface erosion. Positive values indicate that in the zone occurs sediment deposition. During 1993 - 2005, in the flood storage zone sediment deposition does not occur. Sediment that settles in the dead storage zone decreased, this is due to dredging around the intake. Sediment that settles in the effective storage zone increased. During 2005 - 2011, sediment deposition occurs in all zones. In the dead storage zone, deposition of sediment decreased. In the flood storage zone and effective storage zones, deposition of sediment increased. The increase in deposition of sediment that settles in flood storage zone and effective storage zone will reduce reservoir function. Generally, deposition of sediment in Wonogiri Reservoir increase. Dredging is done not greatly affect returns dead storage capacity, because the volume of dredged is small and dredging only done around the intake. As a result 73% of the sediment settles in the effective storage zone and the flood storage zone, and the sediment settles in the dead storage zone only 27%.

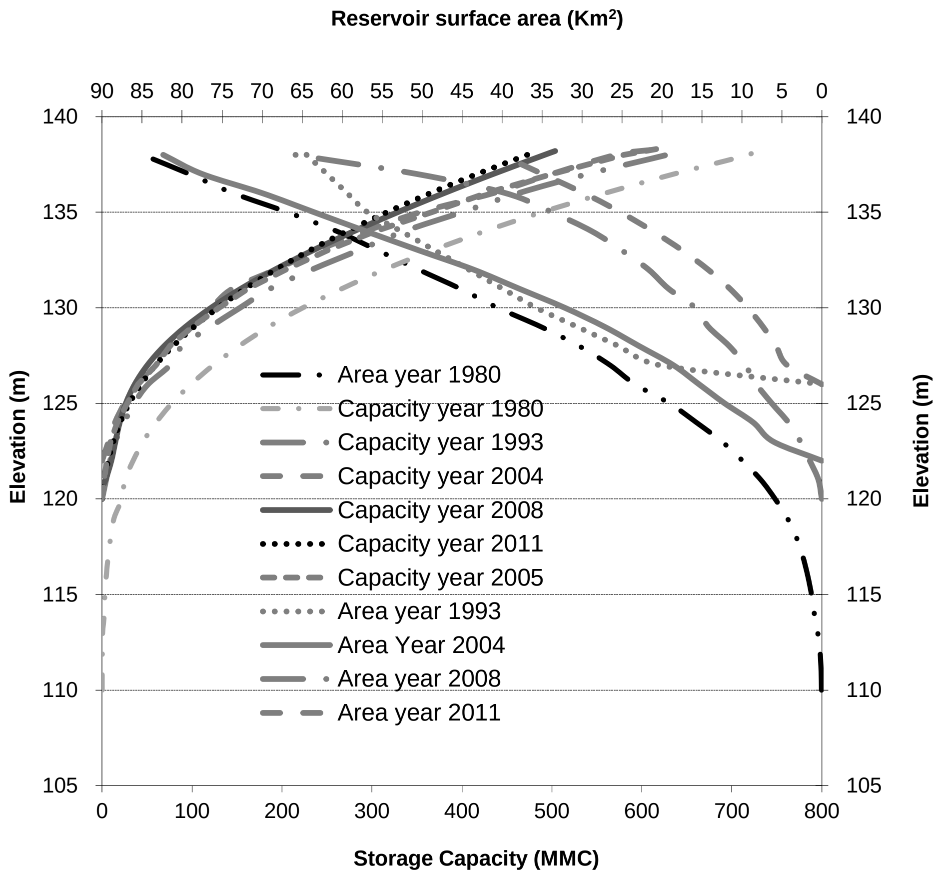


Fig. 2. H-V Curve and H-A Curve of Wonogiri Reservoir (BBWS Bengawan Solo and Perum Jasa Tirta I)

Figure 4 shows the bathymetry map of Wonogiri Reservoir year 1980, 1993, 2004, 2005 and 2011 base on measurement by *Balai Besar Wilayah Sungai Bengawan Solo*, JICA and *Perum Jasa Tirta* I. The darker color indicates the deeper of reservoir depth. Solid line indicates the location of longitudinal profil along the reservoir (Figure 5 and Figure 6). In 1993 the pattern of sediment deposition in the longitudinal direction forms puddles, the deepest part in the middle. Around the intake has occurred sedimentation, the depth became shallower. In 2004 there has been a change in the pattern of sediment deposition. Around the intakes look deeper due to the dredging of sediment that began in 2003. From the Keduang river mouth, it is seen groove toward the intake. In the longitudinal direction, the pattern of sediment deposition has the deeper part in the middle. In 2005, the depth around the intake until Keduang river mouth still deep. In the longitudinal direction, the pattern of sediment deposition has the deeper part in the middle and toward the dam forming a groove. The around intake becomes shallower. In 2011 deposition occurs uniformly across the surface of reservoir zone. Although dredging around the intake is done, the depth around the intake still shallow. This suggests that the dredging is done can not offset sedimentation rate. In the longitudinal direction, the pattern of sediment deposition form puddles with the deepest part in the middle. In tributary sediment deposition occurs toward the upstream direction as a result of backwater. Finer sediments are carried out further into the reservoir. Due to the wider part of the river mouth, velocity decreases and sediment settles easily. So this section becomes shallow. At the Keduang river mouth, this condition becomes critical due to the intake clogging.

Based on the results can be seen a change in the reservoir bottom elevation and sediment distribution. In general, the pattern of sediment deposition have a tendency to form puddles in the longitudinal direction, this is due to the reservoir consists of several tributaries (dendritic). Sediment that settles on flood storage zone and effective storage zone may occur due to reservoirs operated at high water level during floods. So that the sediment settles in the dead zone storage, the reservoir should be operated at low water levels during floods. In each part tributary the reservoir sedimentation in accordance with the theory that changes in cross-section widening from the river to the reservoir causes decrease of the flow rate close to zero. So that coarse material will settle and form a delta in river mouth. These deposits will be formed to the upstream and the downstream direction. This led to a reduction of the effective storage capacity. Finer material will be carried further into the reservoir pool. Sediment flow from Keduang River will turn toward an upstream reservoir until it settles. With this pattern makes the deposition pattern as the sedimentation in 1993 and 2011.

Intake location occupies the deposition area with a high rate. This causes the intake will always clogged sediment. Dredging can not keep pace sedimentation around the intake.

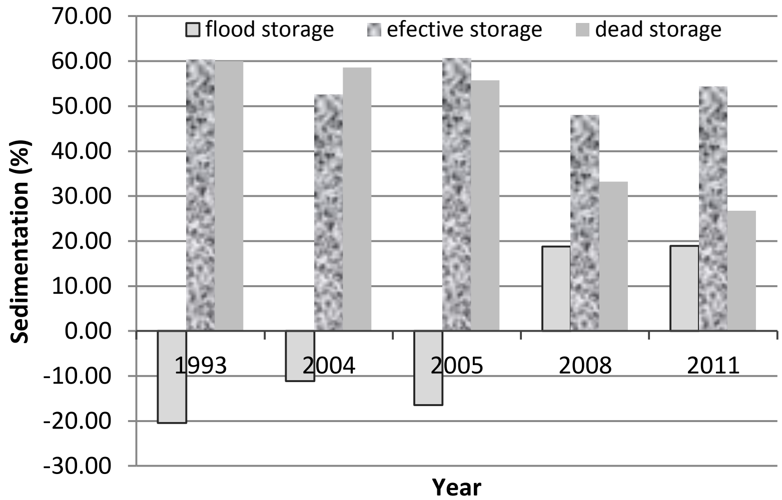
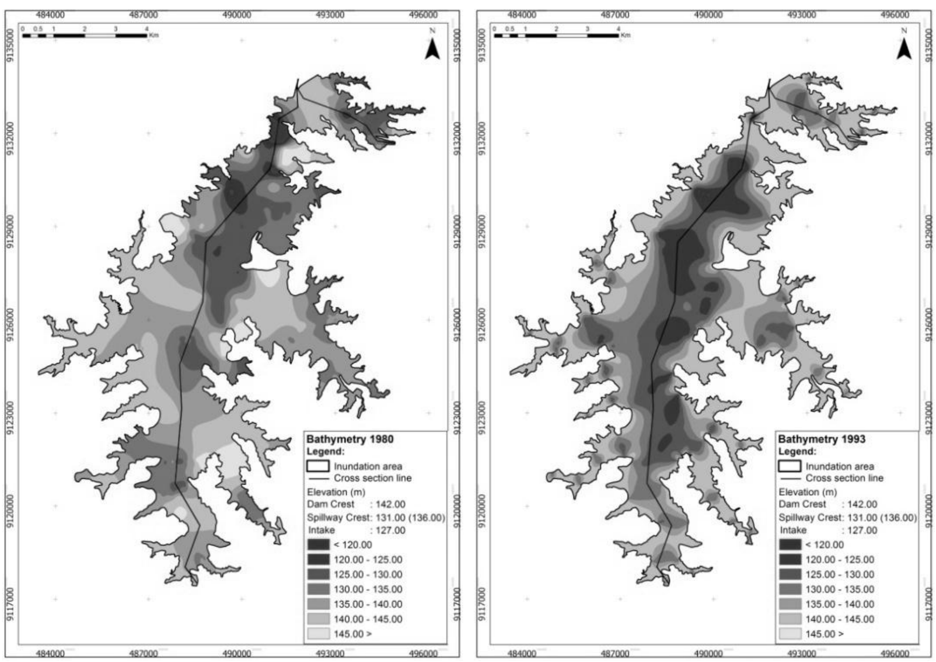
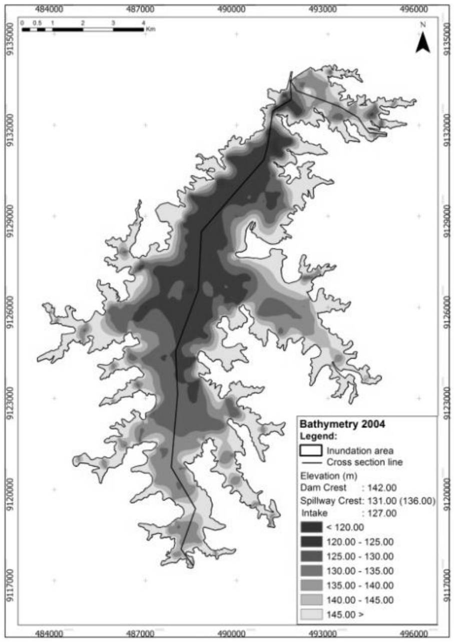


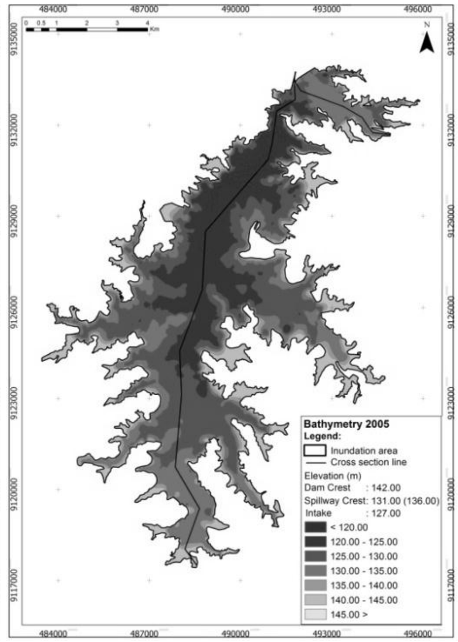
Fig. 3. Sediment deposition in each zone for year 1993 - 2011



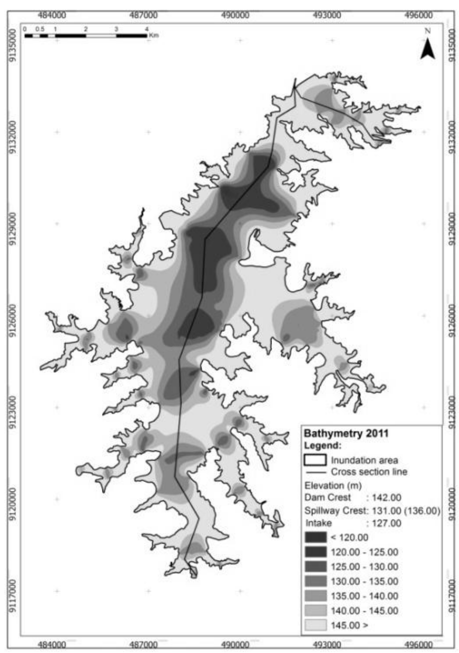
A). Year 1980 B). Year 1993



C). Year 2004



D). Year 2005



E). Year 2011

Fig. 4. Bathymetry Map of the Wonogiri Reservoir

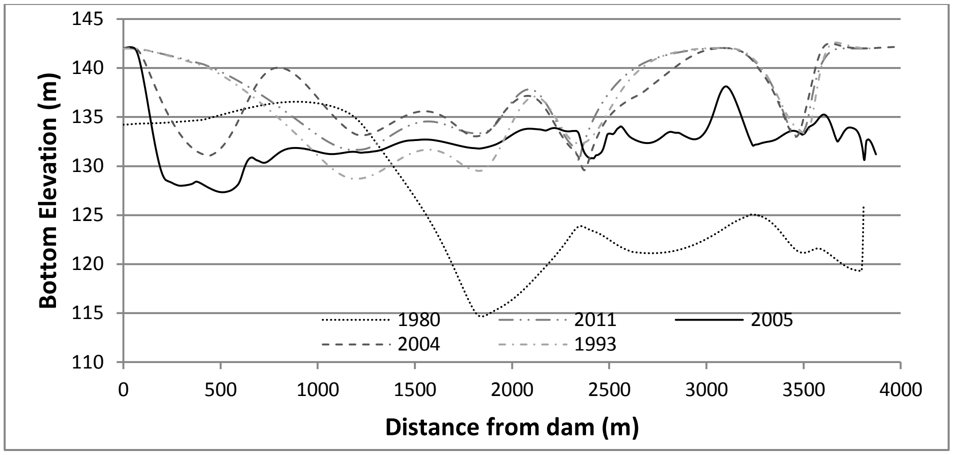


Fig. 5. Longitudinal Profil of Keduang River

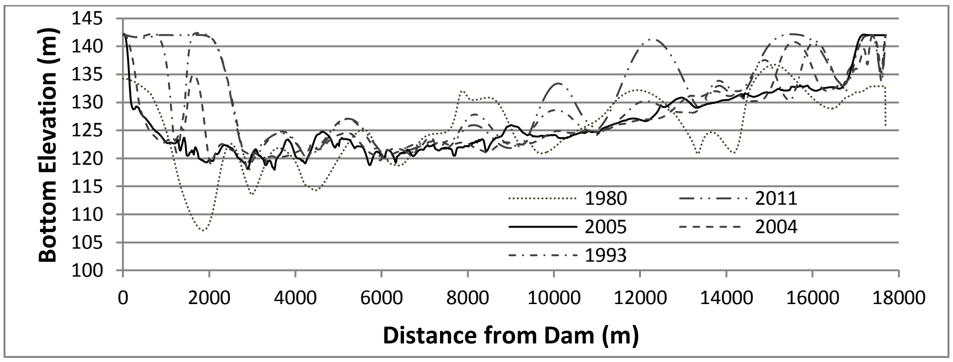


Fig. 6. Longitudinal Profil of Bengawan Solo River

CONCLUSION

Wonogiri Reservoir is a unique reservoir, because the reservoir water inflow came from river mouths that located around the reservoir. Therefore, sediment input will deposit at the river mouth around the reservoir and the deepest part of the reservoir at the center. Intake location occupies the deposition area with a high rate. Future works do research influence reservoir operation on the pattern of reservoir sedimentation, published elsewhere.

ACKNOWLEDGEMENT

Thanks to *Balai Besar Wilayah Sungai Bengawan Solo* and *Perum Jasa Tirta* I, which has provided the data used in this study.

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