Dam Integrity Assessment following the Yogyakarta Earthquake, Indonesia

Consolidated report on activities undertaken through the Monitoring and Information Centre of the European Commission & the Joint UNEP/OCHA Environment Unit

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Cover photo: Wonogiri Dam by Mr. Tore Valstad

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Executive Summary

On 27th of May 2006 a severe earthquake shook the city of Yogyakarta, Java, Indonesia and the surrounding area. In the aftermath of this humanitarian emergency, the Directorate General of Water Resources of the Ministry of Public Works officially requested assistance to assess four embankment dams possibly affected – the Sermo, the Parangjoho, the Wonogiri and the Song Putri dams. The Monitoring and Information Centre, Civil Protection Unit of the European Commission and the Joint UNEP/OCHA Environment Unit jointly offered assistance.

A team consisting of Dr. Peter Tschernutter (Austria) and Mr. Tore Valstad (Norway) was called upon to conduct the assessment. They have issued individual reports covering different topics of the evaluation. This report provides an overview of the initial observations made by the Indonesian Dam Safety Commission and comprises the complementary investigations by both experts made during their site visit between 21st of August and 1st of September 2006.

The main conclusion of the assessment is that all four dams have more or less performed satisfactorily. None of the dams failed, nor suffered damages, which compromised any of the dams' integrity. The Sermo dam was minimally damaged, but suffers from an unfavourable stress condition after the earthquake. Minor cracking and displacement of a few stones in the riprap (surface material - often rocks - on dam wall to reduce erosion) were observed in the Wonogiri dam. In the Parangjoho and Song Putri dam a small, but tolerable increase in the seepage discharge was noticed. In addition, the Parangjoho dam was significantly affected due to some cracks at the dam crest.

After initial repair of the cracks and broken instruments, there were no restrictions in the dam operations under the condition that all dams receive continuous surveillance. Since the reservoir in all dams has been drawn down after the earthquake, the main recommendation of the assessment is an intensified seepage monitoring during the next wet season, especially if the water level rises above the level recorded on the day of earthquake.

In addition, the situation requires an immediate repair or replacement of broken dam monitoring instruments and standpipes, the installation of an automatic seepage recording system besides the manual equipment, and the establishment of seepage limits for the dry and rainy season.

1. Introduction

Situation

An earthquake struck Yogyakarta Province in the early morning of 27 May 2006. Expert opinions differ about the epicentre (range from 37.2 km to just 25 km away from Yogyakarta), the magnitude (range from 5.9 to 6.3 on Richter scale) as well as the depth of the earthquake (range from 10 to 33 kilometres). Over 700 aftershocks were measured. Four districts in the Yogyakarta province (Sleman, Bantul, Gunung and Kulon Progo) and the central Java province (Malengang, Boolali, Klaten and Purworejo) were affected. The earthquake reduced hundreds of buildings to rubble, disrupted essential services and damaged roads and airport runways. Reports confirmed more than 5000 dead and 15,000 injured with 200,000 to 600,000 people displaced. The high population density living in close proximity to the epicentre explains these high numbers. In addition, the volcano Merapi, close to the epicentre, increased activity following the earthquake.

Four large dams are situated in the area where the epicentre was, namely the Wonogiri, Parangjoho, Song Putri and Sermo dams in the Wonogiri and Kulon Progo districts. During rapid assessment activities by the Indonesian authorities, it became apparent that the earthquake and its aftershocks might have affected the integrity of these four large hydro dams.

Source : http://www.un.org/Depts/Cartographic/map/profile/indonesi.pdf

International collaboration

The Joint OCHA/UNEP Environment Unit (JEU) is the United Nations mechanism to mobilize and coordinate the international response to environmental emergencies and natural disasters with major environmental impacts. Initiated over ten years ago by governments, the Joint Environment Unit integrates the United Nations Environment Programme's (UNEP) technical expertise into the Office for the Coordination of Humanitarian Affairs' (OCHA) response coordination structure.[1]

The Monitoring and Information Centre (MIC) of the Civil Protection Unit, operated by the European Commission in Brussels, is the operational heart of the Community Mechanism for Civil Protection. It gives countries access to the community civil protection platform. Any country affected by a major disaster – inside or outside the EU – can launch a request for assistance through the MIC.[2]

The JEU and the MIC jointly offered assistance to the Indonesian authorities. In July, the Indonesian Ministry of Public Works through the Directorate General of Water Resources officially requested assistance for an assessment of the four dams.

In response, a joint expert mission of the European Union and the United Nations was organized from 21 August to 1 September 2006. The mission consisted of Dr. Peter Tschernutter of the University of Technology, Vienna, Austria and the Institute of Hydraulic Engineering and Water Resources Management, and Mr. Tore Valstad of the Norwegian Geotechnical Institute, Oslo, Norway. Their task was to assess the integrity of the dams and to propose immediate remediation/mitigation measures as required. The OCHA Country Office organised and facilitated contact between the national authorities and the mission team. During the mission, discussions were held with the Dam Safety Head Office in Jakarta and their local offices, the Office of Balai Sermo in Yogyakarta and the Office of Batas Basin in Solo, and site visits to all dams were carried out. At the end of the mission, the experts met with the national authorities for a debriefing and presented a preliminary draft report.

Consolidated report: Objectives

The present report provides an overview of the initial observations made by the Indonesian Dam Safety Commission and comprises the observations and conclusions made by Mr. Tschernutter and Mr. Valstad in their respective reports, which emphasized slightly different issues.

This joint European Commission and United Nations mission could not have been accomplished without the generous support of the Norwegian and Austrian authorities. We are grateful for their assistance.

[1] http://ochaonline.un.org/webpage.asp?MenuID=12041&Page=640
[2] http://ec.europa.eu/environment/civil/prote/mic.htm

2. Secondary Risks following Natural Disasters

Major disasters have acute, negative environmental impacts that can threaten human life and welfare. These impacts may include damage to industrial facilities such as chemical plants, acute waste management problems, and erosion and landslide risks. Major disasters may also result in environmental issues that are not life threatening and therefore less urgent, but which are nonetheless important and require attention in the early recovery process – for example, damage to ecosystems.

When affected by a natural disaster, like an earthquake, large infrastructure and hazardous material storage facilities can pose an additional risk. It is important not to neglect these secondary risks in the aftermath of a humanitarian emergency in order to prevent a reaction of disasters from affecting an already weakened society. The consequences of a collapse of one of the four dams would have very serious humanitarian impacts. Moreover, it is vital that these possible risks are identified as soon as possible and preferably in the emergency response phase.

The earthquake and dams

Expert opinions differ about the epicentre (range from 37.2 km to just 25 km away from Yogyakarta), the magnitude (range from 5.9 to 6.3 on Richter scale) as well as the depth of the earthquake (range from 10 to 33 kilometres). Because there was no strong motion recorder in operation in the affected area, the team has not been able to assess the shaking that the dams were exposed to.

The distance and direction from the epicentre, as estimated by the meteorological and geophysical service of Indonesia, the Badan Meteorologi & Geofisika (BMG) and the United States Geological Survey (USGS), are given in Table 3.1 & 3.2.

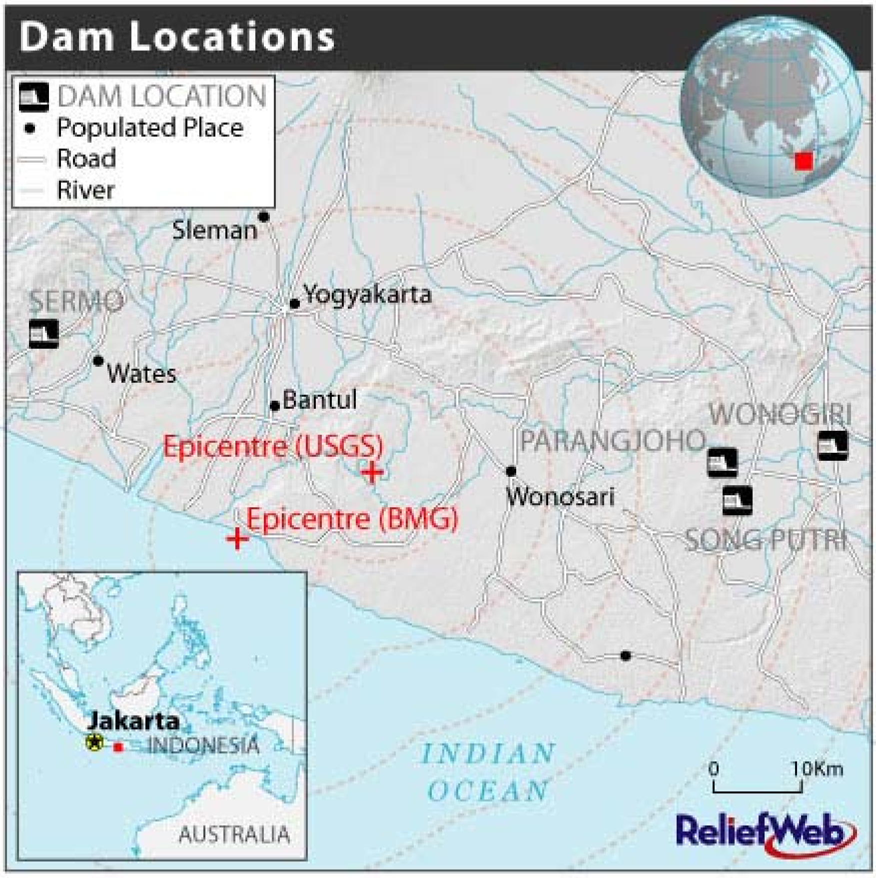
Table 3.1 Position of dams

Dam	Geographic Coordinates		UTM – Zone 49M	
	Latitude (°)	Longitude (°)	Nothing (m)	Easting (m)
Sermo	07S49.4	110E07.4	9135169	403310
Parangjoho	07S57.1	110E49.0	9121037	479798
Song Putri	07S59.5	110E49.8	9116585	443797
Wonogiri	07S56.2	110E55.6	9122699	491921

Table 3.2 Distance from epicentre to dam

Dam	Relative to BMG epicentre		Relative to USGS epicentre	
	Bearing (°)	Distance (km)	Bearing (°)	Distance (km)
Sermo	293	40.0	317	31.5
Parangjoho	088	39.4	081	55.4
Song Putri	095	41.1	086	56.3
Wonogiri	087	51.7	081	67.6

The distance to the causative fault is shorter than the epicentre distance, especially for the dams on Solo River. The distance is, however, long enough to cause significant attenuation of the shaking experienced along the causative fault.



The names shown and the designations used on this map do not imply official endorsement or acceptance by the United Nations.
Map data source: UN Cartographic Section, Indonesia Authorities, BMG, USGS.

3. Analysis

General Observations

Issues and common features

The four embankment dams included in this study are all sound. Each is designed, constructed and operated according to sound principles for embankment dam engineering.

The earthquake that hit the Yogyakarta district early morning on 27th May 2006 caused significant damage to building structures. So far any strong motion accelerogram (a record of an accelerograph, i.e. a strong motion seismograph) for the event has not been seen, but it is obvious that poorly built earth structures also have suffered damage.

The four dams all performed satisfactorily during the earthquake. None of the dams failed, nor suffered damages, which compromised any of the dam's integrity. Two dams have undergone noticeable displacements (Sermo and Parangjoho), but the magnitude was not large enough to cause displacements larger than the displacements due to ordinary loadings from own weight and reservoir pressure.

Limited information was available regarding the embankment fill materials. However, dam authorities informed that the core and general embankment fill is sandy clay obtained from borrows and general excavation. Such well-graded materials are known to be nearly impervious and stable when well compacted. What is very important for earthquake loading is that these materials generally do no lose strength during earthquake shaking. All four dams contain a significant amount of rock fill. That is the material obtained by blasting from quarries and from general excavations. Rock fill is supposed to be a hard and free draining material. The rock fill observed in the four dams stem from two distinct rock types: volcanic breccia and andesite. It is apparent from observations on riprap that the volcanic breccia partly weather to a fine-grained soil exposed to the elements. If this also occurs with the rock fill body of a dam the result will be a slow, but continuous creep deformation of the dam and partly clogging of the open pore space between the rock fill body. Thus the free draining property of the rock fill may be questioned as time passes.

> The earthquake creates ground movements that can be categorized as a "shake," "rattle," and a "roll." Every structure in an earthquake zone must be able to withstand all three of these **loadings** of different intensities. Although the ground under a structure may shift in any direction, only the horizontal components of this movement are usually considered critical in a structural analysis.

> **Riprap** is rock or other material used to stabilize shore. Riprap reduces water erosion by resisting the hydraulic attack and dissipating the energy of flowing water or waves.

The record for embankment dams' behaviour during earthquakes is generally favourable. No catastrophic failure has occurred with an uncontrolled release of the reservoir with embankment dams during an earthquake. However there have also been a few cases of unsatisfactory performance.

Embankment dams constructed from uniform silt, sand and fine gravel have suffered significant damage during earthquakes due to cyclic mobility and liquefaction. On the other hand, dams built out of materials that do not lose strength due to cyclic loads, i.e. clay and free draining rock fill are able to withstand severe earthquake shaking.

Seepage observations

The seepage observations of the dams have been evaluated to see if the earthquake has changed the ability of the dams to retain water. All four dams have systems for collection of water seeping through the “impervious” portion of the dam and V-notch weirs to measure the quantity of seepage. We have obtained information about the seepage observations from Sermo, Wonogiri and Parangjoho Dams. The observations have been plotted as seepage quantity against reservoir water elevation. The aim is to investigate if quantity of seepage has changed due to the earthquake shaking.
(Details on the seepage calculations can be found in the Annex I)

A **weir** is a notch of regular form through which water flows. The term is also applied to the structure containing such a notch. Thus a weir may be a depression in the side of a tank, reservoir, or channel, or it may be an overflow dam or other similar structure. Weirs are classified in accordance with the shape of the notch; such as rectangular weirs; triangular, or **V-notch weirs**.

3.1 Sermo dam

Expert assessment

The Sermo dam has a weak left abutment that is being repaired. The records from inclinometer casings and magnetic ring settlement gauges show that the embankment was permanently displaced due to the earthquake shaking. The shaking caused a compaction and deflection of the dam body especially between elevations 100 to 125, i.e. 20 to 45 m below the dam crest. The deformations accumulate to vertical settlement as well as horizontal displacements of about 50 mm.

The displacements show up at the surface of the dam to a limited extent. This leads to the fact that the upper part of the dam body is “arching” above a compressed zone. The upper part – on top of the compressed zone - is dry and stiff compared to the lower and saturated part. As a result of the different conditions in both parts, there may be an unfavourable stress condition within the dam body during filling of the reservoir in the next wet season. In the next wet season, the core will most likely consolidate and re-establish its ordinary stress field, but hydraulic fracturing and leakage through the core may take place.

Seepage observations

The plot for Sermo Dam, Figure 1 (see Annex IV), has compared the observations for the dry seasons 2004 and 2005 (Period 1 May to 31 October). The plot shows that the observations for the period after 26 of May are very close to the corresponding observations in 2004 and 2005. In the period prior to the earthquake, there is more seepage than the previous two years, but that is due to significant precipitation during the month of May 2006.

Settlement observations

The Sermo Dam has internal settlement devises (ring magnet system) and inclinometers for lateral displacement measurement. The two installations are both on the centre section, Station 15, one on the centre line and one in the downstream slope 25 m off the centre line.

One of the inclinometers showed a displacement of about 850 mm immediately after the earthquake, but repeated observations show no displacement. The team concluded that these are incorrect observations. The observations of the inclinometer channels should have been more consistent (less variation). Due to the fact that the instrument has not been calibrated for years, the procedures for the inclinometer readings should be scrutinized and a routine for recalibration of the instrument implemented.

The internal settlement device, SG1 shows that some settlement has taken place between elevation 110 and 125 mASL. The plot of the observations between February 2005 and June 2006 in Figure 4 (see Annex IV) show a maximum settlement of 30 mm. Since there is zero settlement above elevation 130 mASL, there must be a zone of compression and extension mid height in the dam and that the top of the dam is arching above this zone. The zone of extension suggests that the material is loosened and that water may percolate easier though this zone during the next filling of the reservoir. Future observations may show recompression of the loosened zone and settlement extending towards the dam surface.

3.2 Parangjoho Dam

(For basic data on the dam, see Annex II)

Initial assessment by the Dam Safety Commission

The crack at the dam crest extends from left (near the intake) to one-third of the length of the dam (about 150 m, about 0.5 cm wide and 0.5 – 1 m deep) near the upstream edge. There is a long crack in the middle of the dam at the downstream side. It was observed that both intake slide gates could not be operated. The bridge over the intake area had shifted about +/- 5 cm. At the intake tower, all reinforced concrete columns sustained cracks. Further, piezometer readings needed to be calculated for the assessment. There were no measurements available for displacements and horizontal movements.

Also, a slightly increasing seepage (about 0.3 l/s) was measured after the earthquake. Manual seepage measuring device used weekly did not cover seepage value peaks. Repair of the equipment was requested. The seepage water was clear, however, and contained no sediment. At the same time, no depressions or deformations in the up- and downstream dam slopes and abutments were noticed. There was an intensive monitoring for at least 6 weeks.

Temporary conclusion
The cracks at the dam crest and in the middle of the dam were repaired prior to the mission team's arrival, as were the intake slide gates and the up- and downstream dam slopes and abutments. The seepage measuring devices, however, still need to be repaired.

<u>Expert assessment</u>

Reservoir level: 192.68 m a. s. l.

The reservoir was nearly empty and the water level was near the minimum water level (LWL);
Weather: dry period.

The Parangjoho dam developed longitudinal cracks along the crest during the earthquake. Cracks were evident under the tiles surface on the crest. The maximum crack width is about 20 mm.

Longitudinal cracks are common in embankment dams. They typically occur during first filling of the reservoir and other exceptional loadings. They are, as a rule of negligible consequences to the dam's performance since they do not allow any water percolate through the dam. The standard practice is to backfill the crack and recompact the embankment.

Longitudinal cracks could be a symptom of sliding in the dam body. Sliding would be evident if the two edges of the crack rest at slightly different elevation. This does not seem to be the case for Parangjoho Dam.

Overall observations include a higher leakage and likely changed dam behaviour after the earthquake.

<u>Seepage observations</u>

Left section:	58 mm, 1.15 l/s
Right section:	43 mm, 0.55 l/s

Left section:	Uncoloured clear water No sediment in the seepage collecting pool
Right section:	Lightly coloured water – colour similar to reservoir water. Dark (black) fine sediments in the seepage collecting pool

Comment:
There was relatively high seepage value for the low reservoir level and fine sediment in the right drainage section, observed.

The figure for the Parangjoho, Figure 2 (see Annex IV) includes observations from May 2005 to July 2006. The seepage collection and measuring system at Parangjoho is divided in two sections. The left weir measures seepage stemming from the embankment and the right weir measures seepage from springs in the foundation.

The figure shows that the seepage quantity stemming from the springs is independent of the reservoir water elevation, while the seepage through the embankment increases with reservoir water elevation. Comparing observations before and after 27 May 2006 shows that the seepage from the springs is unchanged, while the seepage through the embankment has a small, but significant increase. Comparing the observation from the dry season 2005 with the observations after the earthquake with a water level of 195 mASL, the seepage has increased from 0.8 l/s to 1.4 l/s, i.e. an increase of 0.6 l/s (litre per second).

The seepage is still small, less than 2 l/s. The seepage water is clear. The increase in seepage quantity is of no safety concern at the moment.

3.3 Wonogiri Dam

(For basic data on the dam, see Annex II)

<u>Initial assessment by the Dam Safety Commission</u>

There were no horizontal or diagonal cracks, no depressions or other signs observed. The concrete structures showed no damage and the seepage water was clear and contained no sediment. No increased seepage was noticed after the earthquake. Most of the dam monitoring instruments, however, was not working, such as telectric and hydraulic piezometers, settlement gauges, seismograph, standpipes. The immediate repair of these instruments was suggested.

Temporary Conclusion
The dam’s condition appears normal.

<u>Expert assessment</u>

Reservoir level: 133.09 m a. s. l.

The reservoir water level was about 2.9 m below the normal water level (NWL);
Weather: dry period.

Despite the Dam Safety Commission, at least one larger transverse shearing crack in the upper upstream dam slope with local deformations of the protection layer (riprap) was observed.[3] At other locations of the upstream dam slope (Riprap) indications of minor deformations (probably short cracks) were also observed. No indications of cracking or larger deformations were observed at the dam crest and the downstream dam slope.

Seepage observations

The figure for Wonogiri Dam, Figure 3, (see Annex IV) includes observations from January to July 2006. The plot shows that the seepage quantity after the earthquake correspond to the values observed during dry periods prior to the earthquake.

Seepage reading V-notch station 20: about 35 to 40 mm, 0.33 to 0.46 l/s

Comment:
Since the seepage collecting system of the main dam is able to collect all leakage coming through the dam, the foundation and the abutments, the seepage value in the dry season can be assessed as rather low.

Both the seepage weirs and the seepage reading scale have been designed for smaller amounts of higher flow values cannot be measured properly.

In conclusion, the earthquake, under the reservoir conditions maintained since the earthquake, did not affect the seepage through the dam.

3.4 Song Putri Dam

(For basic data on the dam, see Annex II)

Initial assessment by the Dam Safety Commission

No cracks were observed at the dam crest, nor any depressions or deformations in the up- and downstream dam slopes and abutments. All standpipes were broken and no readings were available. Seepage increased slightly. The seepage water was clear and contained no sediments.

Temporary Conclusion:
The dam's condition and operations appear normal. The instrumentation still needed to be fixed when the team arrived.

Expert assessment

Reservoir level: 215.93 m a. s. l.

Reservoir water level only about 2.4 m above the minimum water level (LWL);
Weather: dry period.

[3] Details are given in the attached photo documentation (See Annex V).

There were no significant indications found of a change in the dam's performance after the earthquake, allowing for the conclusion that the Song Putri dam did not suffer any obvious damage from the earthquake.

Seepage observations

Seepage reading V-notch: about 78 mm, about 2.3 l/s

Comment:
There was a relative high seepage value for a relative low reservoir level.

4. Conclusions and Recommendations

Sermo dam

<u>General condition of the dam after the earthquake</u>
The seepage did not indicate any impact or change from the earthquake.

<u>Recommendations</u>
The dam should be kept under close surveillance due to an unfavourable stress condition within the dam body. In particular, the dam requires close observation during filling of the reservoir in the next wet season, when the reservoir rises above elevation 110 mASL.

Parangjoho dam

<u>General condition of the dam after the earthquake</u>

The earthquake significantly affected the dam and the intake structure. After the repair of the cracks at the dam crest and the intake gates, the dam can be operated without restrictions although with proper dam surveillance. Surveillance during the coming impounding periods will be most important to ensure safe operation of the reservoir. The instrumentation of the dam must be fixed and upgraded.

Besides these items, the slightly coloured water – colour similar to reservoir water in the right seepage section - and the dark (black) fine sediments in the seepage collecting pool indicate a problem in the dam sealing system. A relative high seepage value for the low reservoir level was measured**.**

<u>Recommendations</u>

- Cleaning the seepage collecting pools
- Seepage water for the left and right section of the dam need to be compared (using electric conductivity as an indicator) to determine the origins of the seepage (directly from the reservoir or from springs)
- Intensive monitoring up to the NWL and if possible up to HWL for at least the next two impounding periods (standpipes, seepage – twice a week, electrical conductivity and sediment sampling of the seepage water (dry period) weekly.
- Installation of an automatic seepage recording system and establishment of seepage limits for the dry and rainy season.
- Repair of standpipes to measure at least 3 profiles (crest, berme, dam toe).
- An emergency preparedness plan in case of dam failure with guidelines for the population living below of the reservoir should be drafted.

Wonogiri dam

General condition of the dam after the earthquake

The main dam with all appurtenant structures and the subsidiary dam appear to be minimally affected by the earthquake, and therefore there are no indications to restrict the dam operation. The instrumentation of the dam must be fixed and upgraded.

Aside from the cracks detailed by the Dam Safety Commission above, the earthquake also caused at least one larger transverse shearing crack in the upper upstream dam slope with local deformations of the protection layer (riprap).

Recommendations

- Immediate repair of broken dam monitoring instruments.
- Monitoring up to the normal water level (NWL) and if possible up to the high water level (HWL) for at least the next two impounding periods (standpipes, seepage – weekly).
- Installation of an automatic seepage recording system - in addition to the manual equipment - and establishment of seepage limits for the dry and rainy season.
- Fixing existing standpipes or installation of new standpipes for monitoring of the groundwater level in at least 5 profiles (crest downstream edge, dam toe) of the main dam.
- Monitoring and recording of the standpipes - at least once a week - within the next two years. A reduction in the frequency of testing can be decided in the future depending on the results.
- Updating of the emergency preparedness plan and upgrading of the public warning and alarming system.
- Installing, monitoring and recording of standpipes in at least one profile of the Subsidiary Dam.
- Documentary through photographs of the upstream shear crack during the coming two years for comparison.

Song Putri Dam

General condition of the dam after the earthquake

The dam with all appurtenant structures was less affected by the earthquake and therefore there are no reasons to restrict operations of the reservoir. The instrumentation of the dam must be fixed and upgraded.

A relative high seepage value for the low reservoir level was measured**.**

Recommendations

- Intensive monitoring up to the NWL and if possible up to HWL for at least the next two impounding periods (standpipes, seepage – twice a week, sediment sampling of the seepage water weekly in the dry period).
- Repair of standpipes to measure at least 2 profiles (crest, berme, dam toe).
- Installation of an automatic seepage recording system and establishments of seepage limits for the dry and rainy season guidelines measures for the population living below the reservoir should be drafted.

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Annexes

Annex I: Seepage Calculations

The relationship between the head and the discharge over a triangular, sharp crested weir is:

$$Q = \frac{8}{15} C_D \tan\left(\frac{\alpha}{2}\right) \cdot h^{2.5} \sqrt{2g}$$

where	Q	discharge or flow (L^3/T)
	C_D	coefficient 8)
	α	angle of weir
	h	measuring head (L)
	g	acceleration of gravity (L/T^2)

For a weir with a maximum head of 300 mm the coefficient, C_D is between 0.57 and 0.60. For head in the range between 60 and 300 mm C_D = 0.581 is a commonly used value. At the latitude of Yogyakarta the acceleration of gravity is about 9.78 m/s2. With a C_D coefficient equal 0.581 this gives following formula for calculation of discharge:

$$Q\{litre\ per\ second\} = 4.3339 \cdot 10^{-5} \cdot h^{2.5}\{mm\}$$

It was observed during the site inspection that the head at the V-notch weir was measured vertically from the V-notch to the water surface. This method is incorrect due to the curvature of the water surface. The head is actually the vertical distance from the V-notch to the upstream water surface unaffected by the weir. The rule of thumb is to measure the head at a location four times the head upstream of the V-notch. This rule of thumb should be implemented at all seepage measuring stations.

Annex II: Basic Data of dams

Wonogiri Multipurpose Dam

Location	Bengawan Solo River Basin, Induk River
District	Wonogiri
Nearest village	Danuarjo
Construction Period	1976-1982
Reservoir	
Catchment area	1,350 km^2
Total reservoir volume	735 mill. m^3
Effective reservoir volume	440 mill. m^3
Flood control capacity	220 mill. m^3
Sediment storage volume	120 mill. m^3
Reservoir Surface area	
LWL	26.7 km^2
HWL	73.6 km^2
SWL	87.0 km^2
SWL	91.0 km^2
Reservoir purpose	
Irrigation	30,000ha
Flood Control	from 4,000 m^3 to 400m^3
Hydro Power Generation	28.2 GWh/a
Triple cropping farming	
Fishery	
Raw water for industry and drinking water	
Design Flood data	
Q_{60}	4,000 m^3/s
Design flood	5,100 m^3/s
PMF, Q_{PMF}	9,600 m^3/s
Sedimentation dredging	
Location	intake
Dredging volume	310,000 m^3
Dredging period	2004
Main dam	
Dam Type	Rock fill Central clay core
Max. dam height (above foundation)	40 m
Dam height above river base	30 m
Crest length	830 m
Crest width	10 m
Dam crest elevation	142.00 m a. sl.
Draw down water level (LWL)	127.00 m
Normal water level (NWL)	136.00 m
High water level for Q_{60} = 4,000 m^3/s (SWL)	138.20 m

High water level for Q_{PMF} = 9,600 m^3/s (EHWL)	139.10 m
Dam foundation	weathered volcanic breccia, tuff brecia
Grout curtain	2 rows
Grouting material	cement/bentonite
Grouting depth	14 – 25 m
Embankment volume	1,223,300 m^3
Type of fill material	
Core (167,000 m^3)	mixed clay, river sand, gravel
Filter (144,100 m^3)	selected river sand, gravel
Transition zone (320,200 m^3)	Andesite, volcanic breccia
Rock (586,000 m^3)	Andesite
Upstream slope	1 : 3.1
Downstream slope	1 : 2.2
Spillway	
Type	gated weir, chuteway, flip bucket, plunge pool
Crest weir	131.00 m a.s.l.
Radial gates	4 x 7.5m(W) x 7.8m (H)
Capacity elevation 139,1 m (PMF)	1,360 m^3/s
Q_{60} flow value	400 m^3/s
PMF flow value	1,350 m^3/s
Chuteway width	30 to 20 m
Elevation flip bucket	119,00 m
Stilling basin (plunge pool)	35 x 51m, El.100m
Dam instrumentation	
Seepage measuring station	2 stations (n°14, n° 20) 1 V-notch each
Seepage collecting system	No info available
Piezometers (hydraulic)	12, all out of work
Standpipes	all out of work
Geodetic surface points	14
Stability analyses	
Material properties	
Clay core	γ_s 0 2.02, φ = 23.4°, c = 4.6 t/m^2, k = 7.9 x 10^{-6} cm/3
Filter, random fill	γ_w = 2.21, φ = 35°, c = 0
Rock fill	γ_w = 1.87, φ = 40°, c = 0
Reservoir level HWL	136.00 m
Seismic coefficient (k)	0.12
Calculated safety factor (HWL + k)	required > 1.2 downstream s =1.37 upstream s = 1.35

HPP and Irrigation	
Installed capacity HPP	12.4 MW
Number of turbines	2
Intake capacity	75 m³/s

Subsidiary Dam

Dam type	Rockfill, random backfill downstream
Max. dam height (above foundation)	14 m
Crest length	420 m
Crest width	10 m
Dam crest elevation	142.00 m a. s. l.
Embankment volume	101,100 m³
Type of fill material	
Rock (98,000 m³)	Volcanic breccia, Andesite
Random fill	Clay, tuff, tuff and volcanic breccia
Upstream slope	1 : 3.1
Downstream slope	1 : 1.7, 1 : 2.5

Dam instrumentation	
Seepage measuring station	no
Piezometers (hydraulic)	no
Standpipes	no
Geodetic surface points	no

Dam break analyses
Calculated in 1999/2000; great number of households effected in case of a failure or incident

Emergency preparedness plan, warning and alarming system:
The existing flood forecasting and warning system (1982) is currently under review and a new forecasting and warning system shall be installed in 2009.

Reservoir level May 27th, 2006: *136.74 m a. s. l.*
Reservoir level about 0.7 m above normal water level (NWL) or about 1.5 m below SWL.

Parangjoho Dam

Location*:*	Bengawan Solo River Basin, Tempuran River
District	Eromoko
Nearest village	Demesan
Construction period	1973 – 1983

Dam rehabilitation (crest heightening, upstream stability fill) about 1999

Reservoir

Catchment area	21.8 km²
Total reservoir volume	1.76 mill. m³
Effective reservoir volume	1.19 mill. m³
Reservoir surface area:	
HWL	204.2 ha
NWL	200 ha
Reservoir purpose:	
Irrigation	750 ha
Triple cropping farming	
Tourism	
Design flood data	
PMF, Q_{PMF}	700 m³/s

Dam

Dam type	Homogeneous earthfill
Max. dam height (above foundation)	25 m
Dam height above river base	20 m
Crest length	315.5 m
Crest width	4.8 – 6.6 m
Dam crest elevation (after heightening 1999 + 1.73)	200.73 m a. s. l.
Normal water level (NWL)	196.00 m
High water level (HWL)	198.00 m
Dam foundation	no detailed information available
Embankment volume (before heightening)	323,500 m³
Type of fill material:	
Homogeneous material:	
Up to el. 190 m black clay, above el. clay/sand	
Filter (dam toe, down- and partially upstream slope):	
Rip Rap:	Andesite, volcanic breccia
Upstream slope	1 : 3
Downstream slope	1 : 2, 1 : 2.1
Upstream shoulder	additional stabilising fill (rock) + filter (1999)
Downstream shoulder	heightening, additional filter and Rip Rap(1999)

Spillway

Type	ungated weir, chuteway, stilling basin
Crest weir	196.00 m a. s. l.
Design capacity	310 m^3/s
Chuteway width	47 m
Stilling basin	

Dam instrumentation

Seepage measuring station (separated left and right am toe)	1 station, 2 V-notches
Piezometers (hydraulic)	out of work
Standpipes (monitored, not damaged)	19
Standpipes (originally designed/ damaged)	38/23
Geodetic surface points dam	9
Geodetic surface points abutments	4

Irrigation

Intake capacity	32.9 m^3/s
Slide gates	2

Dam break analyses
Referring to Indonesian Standards (Dam Safety Units) dam break analyses are generally necessary for a reservoir, volume larger than 500,000 m^3, or if the dam is higher than 15 m. In addition no dam break analyses is requested if the hazard risk assessment gives a “low impact” to the downstream area (wide valley, less populated etc.). The Parangjoho Dam has been classified on the hazard risk level “low impact”.

Emergency preparedness plan and warning system
Referring to Indonesian standards no emergency preparedness plan and no warning and alarm system is requested for the Parangjoho Dam.

Reservoir level May 27th, 2006: 193.76 m a. s. l.
Reservoir level about 2.2 m below normal water level (NWL).

Song Putri Dam

Location	Bengawan Solo River Basin, Mlati River
District	Eromoko
Nearest village	Sindukerto
Construction period	1977 – 1984
Reservoir	
Catchment area	2.67 km²
Total reservoir volume (MWL)	0.796 mill. m³
Total reservoir volume (NWL)	0.725 mill. m³
Effective reservoir volume	0.66 mill. m³
Reservoir surface area:	
MWL	8.6 ha
NWL	8.2 ha
Reservoir purpose:	
Irrigation	170 ha
Design flood data :	
Q_{60}	34 m³/s
Design flood Q_{500}	52 m³/s
Dam	
Dam type	Rockfill, earth core
Max. dam height (above foundation)	32 m
Dam height above river base	25 m
Crest length	265.5 m
Crest width	7 m
Dam crest elevation	227.00 m a. s. l.
Normal water level (NWL)	224.00 m
High water level for design flood	225.08 m
Min. water level (LWL)	213.50 m
Dam foundation	lava tuff, volcanic breccia
Embankment volume	350,000 m³
Type of fill material:	
Rock	Andesite
Filter (down- and upstream)	selected sand, gravel
Rip Rap	Andesite
Upstream slope	1 : 3
Downstream slope	1 : 2
Spillway	
Type	ungated weir, chuteway, stilling basin
Crest weir	224.00 m a. s. l.
Crest length	20 m
Design capacity	67.5 m³/s
Chuteway width	20 m
Stilling basin:	

Dam instrumentation:

Seepage measuring station	1 station, 2 weirs
Piezometers (hydraulic)	out of work
Standpipes (monitored, not damaged)	14
Geodetic surface points dam	6

Irrigation:

Intake capacity	0.427 m^3/s
Slide gates	2

Dam break analyses

Referring to Indonesian Standards (Dam Safety Units) dam break analyses are generally necessary for a reservoir volume larger than 500,000 m^3 or if the dam is higher than 15 m. In addition if no dam break analysis is requested, the hazard risk assessment gives a “low impact” to the downstream area (wide valley, less populated etc.). The Song Putri Dam has been classified on the hazard risk level “low impact”.

Emergency preparedness plan and warning system

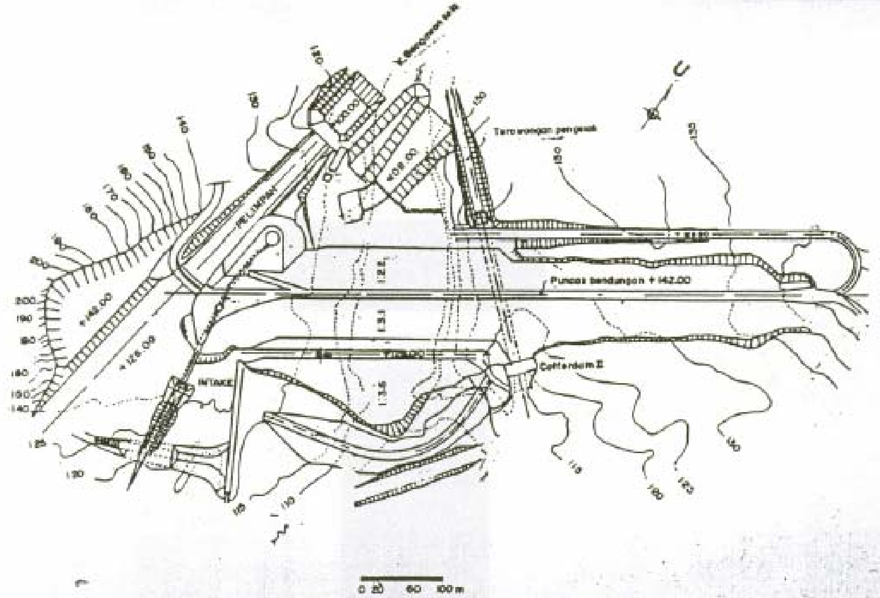
Referring to Indonesian Standards no emergency preparedness plan and no warning and alarm system is requested for the Song Putri Dam.

Reservoir level May 27th, 2006: 222.05 m a. s. l.

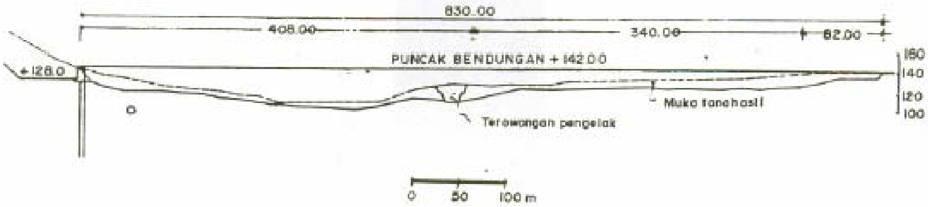
Reservoir level about 2 m below normal water level (NWL).

Annex III: Technical Drawings

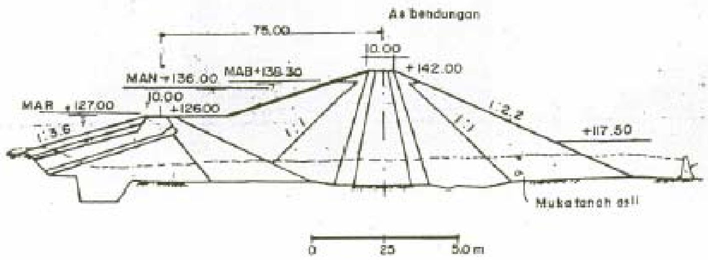
Wonogiri Dam



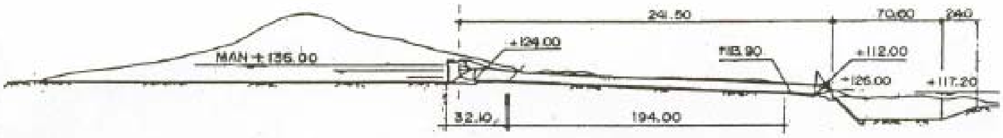
TATA LETAK BENDUNGAN WONOGIRI



POTONGAN MEMANJANG BENDUNGAN

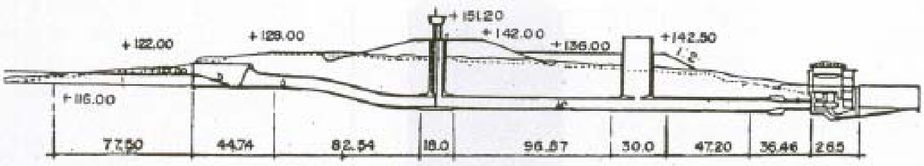


POTONGAN MELINTANG BENDUNGAN



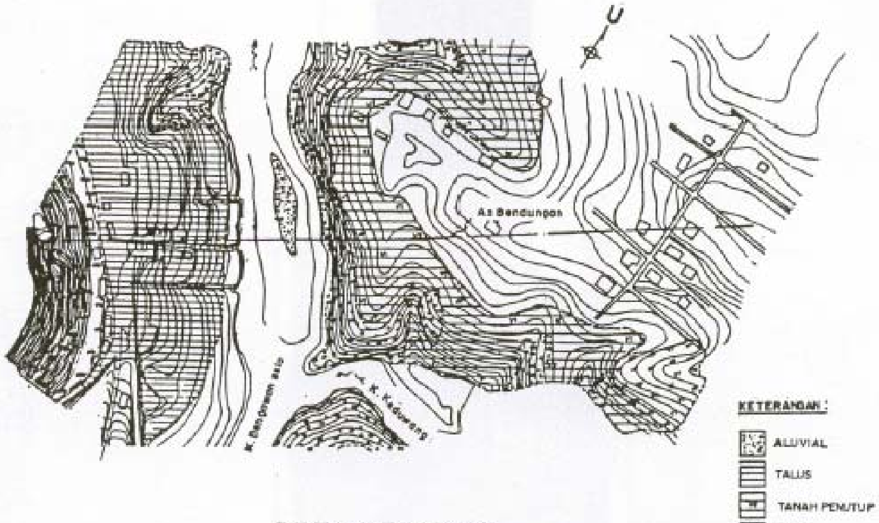
POTONGAN MEMANJANG PELIMPAH

0 20 40 60 100 m



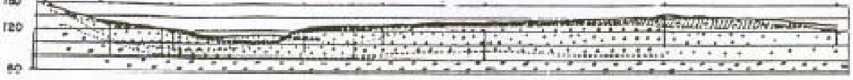
POTONGAN "OUTLET"

0 20 40 60 80 m



PETA GEOLOGI

0 33 66 99 m

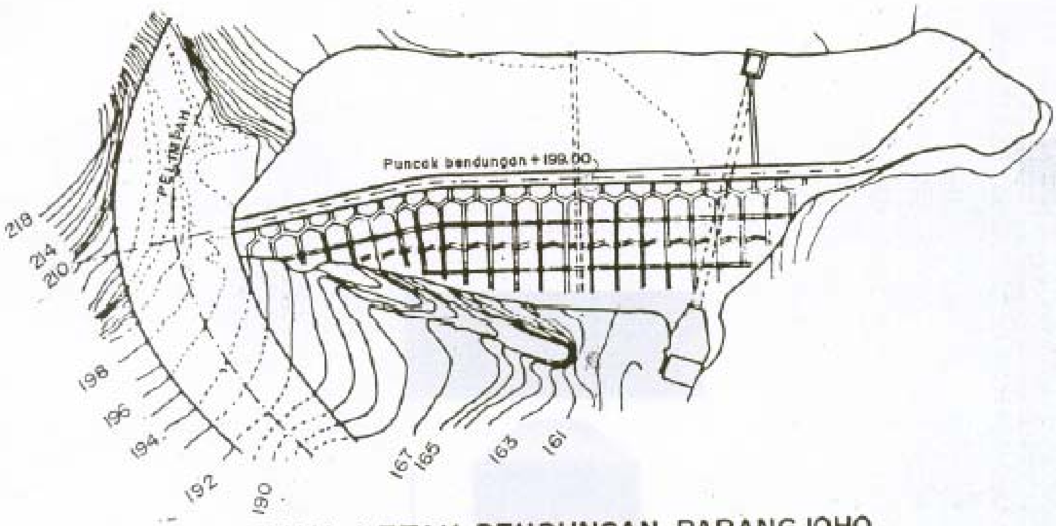


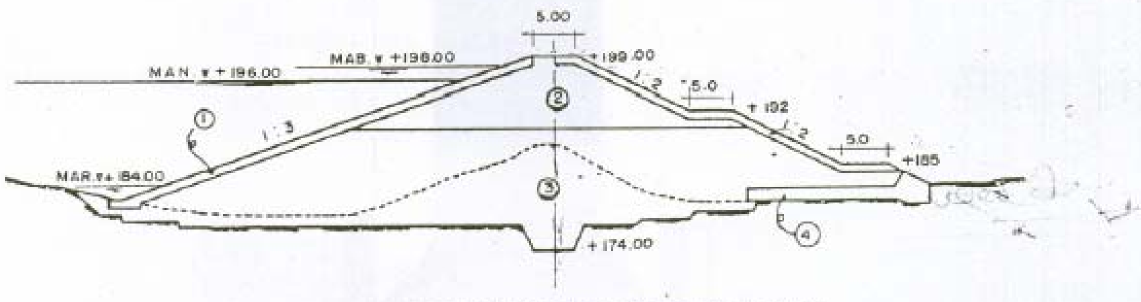
PENAMPANG GEOLOGI

0 40 80 m

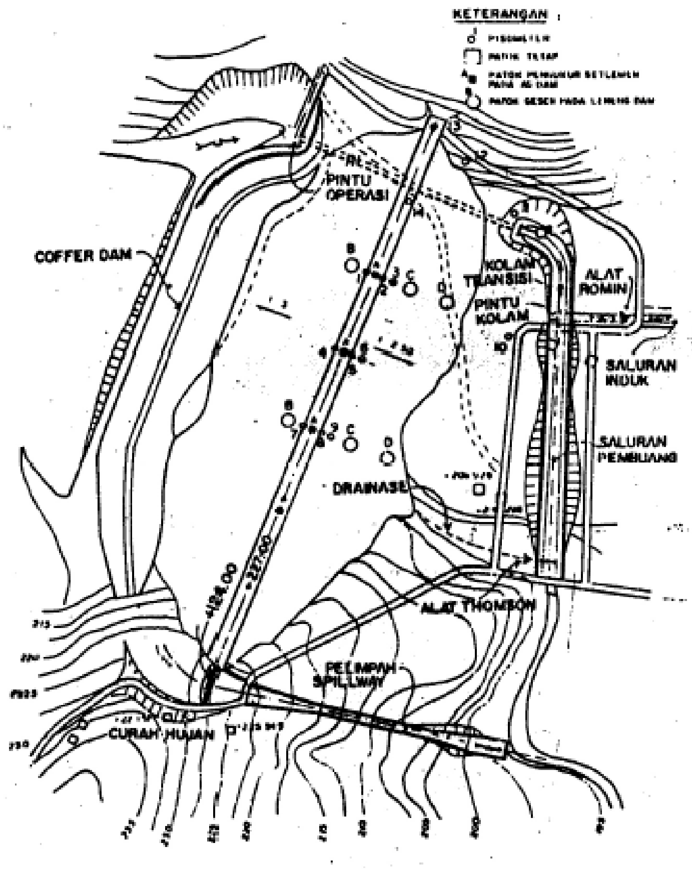
145

Parangjoho Dam

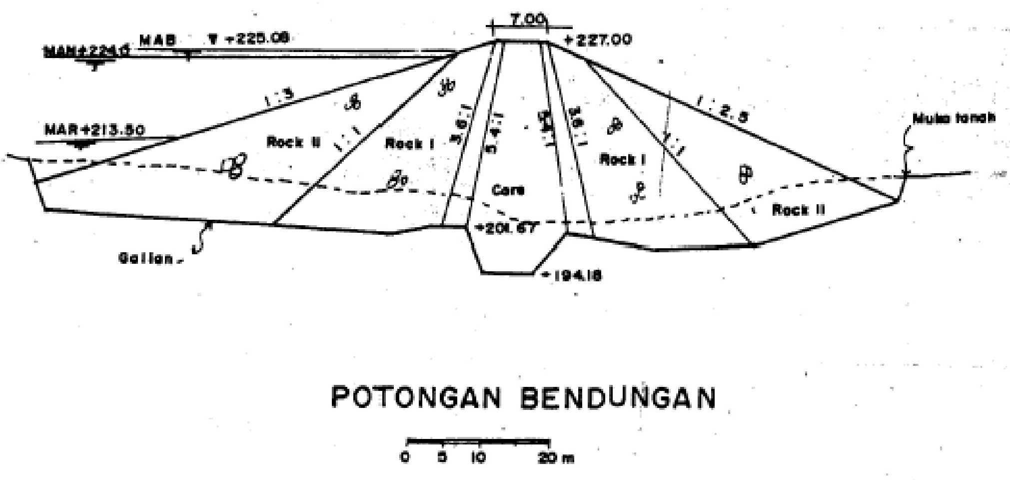




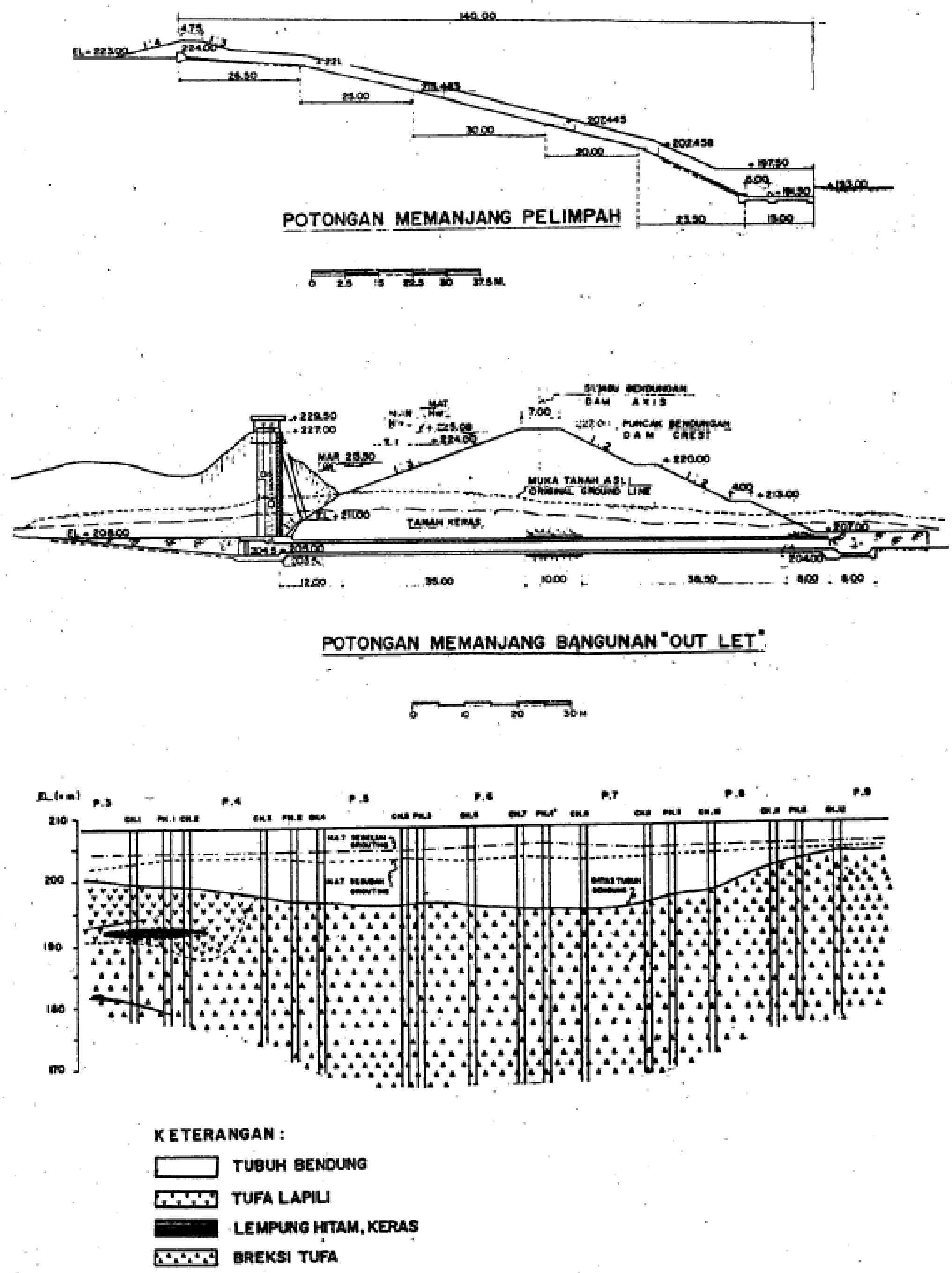
Song Putri



TATA LETAK BENDUNGAN SONG PUTRI



POTONGAN BENDUNGAN



PENAMPANG GEOLOGI BENDUNGAN SONG PUTRI

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Annex IV: Figures

Figure 1

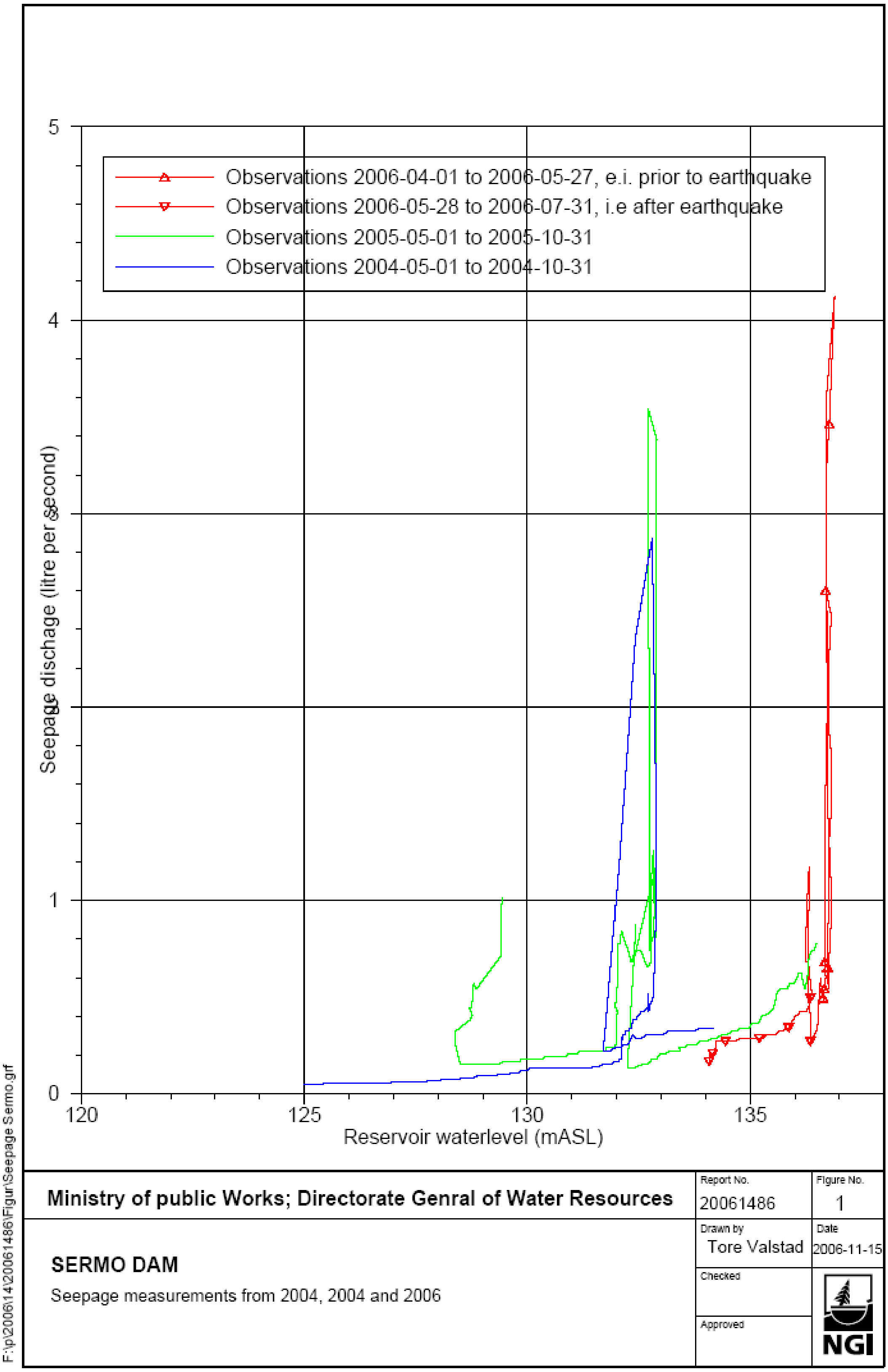
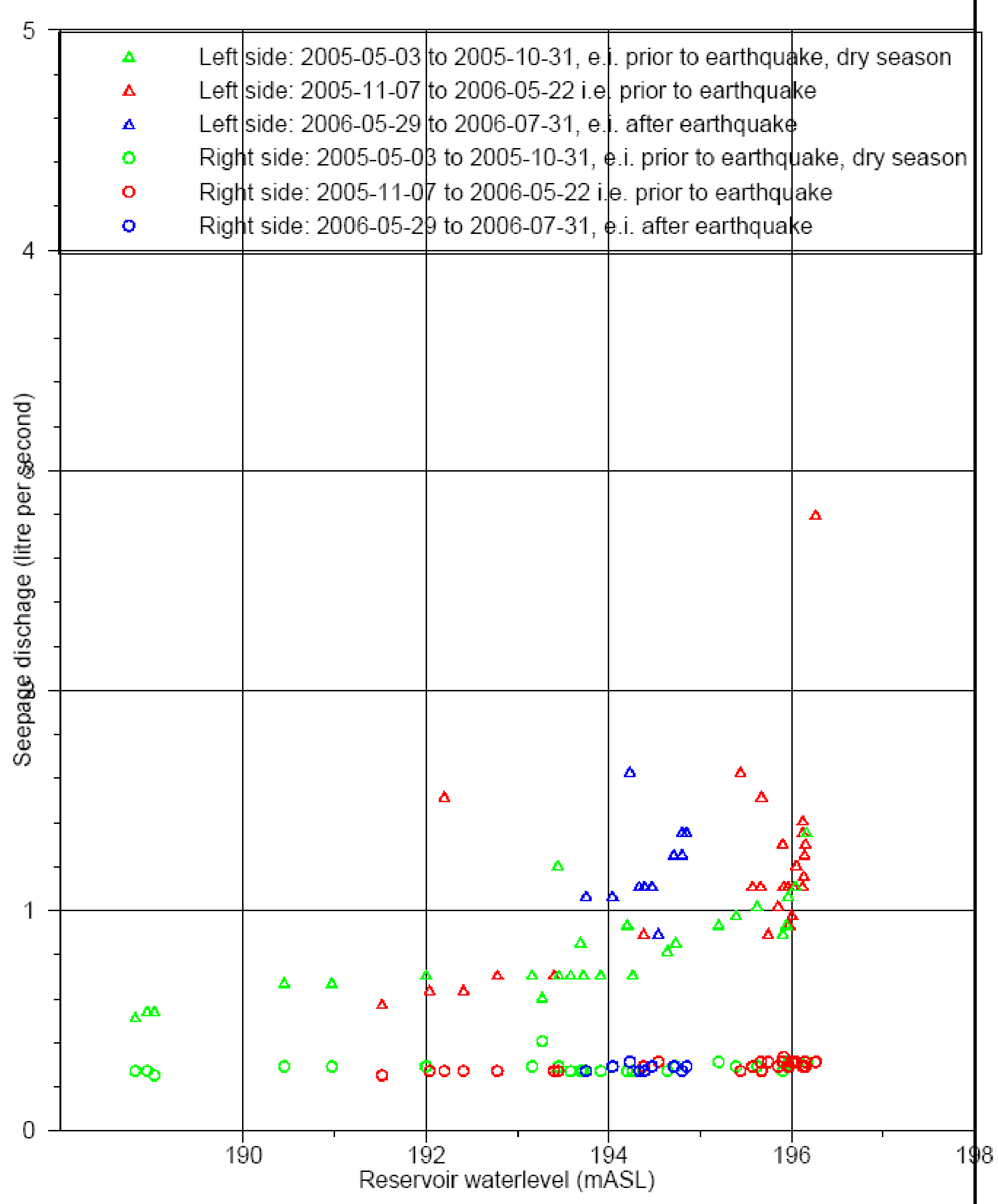


Figure 2



Ministry of public Works; Directorate Genral of Water Resources	Report No. 20061486	Figure No. 2
PARANGJOHO DAM Seepage measurements from 2006	Drawn by Tore Valstad	Date 2006-11-15
	Checked	NGI
	Approved	

F:\p\2006\14\20061486\Figur\SeepageParangjoho.grf

Figure 3

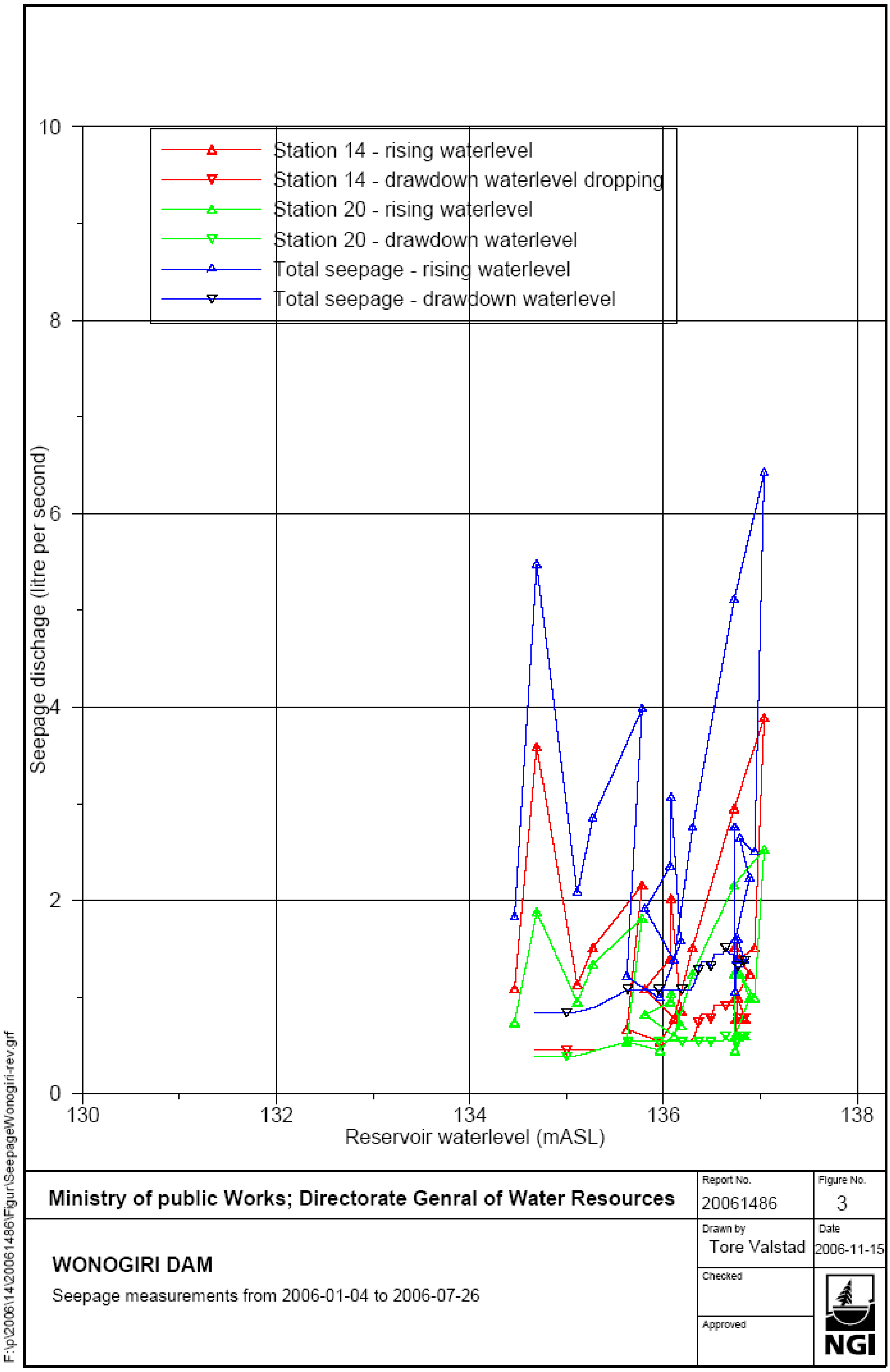
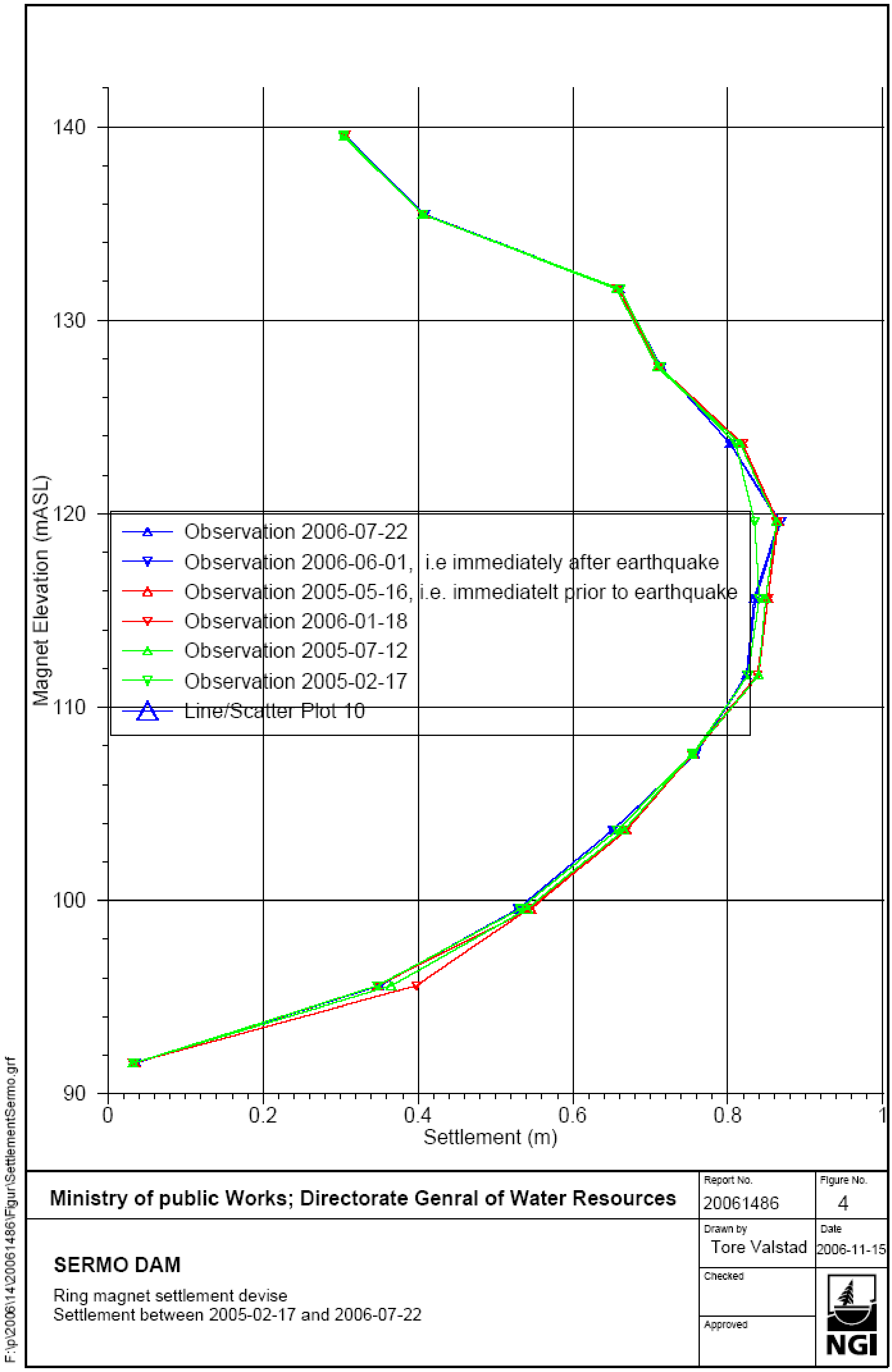

Station 14 - rising waterlevel
Station 14 - drawdown waterlevel dropping
Station 20 - rising waterlevel
Station 20 - drawdown waterlevel
Total seepage - rising waterlevel
Total seepage - drawdown waterlevel
Seepage dischage (litre per second)
0
2
4
6
8
10
130
132
134
136
138
Reservoir waterlevel (mASL)
Ministry of public Works; Directorate Genral of Water Resources
Report No.
20061486
Figure No.
3
Drawn by
Tore Valstad
Date
2006-11-15
Checked
Approved
WONOGIRI DAM
Seepage measurements from 2006-01-04 to 2006-07-26
NGI
F:\p\2006\14\20061486\Figur\Seepage\Wonogiri-rev.grf

Figure 4


140
130
120
110
100
90
Magnet Elevation (mASL)
0
0.2
0.4
0.6
0.8
1
Settlement (m)
Observation 2006-07-22
Observation 2006-06-01, i.e immediately after earthquake
Observation 2005-05-16, i.e. immediatelt prior to earthquake
Observation 2006-01-18
Observation 2005-07-12
Observation 2005-02-17
Line/Scatter Plot 10
Ministry of public Works; Directorate Genral of Water Resources
Report No.
20061486
Figure No.
4
Drawn by
Tore Valstad
Date
2006-11-15
Checked
Approved
NGI
SERMO DAM
Ring magnet settlement devise
Settlement between 2005-02-17 and 2006-07-22
F:\p\2006\14\20061486\Figur\SettlementSermo.grf

Annex V: Photographs of dam structures

CONTENTS


A1: Sermo Dam; Upstream slope


A2: Sermo Dam; Rehabilitated and original riprap at right abutment


A3: Sermo Dam; Spillway approach channel and fixed crest


A4: Sermo Dam; Spillway release channel and flip bucket

A5: Sermo Dam; Downstream slope; Instrument installation in the foreground; Buttress fill in the toe at the left abutment

A6: Sermo Dam; Buttress fill in the toe at the left abutment


A7: Sermo Dam; Downstream slope


A8: Sermo Dam; Spillway at left abutment

A9: Wonogiri Dam; Spillway, power intake and surge tank

A10: Wonogiri Dam; Upstream slope with wave erosion scare

A11: Wonogiri Dam; Gated spillway

A12: Wonogiri Dam; Spillway Channel and flip bucket

A13: Wonogiri Dam; Upstream slope; Newly rehabilitated riprap possibly displaced during earthquake shaking

A14: Wonogiri Dam; Seapage measurement weir

A15: Parangjoho Dam; Upstream slope

A16: Parangjoho Dam; Intake tower

A17: Parangjoho Dam; Downstream slope

A18: Parangjoho Dam, Crack underneath tiles on dam crest


A19: Parangjoho Dam; Spillway approach channel and fixed crest


A20: Parangjoho Dam; Spillway channel and energy dissipator

A21: Parangjoho Dam, Dual seepage measurement weir

A22: Parangjoho Dam, Hydraulic piezometers

A23: Song Putri Dam; Water intake

A24: Song Putri Dam; Intake gate