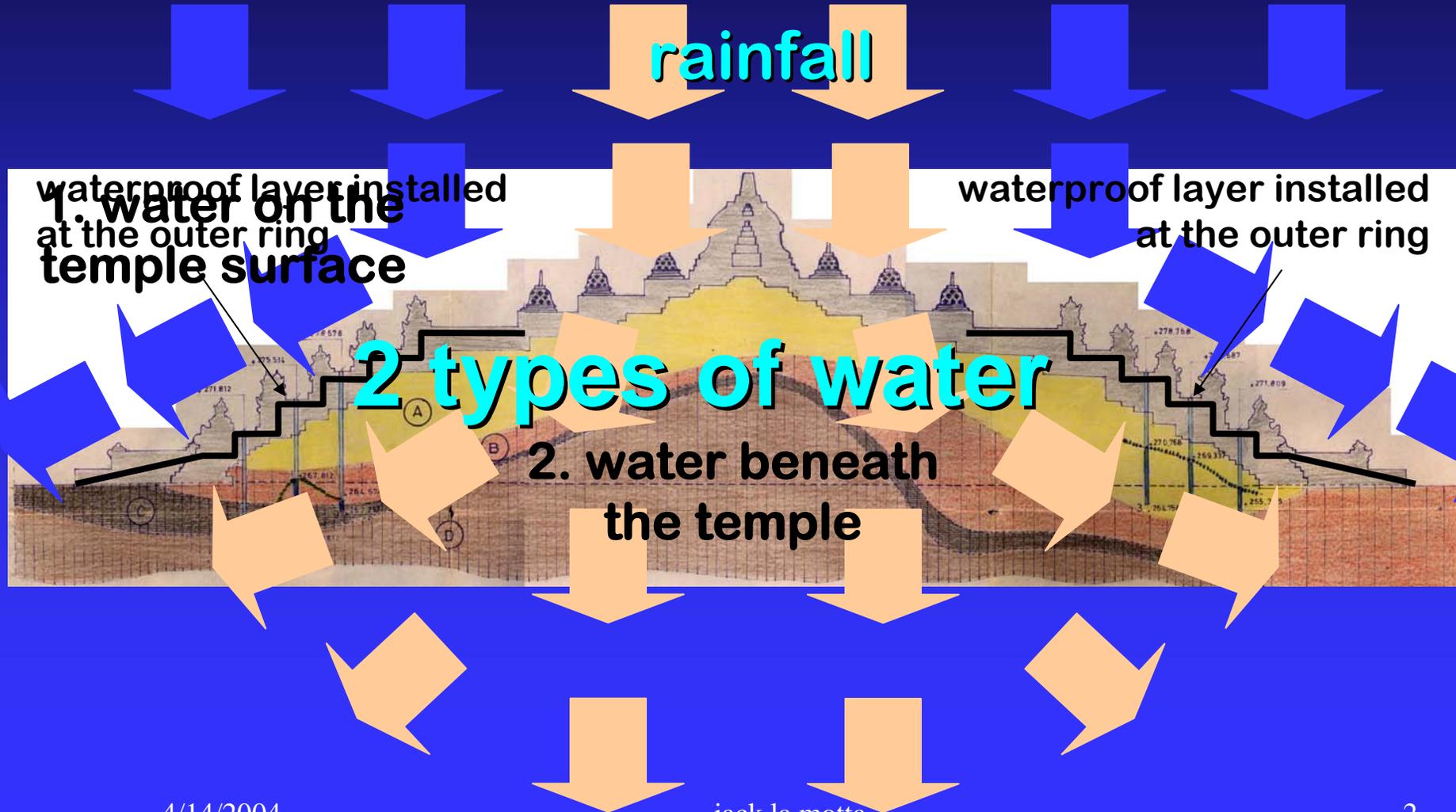


Borobudur Temple

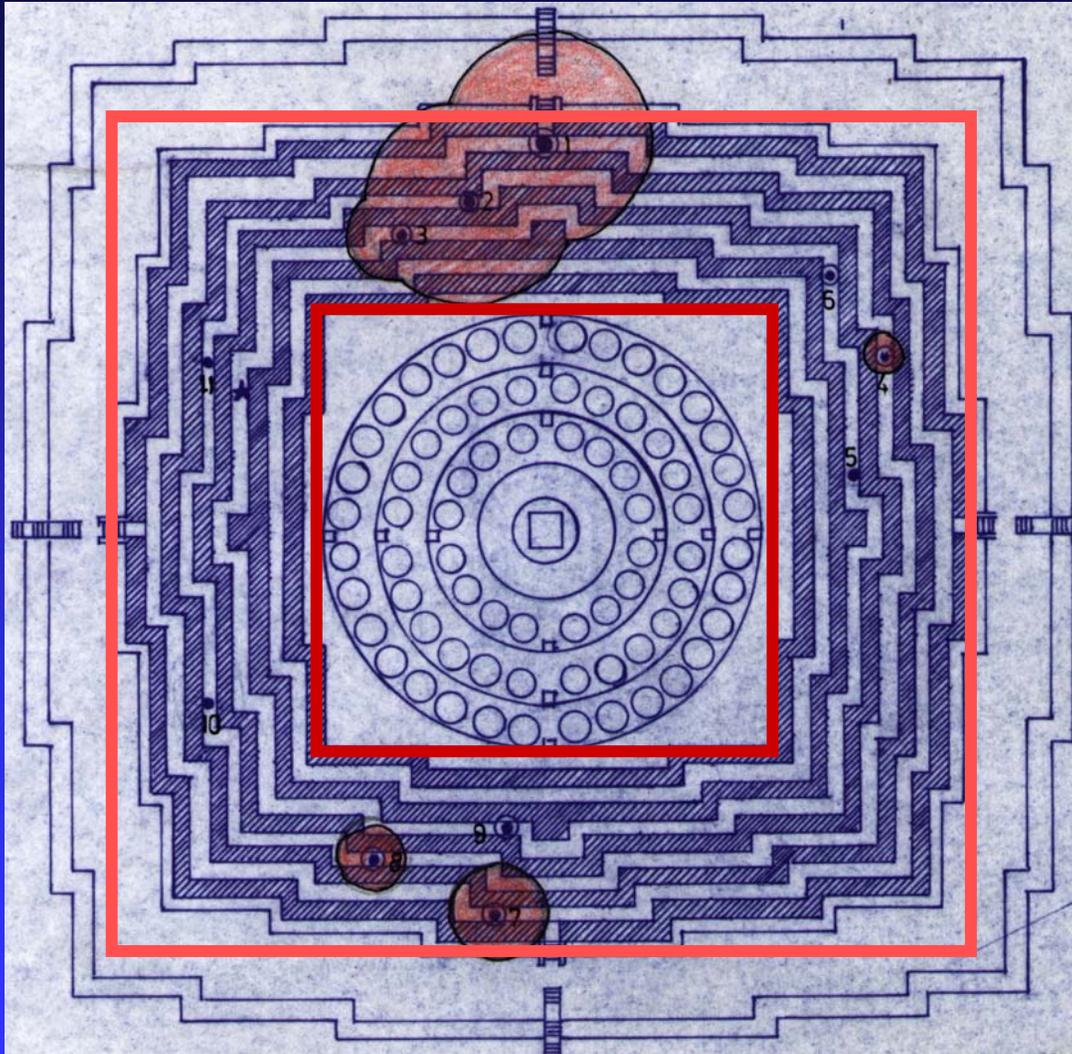
*The Waterworld  
of Borobudur Temple*

Ir. Djoko Luknanto, M.Sc., Ph.D.  
<mailto:Luknanto@ugm.ac.id>

# Water at Borobudur Temple



# Plan View of the Temple



- **at inner ring (terrace)**
  - ◆ rainfall goes directly to the soil below the temple
- **at outer ring (galleries)**
  - ◆ rainfall block by waterproof layer.

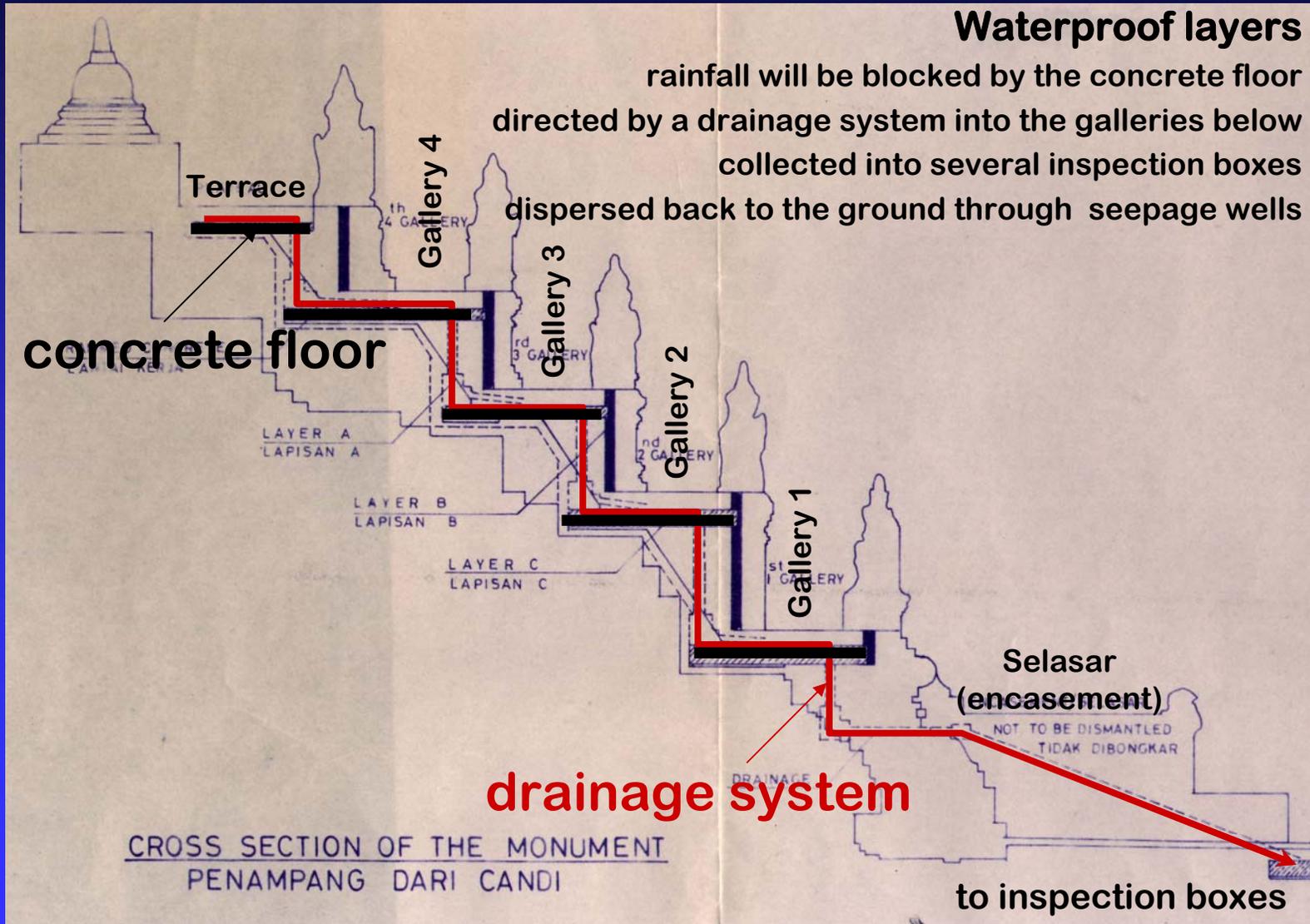
# There are 2 types of water

- 1. Groundwater beneath the temple**
  - small amount of it will eventually flows back through water filters to the surface of the temple
  - Most of it will stay as part of the greater groundwater system for a period of time
- 2. Surface run-off on the temple surface**
  - block by waterproof layer and directed to the drainage system
  - eventually surface water will go to the seepage wells at the the temple yard

# Surface Water

## Waterproof layers

rainfall will be blocked by the concrete floor directed by a drainage system into the galleries below collected into several inspection boxes dispersed back to the ground through seepage wells



# Surface Water Observation

Field data observation by Borobudur  
Conservation and Research Center (BCRC):

- ◆ climatological data (rainfall and evaporation)
- ◆ drainage system
- ◆ inspection boxes and seepage wells
- ◆ waterproof layers
- ◆ water meters

# Groundwater Observation

Indirect field observation of groundwater has also been done by BCRC:

- ◆ water filters
- ◆ surface run-off volume
- ◆ water in the inclinometers

# Water Filters



- Water filters are used to protect the groundwater below the temple from coming out directly to the temple floor, picking up soil particles beneath the temple along the way.
- Up to present the water filters perform well to avoid the piping at the soil.

# Water Meters

- to measure the volume of surface run-off on the temple floors (BCRC installed 8 water meters in the inspection boxes surrounding the temple)



■ before installation

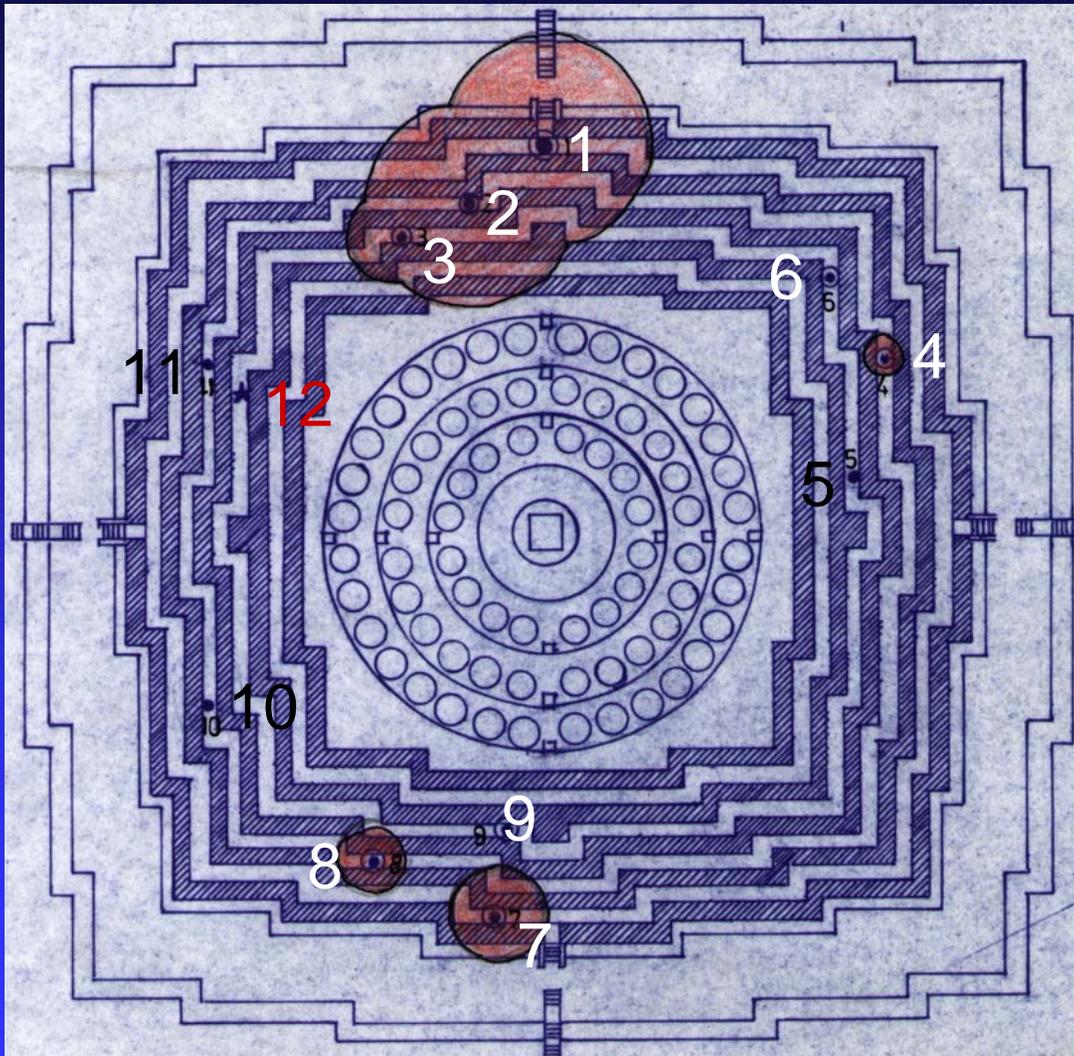


■ after installation

# Inclinometers

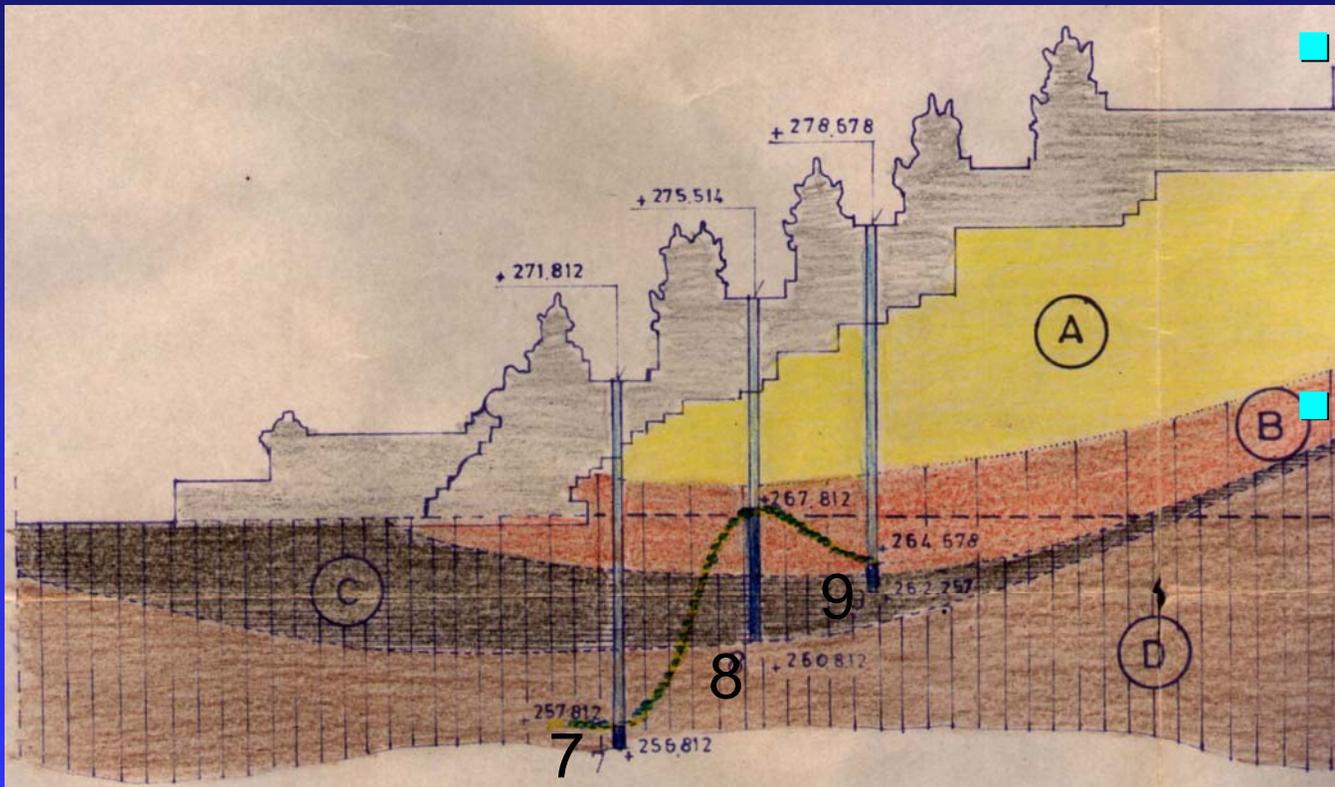
- inclinometer is not appropriate for groundwater monitoring
- inclinometer is a device to measure horizontal movement of a structure
- at Borobudur temple the inclinometers were used to measure the horizontal movement of the temple and to monitor the groundwater table.
- there is no device to monitor directly the groundwater table.

# Location of inclinometers



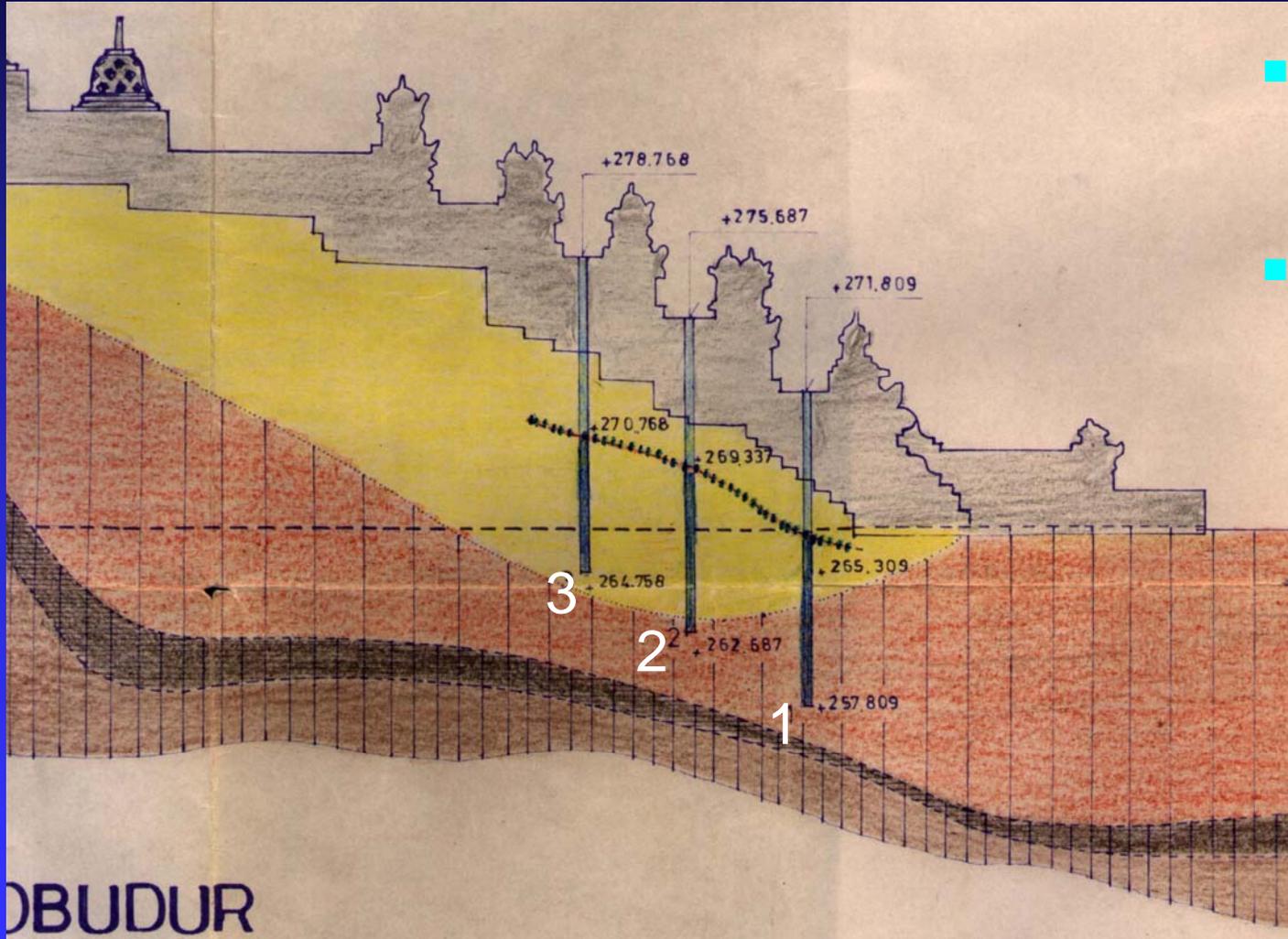
- inclinometers are available at 12 location:
  - ◆ there is water inside: 8 locations (w/ circle)
  - ◆ there is no water inside: 3 locations (w/o red)
  - ◆ multifunction 1 location (no 12)
- From the inclinometer data, it is very difficult to estimate the groundwater table

# Waterlevel at inclinometer 7-8-9



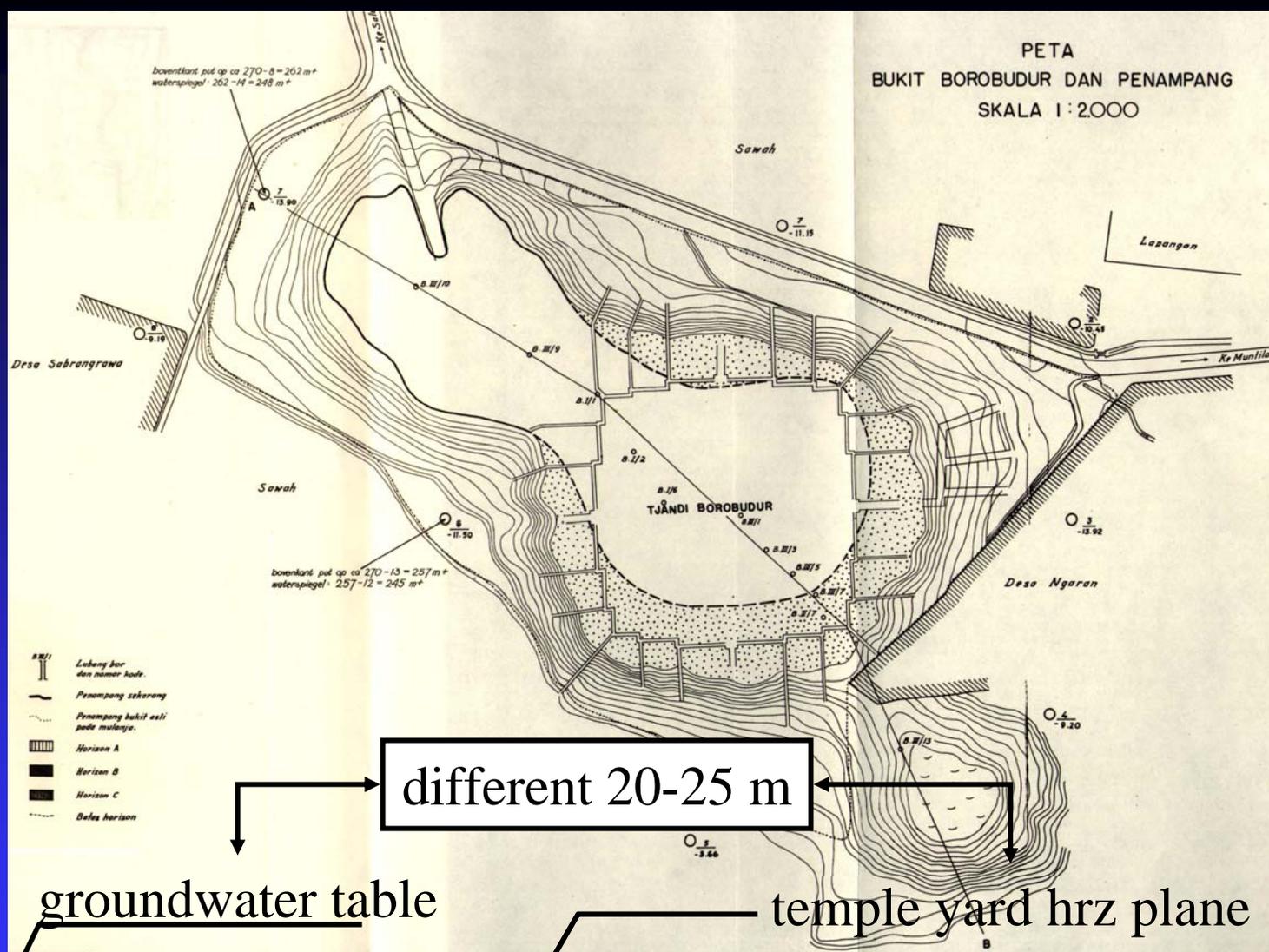
- there are no specific pattern on inclinometer 7-8-9
- the groundwater table could not be predicted

# Waterlevel at inclinometer 1-2-3



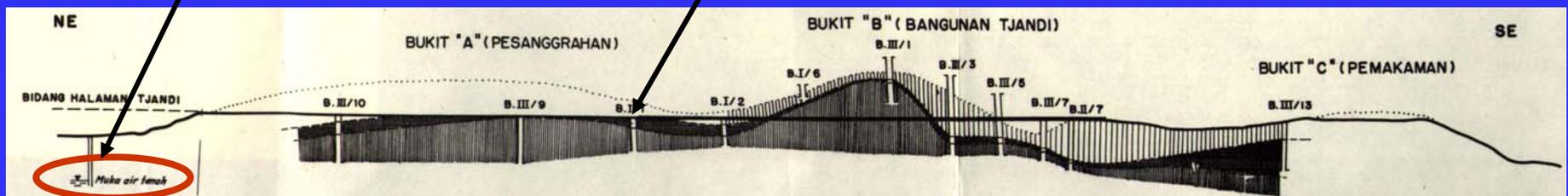
- more regular pattern on inclinometer 1-2-3
- this might be the correct groundwater table for Horizon A

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 SKALA 1 : 2.000

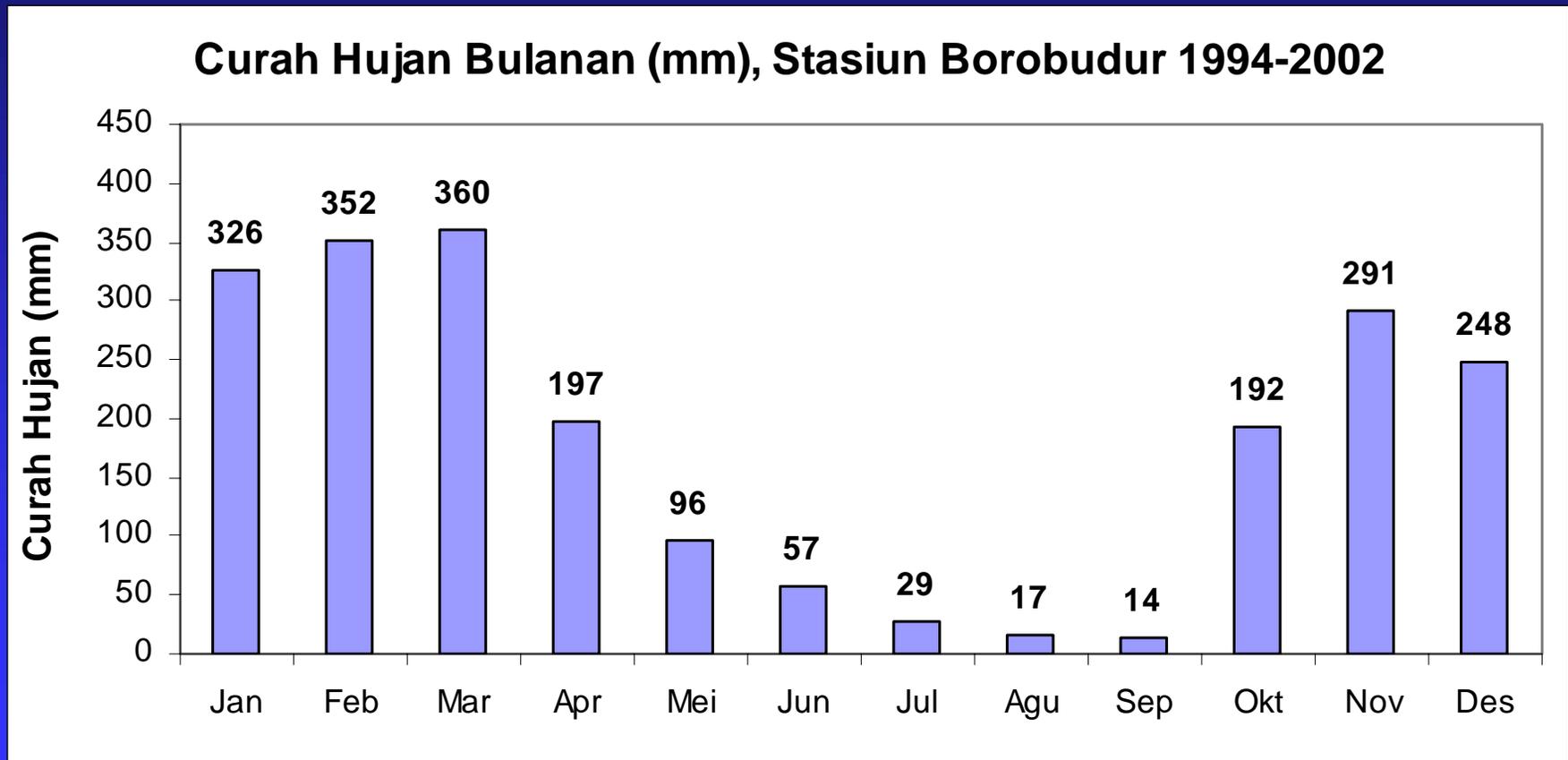


groundwater table

temple yard hrz plane



# Monthly Rainfall (mm), at Borobudur 1994-2002



# Groundwater Flows

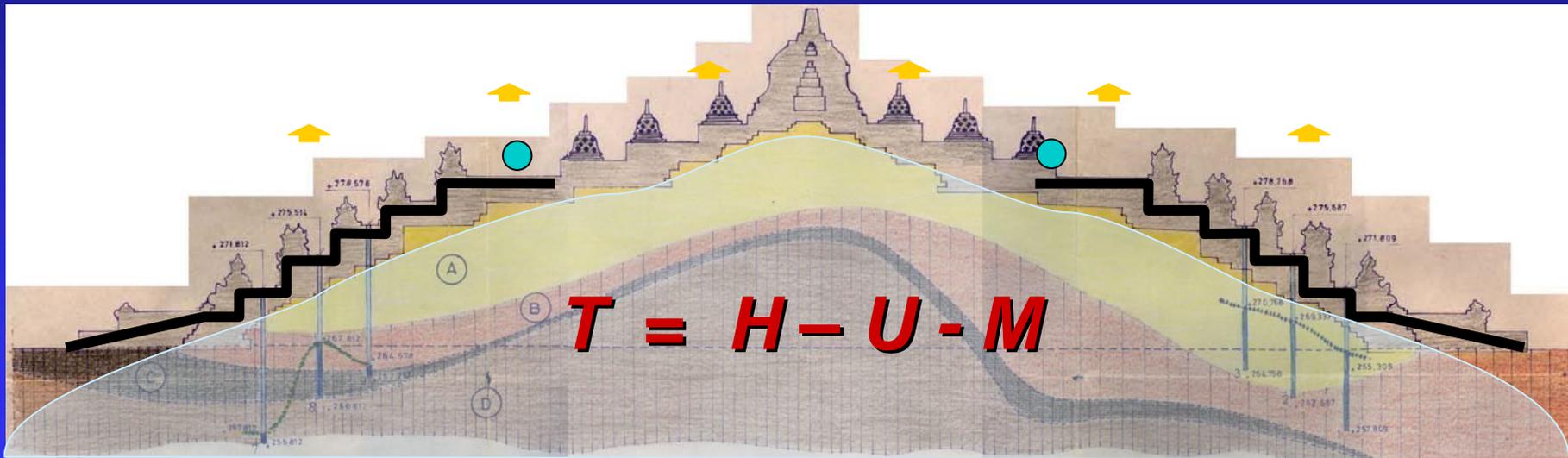
- according to groundwater hydraulics, water flows from locations with higher energy to a lower one
- at rainy season there might be groundwater pressure to the temple wall
- groundwater flow pattern are quite complicated, since there are 4 layer of soils with different characteristic.



# Consideration

- It is very difficult to monitor the groundwater table without the appropriate devices
- Indirect measurement of the groundwater volume cannot exactly predict the groundwater table
- Observation of the groundwater table using inclinometers are not appropriate

# Water Balance at Borobudur temple



↓ rainfall ( $H$ )

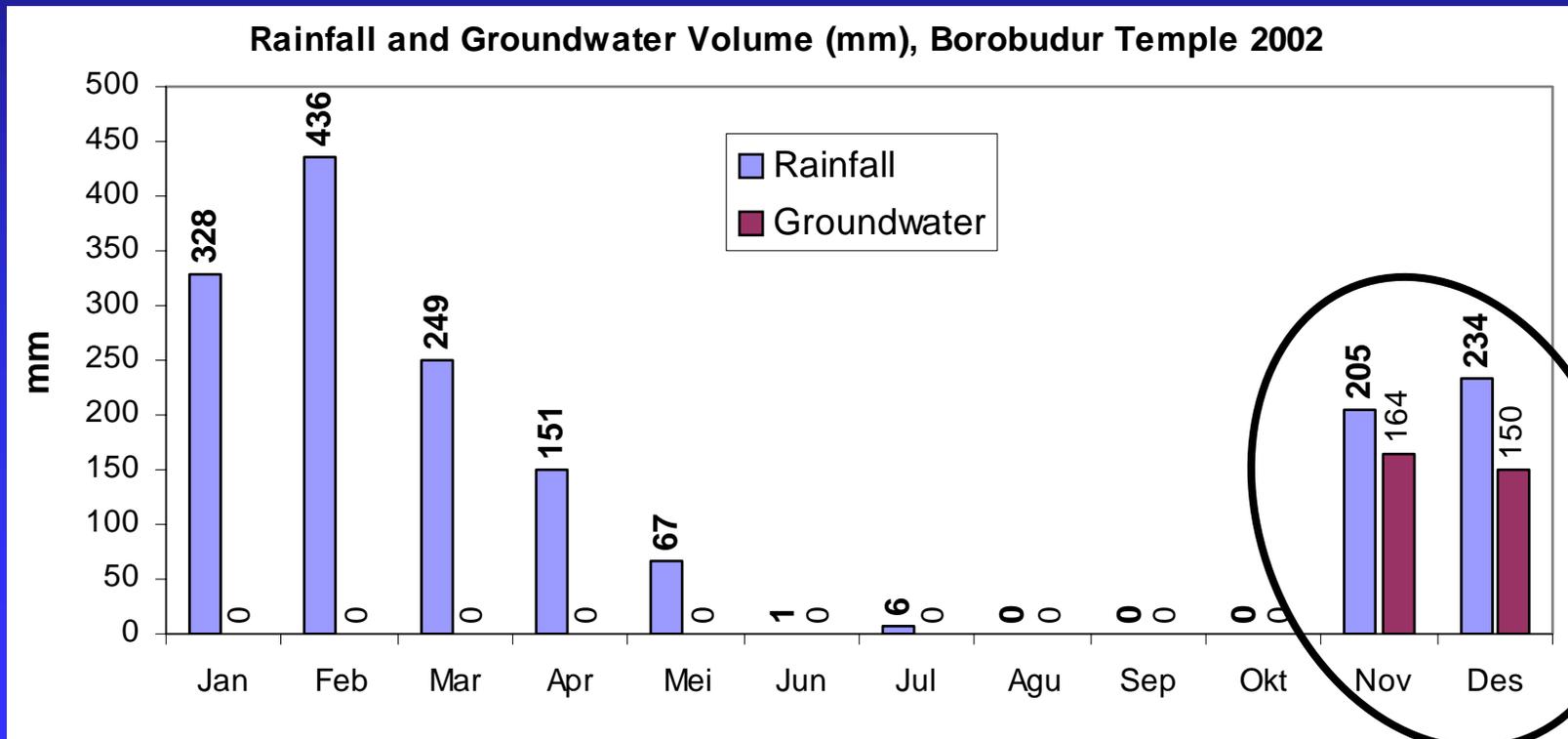
● surface run-off ( $M$ )

↑ evaporation ( $U$ )

■ groundwater ( $T$ )

# Groundwater Volume

- With the use of simplified water balance, monthly volume of groundwater (mm) can be calculated

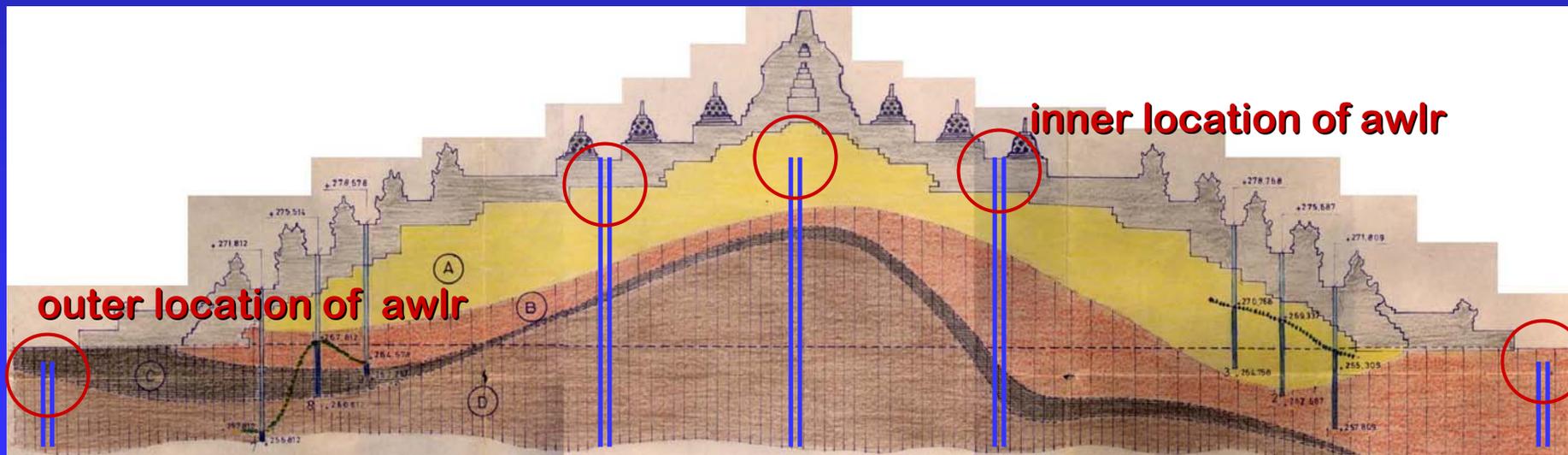


# Recommendation

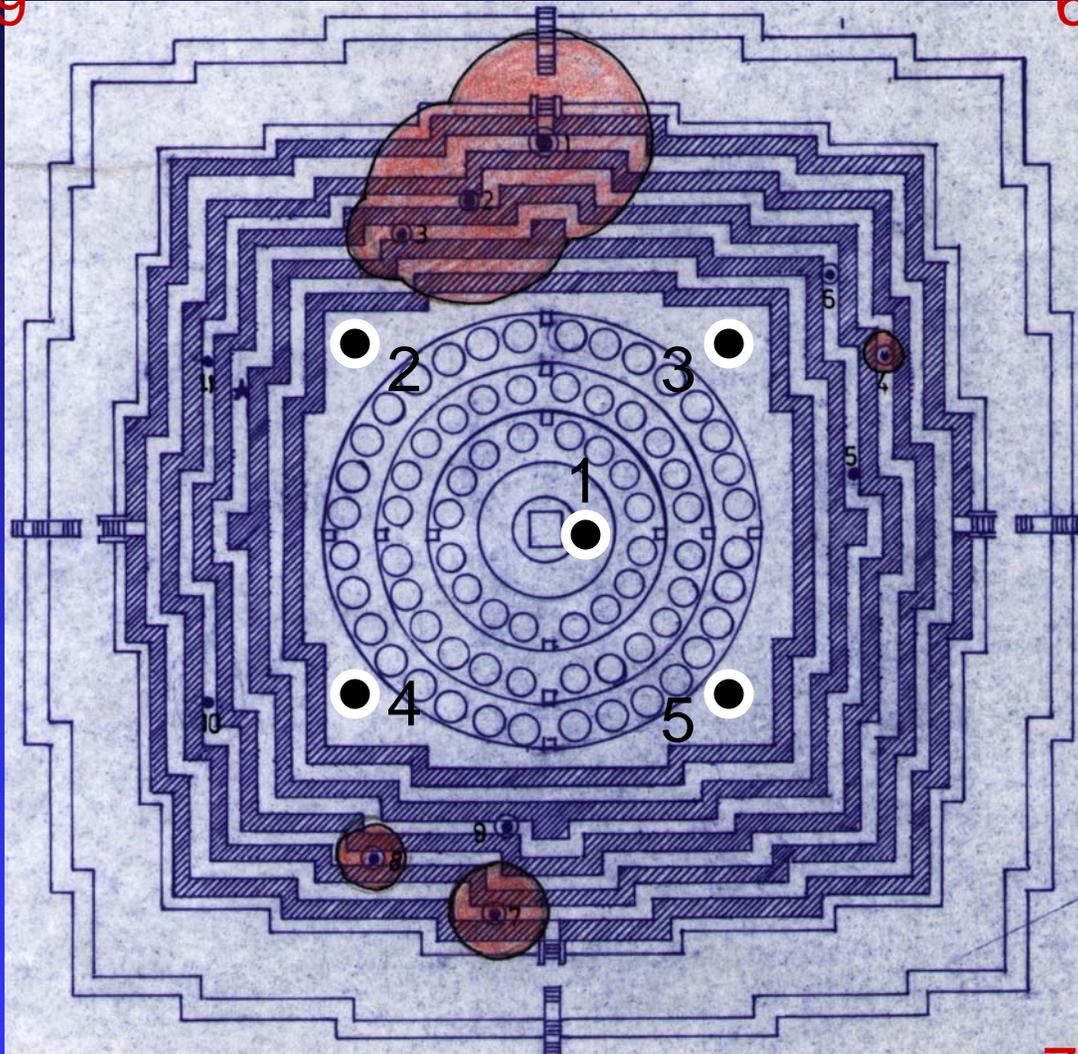
- a. The indirect groundwater study may still be carried out for two more years to get more rigorous results.
- b. Based on the results from Item a, more laborious recommendation for monitoring groundwater table may be given.
- c. For the time being, the study can only suggest the preliminary layout of the monitoring groundwater table, as describe in next slides.
- d. The depth of the monitoring devices can not decided at present, since more study from Item a has to be done first.
- e. More geological investigation shall be done in the future, especially on the hill below the temple in the North-South direction. This geological data is very important when the study of the groundwater hydrodynamic is carried out in that direction.

# Location of AWLR

- at the inner and outer rings of the temple
- simple to install
- never destroy any single feature of the Borobudur temple
- the depth of the AWLR will be decided after the more rigorous studies has been done



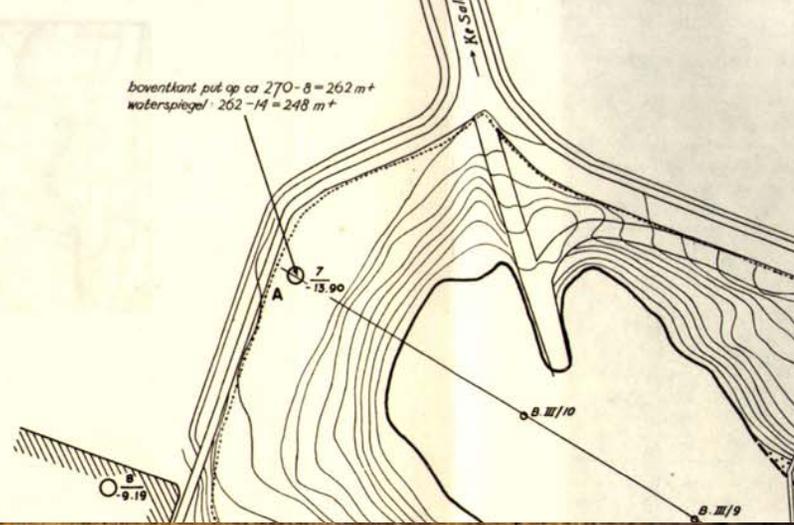
# Plan View of AWLR



- Needs 9 AWLR:
  - ◆ 1 at the center
  - ◆ 4 at the circumference of inner ring
  - ◆ 4 at the circumference of outer ring
- The exact location will be decide based on the simplicity of the installation

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 SKALA 1:2000

boventkant put op ca 270-8=262m+  
 waterspiegel: 262-14=248m+



The End



-  Penampang sekarang
-  Penampang bukit asli pada mulanya.
-  Horizon A
-  Horizon B
-  Horizon C
-  Belas horizon

