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CONTRACT FOR CONSULTANT SERVICES
FOR
SURAKARTA WATER SYSTEM
NO. 01/WS-S/I/AID/78
AID LOAN 497-U-044

GROUND WATER SURVEY COMPLETION REPORT 1981

BURNS & McDONNELL ENGINEERING COMPANY, INC.
AND
TRANS-ASIA ENGINEERING ASSOCIATES, INC.
A JOINT VENTURE

028

BURNS & McDONNELL Engineering Co.
Architect – Engineers A JOINT VENTURE Consultants – Planners
TRANS-ASIA Engineering Associates, Inc.

Surakarta Water Project
Please Reply to: Kotak Pos 105
Surakarta

160/BM/TAE/SKA/81
13 July 1981

Mr. Soesanto Mertodiningrat, Director
Directorate of Sanitary Engineering
Directorate General Cipta Karya
Jl. Pattimura No. 20
Jakarta Selatan

Subject : Contract for Consultant Services for Surakarta Water System, No. 01/WS-S/I/AID/78, dated 26 October 1978 as Amended 08 November 1980

Dear Sir,

In accordance with Section 4.12 and Appendix I of subject Contract, we are pleased to submit fifteen copies of Ground Water Survey Completion Report.

The recommendations on pump sizes will be utilized in selection of the two units to be procured in the near future.

We trust that this report will meet your approval.

Very truly yours,

BURNS & MC DONNELL ENGINEERING CO.
TRANS-ASIA ENGINEERING ASSOC., INC.

J.F. BAUCOM
ACTING CHIEF ENGINEER

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BURNS & McDONNELL ENGINEERING COMPANY, INC.
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A JOINT VENTURE

CONCLUDING REPORT
GROUND WATER POTENTIAL AND PRODUCTION WELL DIMENSIONS FOR SURAKARTA

by

DAVID S. TILLSON
hydrogeologist

and

SUTJIPTO
hydrogeologist

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INTRODUCTION

Ground Water Study - The Surakarta Water Supply Investigation carried out by Burns & McDonnell/ Trans-Asia was programmed in two phases. The first phase resulted in reconnaissance of area wide geology, resistivity surveys, and general information on hydrogeology. Based upon this, areas with the best ground water potential were selected for well installations and finite drilling sites selected.

Well drilling specifications were prepared and a drilling contractor selected to initially install two test-production wells. This first phase was carried out between November 1978 and April 1979.

This report covers the second phase of the investigation. Using existing reports, studies and first phase field investigations, geologic framework and conditions were established. Existing well data, including lithologic logs, construction information, quality analysis, well pumping test and aquifer pumping tests along with the results of test production wells TW-1 and TW-2 installed and tested under this project, were collected and evaluated.

Hydrogeologic conditions, aquifer distribution and character along with ground water potential were derived from the evaluated data. Most productive aquifers have been defined, quality problems indicated, and production well capacities and dimensions recommended.

Scope - The scope of this concluding report is based upon the requirement of an additional 13,000 cubic meters of water per day to meet the current demand for the city of Surakarta.

Source and Use of Data and Information - Several very adequate reports are available on the geology of the region including R. W. van Bemmelen's classic Geology of Indonesia published in 1949. Recent reports: Hydrogeology of Gemolong area by Binnie and Partners, 1978 and Ground Water Development Project, Madiun - Upper Solo Watersheds by Electroconsult/Nippon Koei, 1977 outlined the geology and established its vertical extent and configuration with test wells. Interest in Hominid fossils from the Sangiran Dome north of Surakarta has resulted in publications with detailed geologic descriptions of sediments and structures. This information along with other lesser reports was used to develop a geologic framework including formation characteristics and their distribution within the project area.

Information on about 35 wells was collected and utilized for evaluating hydrogeologic conditions in the considered project area. The variable origin, value, reliability and completeness of this basic data necessitated selective and weighted use.

Well data from the old Surakarta artesion wells drilled by the Dutch is on open file with the Geological Survey of Indonesia in Bandung. Data

is in the form of field notes and correspondence and appears to be very reliable.

Aquifer Transmissivity depends upon the permeability of the composing material as well as the thickness of the material. When permeable aquifer layers are separated by thick impermeable layers the aquifer thickness becomes that intercepted by the well screen, the remainder being isolated to semi-isolated. Information from production and test wells used for evaluating aquifer potential penetrate geologic formations completely in some instances and only partly in others resulting in various Transmissivities.

Well Specific Capacities will depend on aquifer characteristics, well design, construction, and development, partial penetration (or use) of the aquifer, and duration of pumping. Hence comparing Specific Capacities from various pumping tests must be done with caution and appropriate adjustments.

Lithology is logged by engineers, geologists, well drillers and laymen. The same material will be given various descriptions depending upon previous training and experience. Despite this, well logs are considered to be the most reliable and available data. Well logs are used to determine geologic formations present and their character, extent and thickness which will relate to aquifers, aquitards, and aquicludes. These help to define local geology within the regional framework described in reports on original geology.

Well construction information is commonly available and reliable. Construction is unknown for some wells including several of the old Surakarta wells.

Quality analysis is abundant and apparently very reliable with a few noted exceptions.

GEOLOGY

General Geology - Geologic history of the region pertinent to this project is dominated by the volcanic activity of surrounding Lawu, Merapi, and Merbabu volcanoes. Aquifers practically usable for the Surakarta water supply are formed primarily from fluvial, alluvial and pyroclastic deposits of these three volcanoes from early Pleistocene to present.

Geologic History - During the early Pliocene the project area was an open marine basin in which marls, limestones, and marine clays accumulated. This basin became shallower during late Pliocene. Volcanic activity from ancestral Lawu, Merapi and Merbabu followed at the beginning of the Pleistocene blocking drainage and forming a shallow sea. Within this shallow sea volcanic derived tuffs and breccias followed by black clays with some marine intercalations of the Putjangan formation accumulated.

During middle Pleistocene volcanic activity continued. Products of this activity were again deposited in the basin. The north bordering Kendeng Ridge and the basin

were uplifted above sea level. This uplift was accompanied by renewed volcanic activity from the same volcanoes. Eroded clastics from the Kendeng Ridge and volcanic deposits from the early volcanoes resulted in the fluvial sandstone and conglomerates alternating with tuff and tuff breccia of the Kabuh formation.

Volcanic activity continued until the end of the middle Pleistocene depositing tuffs and tuff breccias in the basin with occasional sand and pebble beds from the north. These deposits make up the Notopuro formation. Modest folding of these formations followed during the upper Pleistocene, forming anticlinal domes.

Merapi, Lawu an Merbabu volcanoes continued actively throughout the Holocene constructing ever greater cones and contributing volcaniclastic and alluvial sediments to the Younger Volcanic deposits.

Recent alluvial and floodplain sediments occupying the low plain adjacent to the Bengawan Solo River have been deposited by the river.

FORMATIONS

Tertiary (Pliocene) Marine Formations - Marine limestones, fossiliferous limestones, marls and clays make up these low permeability, residual saline formations known as the Kalibeng beds in the project area. The saline nature of the ground water along with the general fine grained nature precludes

consideration as aquifers. Ground water from this formation is a possible source of contamination however.

These marine formations form a broad east-west trending structural basin some 250 to 300 meters deep beneath Surakarta in which material suitable for good aquifers, notably the Notopuro and Kabuh formations, and Younger Volcanics deposits have subsequently accumulated.

Putjangan Formation - The Putjangan formation is composed primarily of fine grained silts and clays with low permeability. Some sandy layers are present but tend to be saline, apparently because of periodic intercalations of marine sediments. This formation is up to 300 meters thick in the project area based on outcrops north of Surakarta.

Kabuh Formation - The Kabuh formation consists of coarse grained cross bedded volcanic sandstones and conglomerates intercalated with layers of fine volcanic tuff. The facies changes rapidly. In some places this material is practically uncemented while in other localities the same beds are cemented well enough to limit their permeability. The sandstones and conglomerates provide potential aquifers while the fine grained clays and tuffs usually lack adequate permeability. Thickness changes rapidly but probably varies from about 50 meters to 200 meters in the project area.

Notopuro Formation - The Notopuro formation is similar to the Kabuh formation and is often indistinguishable. The Notopuro is primarily tuff and tuff breccia with lesser fluvial sandstones and

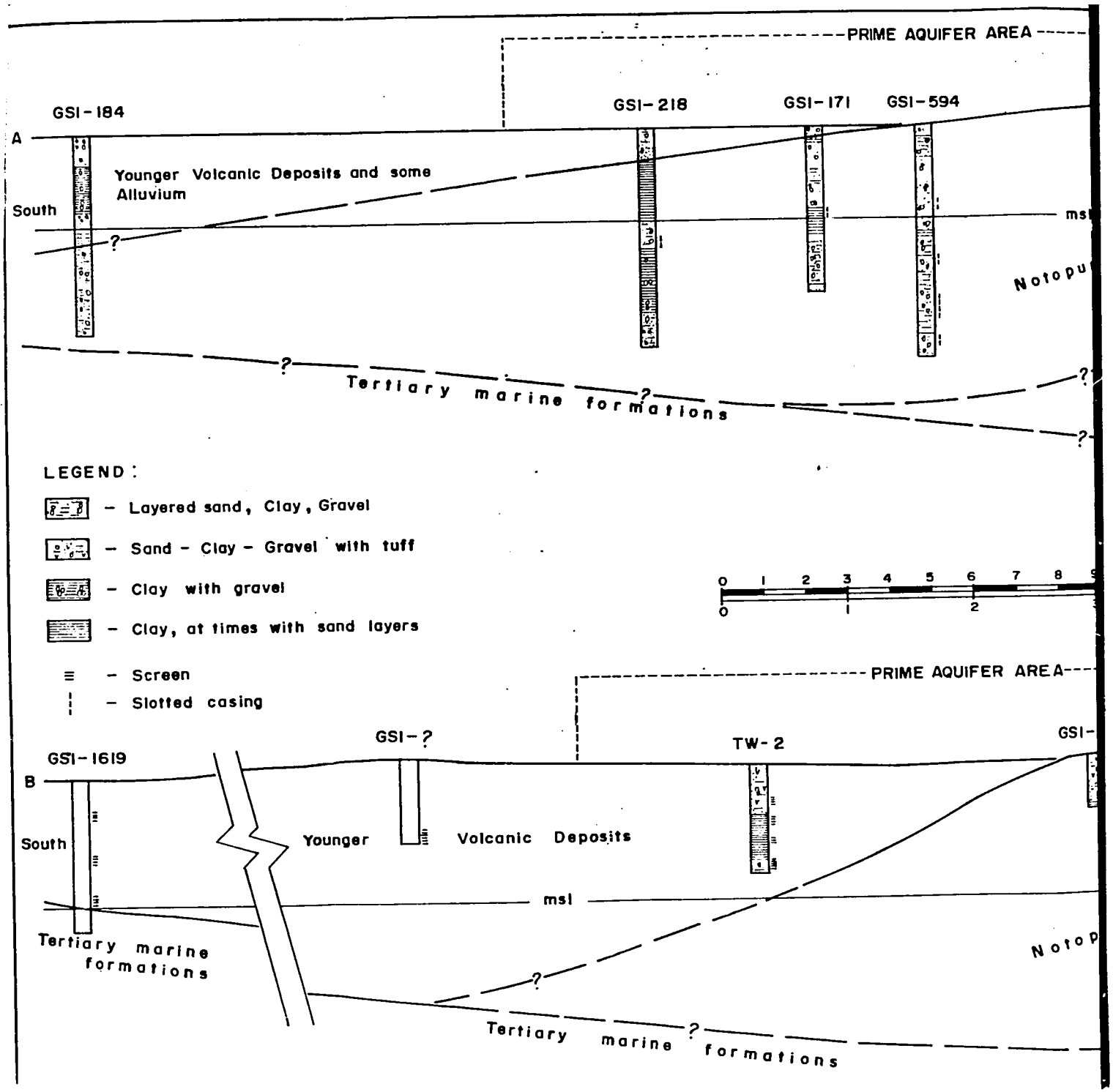
conglomerates in contrast with the Kabuh. Hydrogeologically the permeable layers have characteristics comparable to the Kabuh formation.

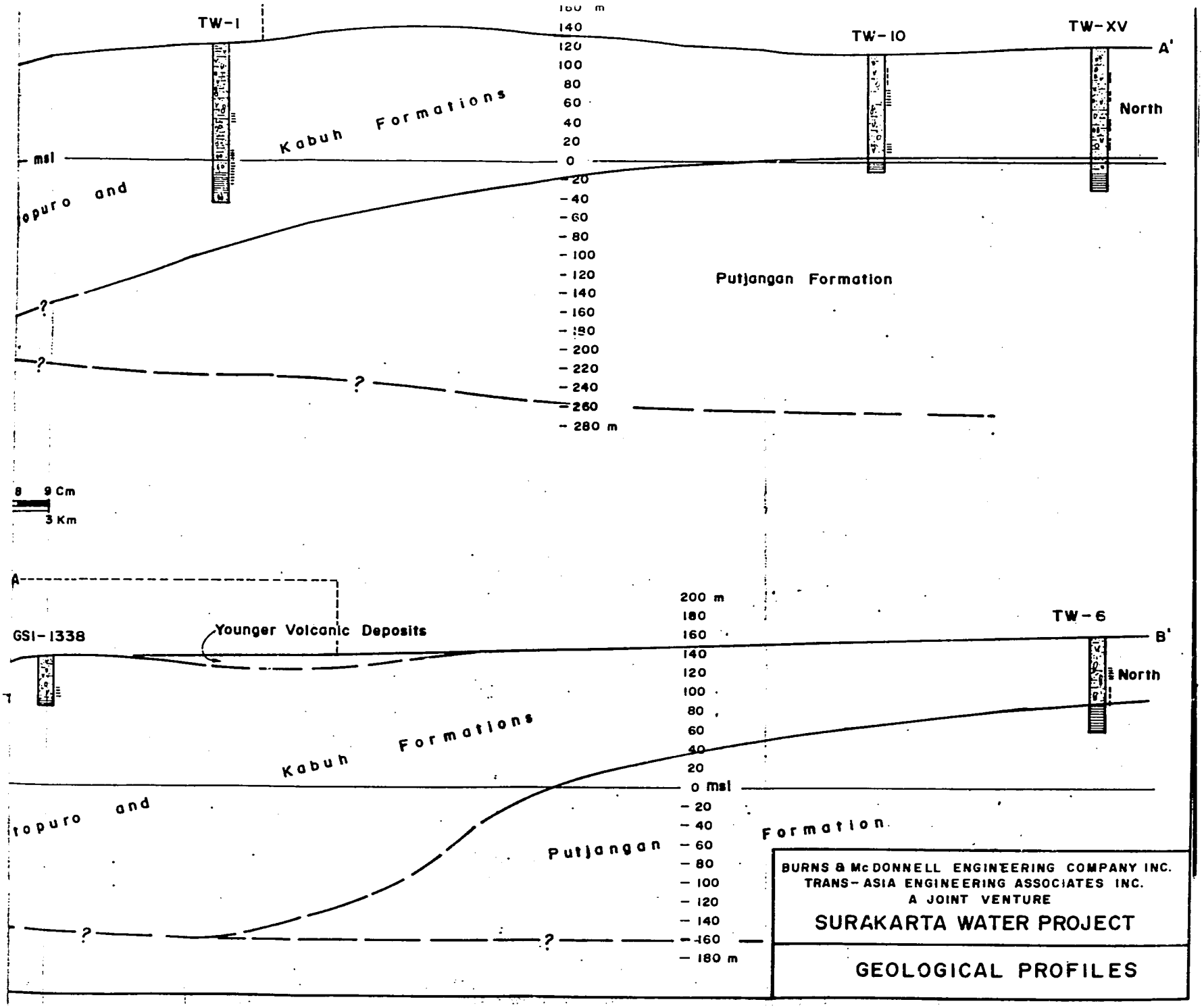
Younger Volcanic Deposits - Younger Volcanics consist of volcaniclastic material accumulating directly from volcanic activity interbedded with fluvially reworked, transported, and deposited volcanclastics. The resulting deposits are lenticular and discontinuous interbedded tuffaceous sands, breccias gravels, tuffs, silts and clays. The beds may range from a few inches to tens of feet in thickness.

These Holocene deposits are loose to compact and cemented. Permeability will be good for gravels and coarse and sorted sands and poor to nonexistent for the tuffs, silts and clays. Sediments will tend to become finer with distance away from their source but generally the same for their position around the flank equidistant from the cone. Aquifer potential is very good, particularly where sands and gravels dominated the sequence.

Thickness of this unit is highly variable ranging from absent to hundreds of meters depending on the topography upon which the volcaniclastics accumulated and distance from the source. Within the area considered for this report several hundred meters would be an estimated maximum thickness.

Alluvium - It is doubtful whether Alluvium can be distinguished from Younger Volcanics (or should be)


PRIME AQUIFER AREA
GSI-184
GSI-218
GSI-171
GSI-594
A
South
Younger Volcanic Deposits and some Alluvium
msl
Notopu
Tertiary marine formations
LEGEND:
- Layered sand, Clay, Gravel
- Sand - Clay - Gravel with tuff
- Clay with gravel
- Clay, at times with sand layers
- Screen
- Slotted casing
0 1 2 3 4 5 6 7 8
0 1 2
PRIME AQUIFER AREA
GSI-1619
GSI-?
TW-2
GSI-
B
South
Younger Volcanic Deposits
msl
Tertiary marine formations
Notop
Tertiary marine formations


TW-1
TW-10
TW-XV
A'
North
Kabuh Formations
msl
topuro and
Putjangan Formation
160 m
140
120
100
80
60
40
20
0
-20
-40
-60
-80
-100
-120
-140
-160
-180
-200
-220
-240
-260
-280 m
8 9 Cm
3 Km
A
GSI-1338
Younger Volcanic Deposits
TW-6
B'
North
Kabuh Formations
topuro and
Putjangan Formation
200 m
180
160
140
120
100
80
60
40
20
0 msl
-20
-40
-60
-80
-100
-120
-140
-160
-180 m
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SURAKARTA WATER PROJECT
GEOLOGICAL PROFILES

as the river system is continuous and deposits contemporary. Any Alluvium present will have hydrogeological characteristics similar to the Younger Volcanics also.

AQUIFER DISTRIBUTION AND CHARACTER

Notopuro and Kabuh Formations - The Notopuro and Kabuh formations outcrop north of Surakarta and the Pepe River. It appears that these formations have been minimally eroded except at local domes and their structural surface generally conforms to the present topography. These formations should project predictably to the south and beneath the Younger Volcanic deposits depending upon local geologic structural variations. This appears to be confirmed as these formations extend beneath the city of Surakarta where they were encountered to several hundred meters depth by eleven deep wells.

Van Bemmelen has projected an inferred fault from the Lawu volcano through Surakarta. This fault cannot be proven and is considered to be nonexistent, or if present, insignificant.

The Kabuh formation, which is the primary aquifer of these "older volcanic deposits" varies in thickness and character over short distances.

Aquifer Transmissivities vary accordingly. The known Transmissivities from this formation and in some cases the Notopuro is included, range from 32 to 1186 $m^3/d/m$ (cubic meters per day per meter width of aquifer). The lower Transmissivities are from the

area 10 to 20 kilometers north of Surakarta where the Kabuh formation is only about 50 meters thick. The formation thickens to the east and north east and Transmissivities increase although wells have not fully penetrated the formation.

Test-Production well TW-1 at Busukan just north of Surakarta indicates the Kabuh formation is at least 100 meters thick. Here the Transmissivity is 500 m^3/day/m.

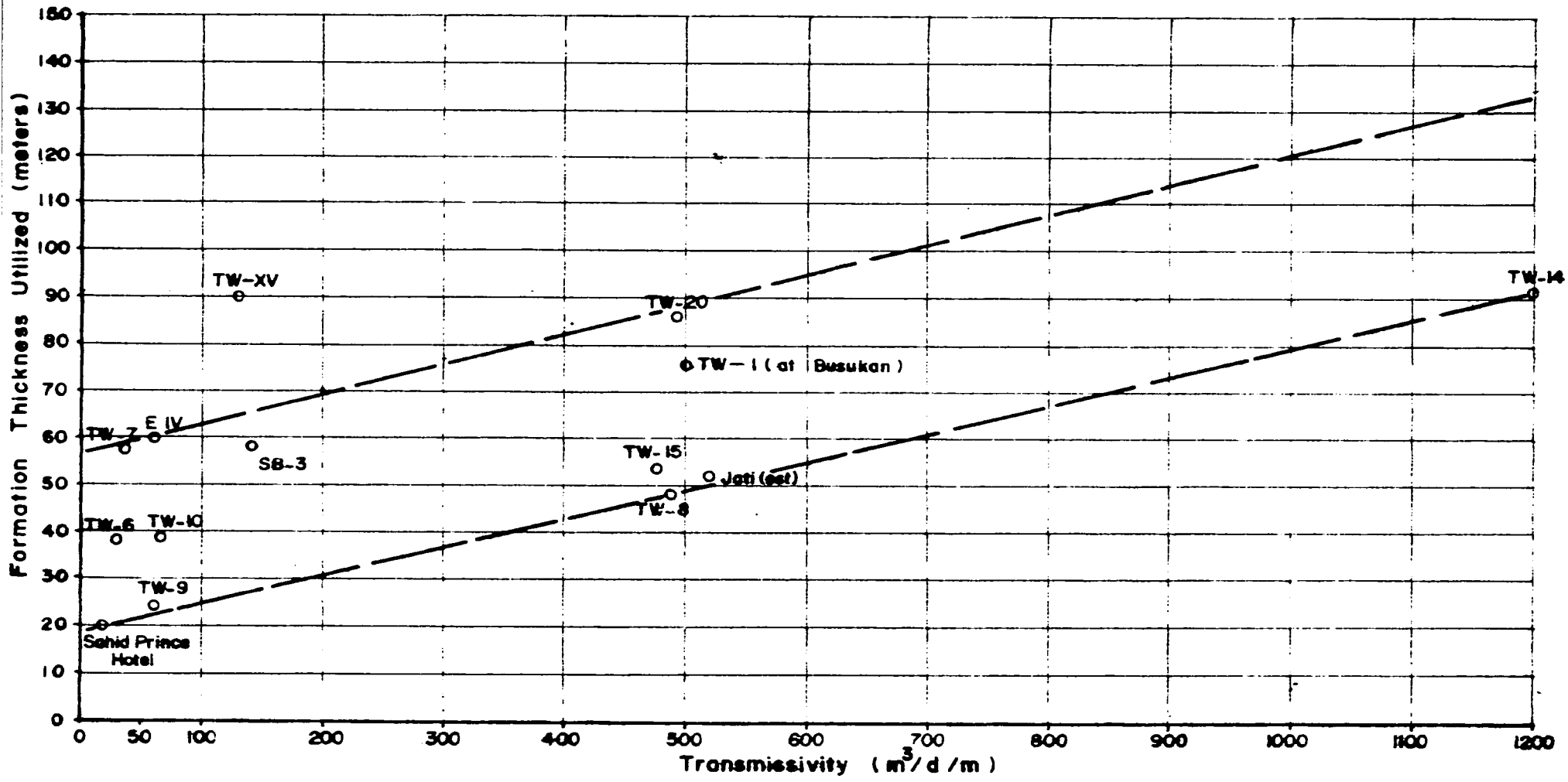
Lithologic logs for eleven wells in Surakarta (all but two drilled before 1900) indicate the Kabuh formation extends at least 220 meters below the surface which would make it about 150 to 170 meters thick at a minimum when considering the presence of the overlying Notopuro formation. Pumping test data suitable for determining Transmissivity values of this aquifer beneath Surakarta are unavailable. Drawdown and discharge information obtained during well drilling and after construction completion, adjusted for well entry losses, partial penetration effects and other contingencies suggest the possibility that transmissivities of 500 to 600 m^3/d/m might be characteristic of the aquifer. It can be shown that increasing the thickness of the Kabuh formation utilized for screens will increase the Transmissivity. If this holds true for the aquifer beneath Surakarta, Transmissivity values expected would be 700 to 1000 m^3/d/m, a conservative estimate. This estimate will be even greater depending on the full total thickness of the aquifer.

The Notopuro, Kabuh and Putjangan sequence apparently thins rapidly to the east as it was not encountered in deep well GSI 918, at Karanganyar, 13 kilometers from Surakarta. This sequence is also missing at well GSI 1619 at Ceper, 20 kilometers south west of Surakarta where the Younger Volcanics lie directly on Tertiary marine formations. Tertiary marine formations outcrop near Ceper also while the older volcanic sequence does not.

The Kabuh formation, with its discontinuously bedded and lenticular permeable zones alternating with impermeable and semipermeable layers will function as a poorly interconnected hydraulic unit. Ground water flow to wells will essentially be horizontal. Static water levels will vary from one layer to the next, generally becoming higher in elevation with each successive deeper producing zone.

Permeable portions of outcropping Kabuh formation will be favorable for recharge. The Notopuro formation overlying the Kabuh has generally similar characteristics but with fewer permeable fluvial layers than the underlaying formation. Appropriate outcrops of the Notopuro will allow recharge.

Leaky artesian conditions are indicated from three pumping tests on wells constructed within the Kabuh and Notopuro formations. This leakage could be upward as well as downward. Continuous impermeable layers that would serve as an aquiclude forming true confining conditions are leaking.



Relationship of Kabuh / Notopuro Formation Thickness Utilized for Placing Screens and Transmissivity

Data useable for determining Storage Coefficients and vertical hydraulic conductivity is unavailable. Storage Coefficients developed from observation of well data for the Kabuh formation in the Sragen area, 25 kilometers north east of Surakarta, range from 1.5 to 2 x 10^{-3}. It appears that these should be projectable to the project area.

Younger Volcanic Deposits - The Younger Volcanics are present south of Surakarta and the Pepe River as well as east of Surakarta and the Bengawan Solo River. These deposits originated from Lawu, Merapi and Merbabu volcanoes intermittently and variably as pyroclastics. Their accumulation forms a concentric radial topographic pattern about the cone of origin, filling surface irregularities as the volcano builds and expands.

The fluvial deposits and coarse pyroclastics represent the aquifer portion of this geological formation. These permeable layers are characteristically lenticular and discontinuously layered and interbedded, generally becoming finer away from the source. The volcanic origin of these deposits dictates that they will have similar interbedding throughout their thickness. Well logs support this to at least 100 meters depth.

Several pumping tests from wells tapping these Younger Volcanics are available and indicate its

Transmissivity range. Screen was placed between 24 and 72 meters depth in well TW-1 at Jonggrangan. Transmissivity obtained was 1028 $m^3/d/m$ indicating a very good aquifer. Well TW-XIV B at Bulusan has a Transmissivity of 130 $m^3/d/m$ with the screen placed to depth 31 meters. This suggests that a well installed to the full thickness of the formation would intercept enough aquifer to give a Transmissivity of 400 $m^3/d/m$.

Specific Capacity of well GSI 918 at Karanganyar with the screen placed at 86 meters was 4.2 and 8.3 l/s/m for two different tests. The lower Specific Capacity will theoretically compare to a 625 $m^3/d/m$ Transmissivity if the well is 100% efficient and very probably more as wells are rarely this efficient. An aquifer Transmissivity at this well could be realistically estimated at 1000 plus $m^3/d/m$.

Specific Capacities of four other wells with screens bottoming between 24 to 83 meters in the Younger Volcanics range from .9 to 1.6 l/s/m. These Specific Capacities relate to Transmissivities of about 125 to 190 $m^3/d/m$ in 100% efficient wells. Again, realistically, Transmissivities might be 300 plus $m^3/d/m$.

The Younger Volcanics are discontinuously layered and lenticular. The aquifer layers are hydraulically interconnected for the most part but restricted and

delayed ground water movement must be characteristic. Ground water flow to wells will be essentially horizontal. Pumping test data discussed above is for wells up to 86 meters deep. Wells installed to greater depths will undoubtedly intercept additional aquifer layers resulting in greater Transmissivities. It appears then that wells 100 to 150 meters deep might result in Transmissivities of 500 to 1000 $m^3/d/m$.

Test-Production Well TW-2 installed under the Surakarta Water Project utilized 74 meters of aquifer bearing formation. Transmissivity obtained from a controlled aquifer pumping test was 437 $m^3/day/m$.

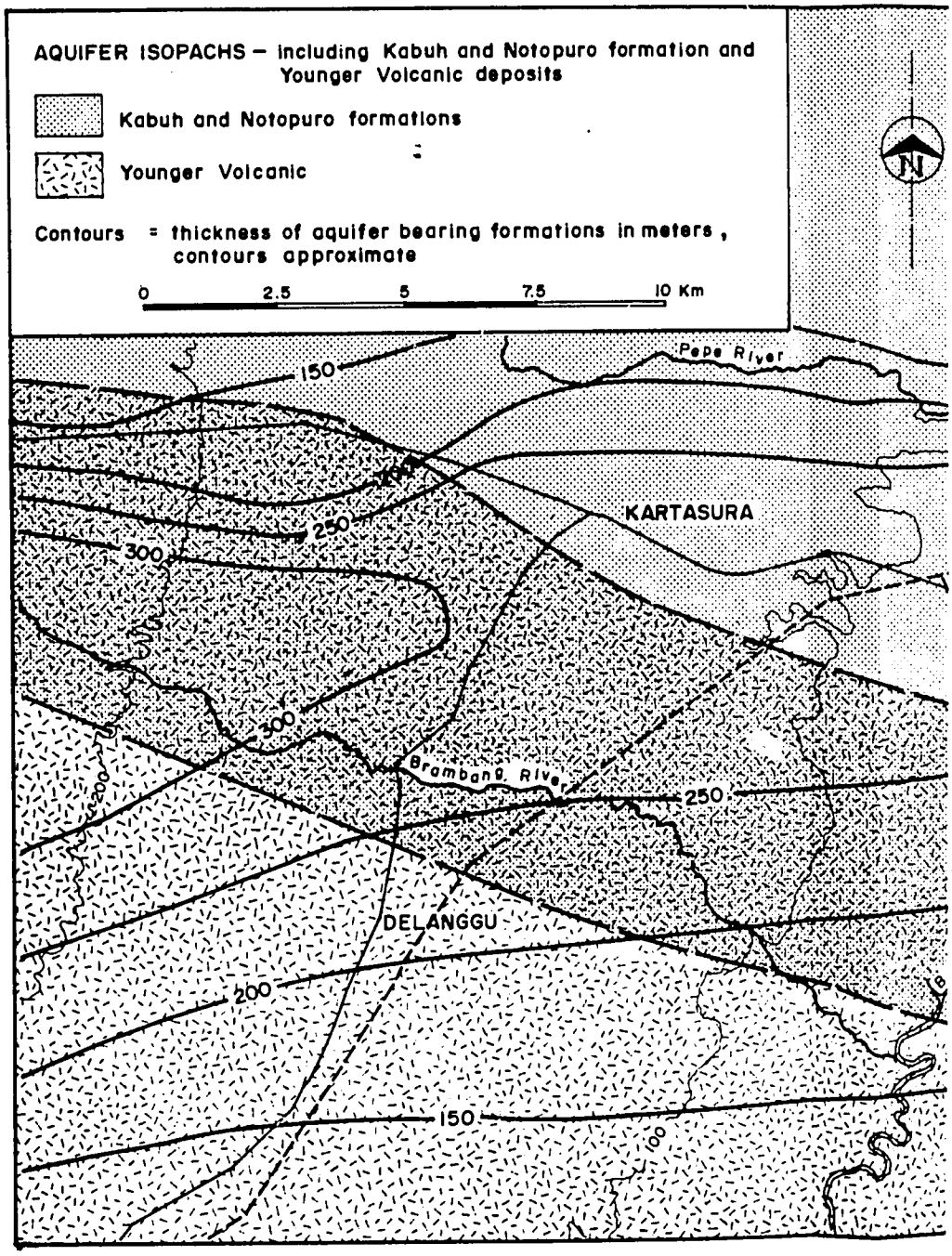
Pumping test data on TW-1, Jonggrangan, and TW-XIV B, Bulusan, indicate leaky artesian aquifer conditions prevail. TW-1 observation well data indicated a vertical permeability of 9.8 $gpd/ft.^2$. The nature of sediments indicates recharge will be possible through the permeable beds that are exposed at and near the surface, although it will be random and variable. Recharge will resupply the aquifer almost directly and ground water need not originate "high on the flanks of mount Merapi".

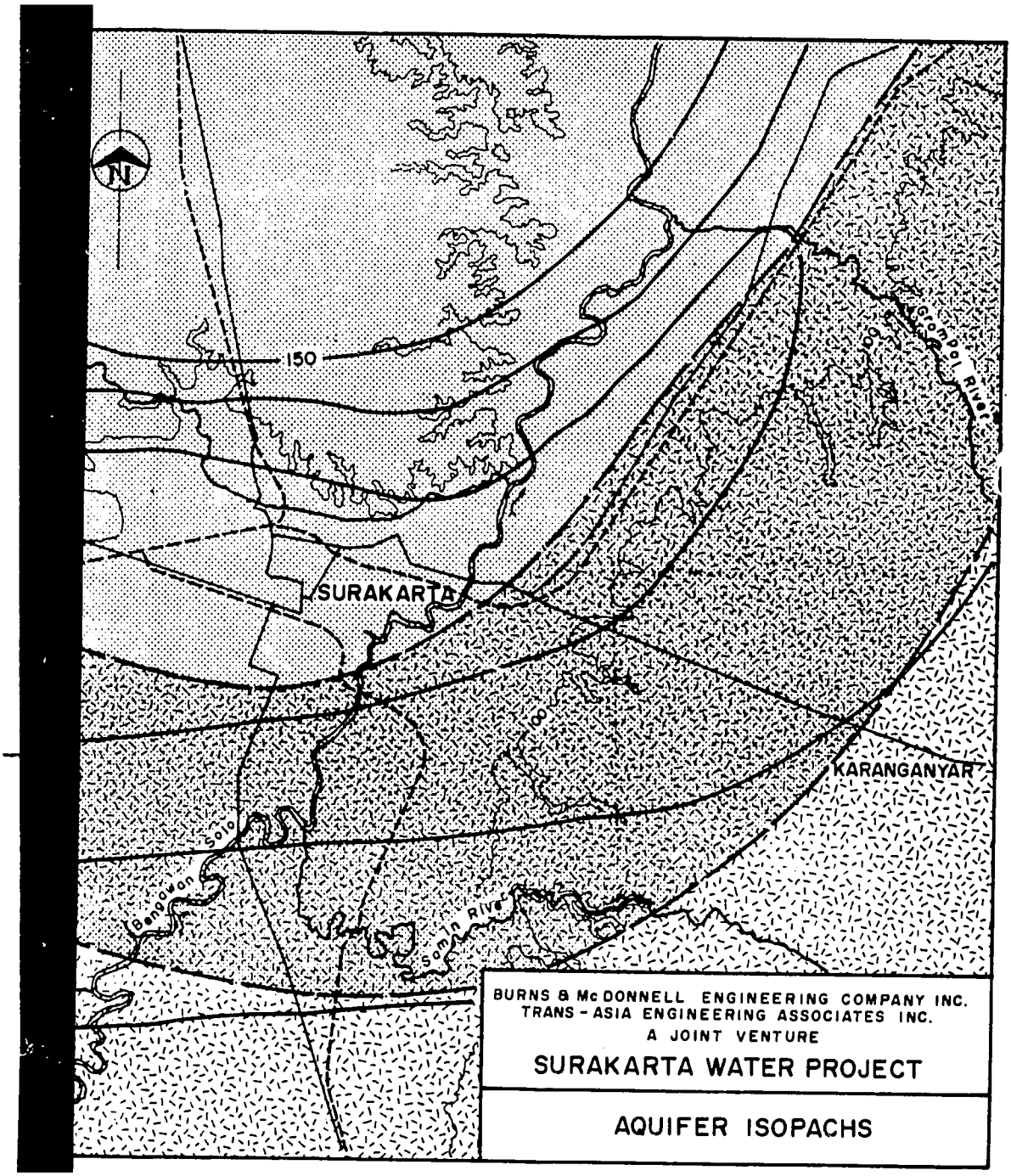
Any lowering of the piezometric surface through ground water withdrawal from storage will enhance vertical recharge also.

A Storage Coefficient of 2.8×10^{-3} was obtained from the aquifer pumping test at TW-1 indicating a semiconfined aquifer.

SUMMARY OF FORMATIONS AND HYDROGEOLOGY

Formation	Age	Description	Hydrogeology
Alluvium	Holocene	Continuous with and indistinguishable from Younger Volcanic deposits	Interbedded sands, and gravels with breccia and tuffs, layered and lenticular Capable of supporting municipal capacity Wells
Younger Volcanic deposits	Holocene	Volcaniclastic and fluvially reworked volcaniclastic deposits, discontinuously layered, lenticular and interbedded	
Notopuro formation	middle to late Pleistocene	Primarily tuff and tuff breccia with some fluvial sandstones and conglomerates	Contains layers of sand and gravel with good permeability Capable of supporting municipal capacity Wells
Kabuh formation	middle Pleistocene	Coarse grained cross bedded volcanic sandstone and conglomerate with layers of volcanic tuff, layered and lenticular	
Putjangan formation	early Pleistocene	Claystone, volcanic agglomerate	Fine grained material not suitable for use as aquifer
Tertiary marine formations (Kalibeng beds)	Pliocene	Marine claystone limestone and sandstone	Source of saline ground water


AQUIFER ISOPACHS – including Kabuh and Notopuro formation and Younger Volcanic deposits
Kabuh and Notopuro formations
Younger Volcanic
Contours = thickness of aquifer bearing formations in meters, contours approximate
0
2.5
5
7.5
10 Km
N
Pepe River
150
250
300
KARTASURA
300
Brambang River
250
DELANGGU
200
150


N
150
SURAKARTA
KARANGANYAR
Bengawan Solo
Somin River
Gromdol River
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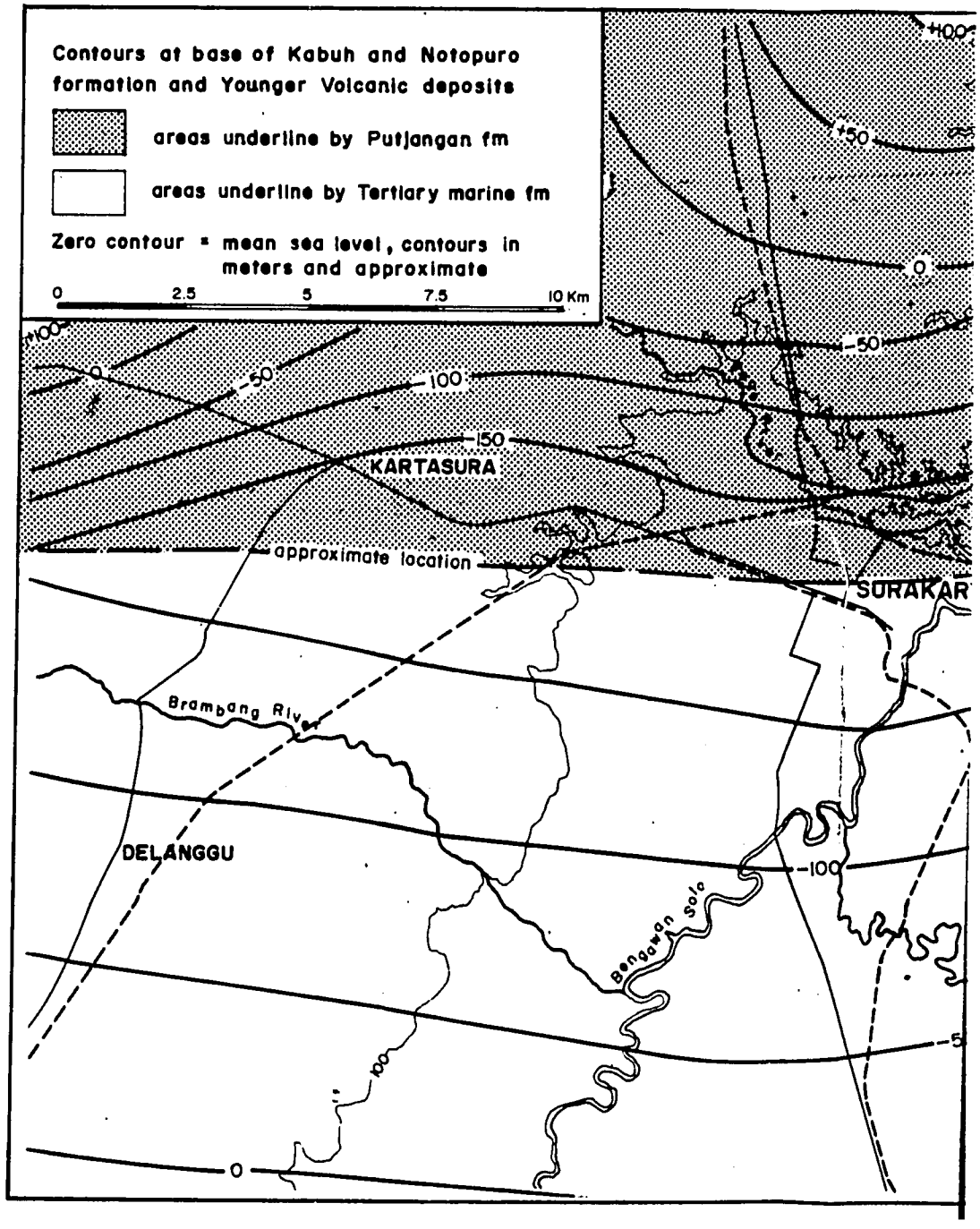
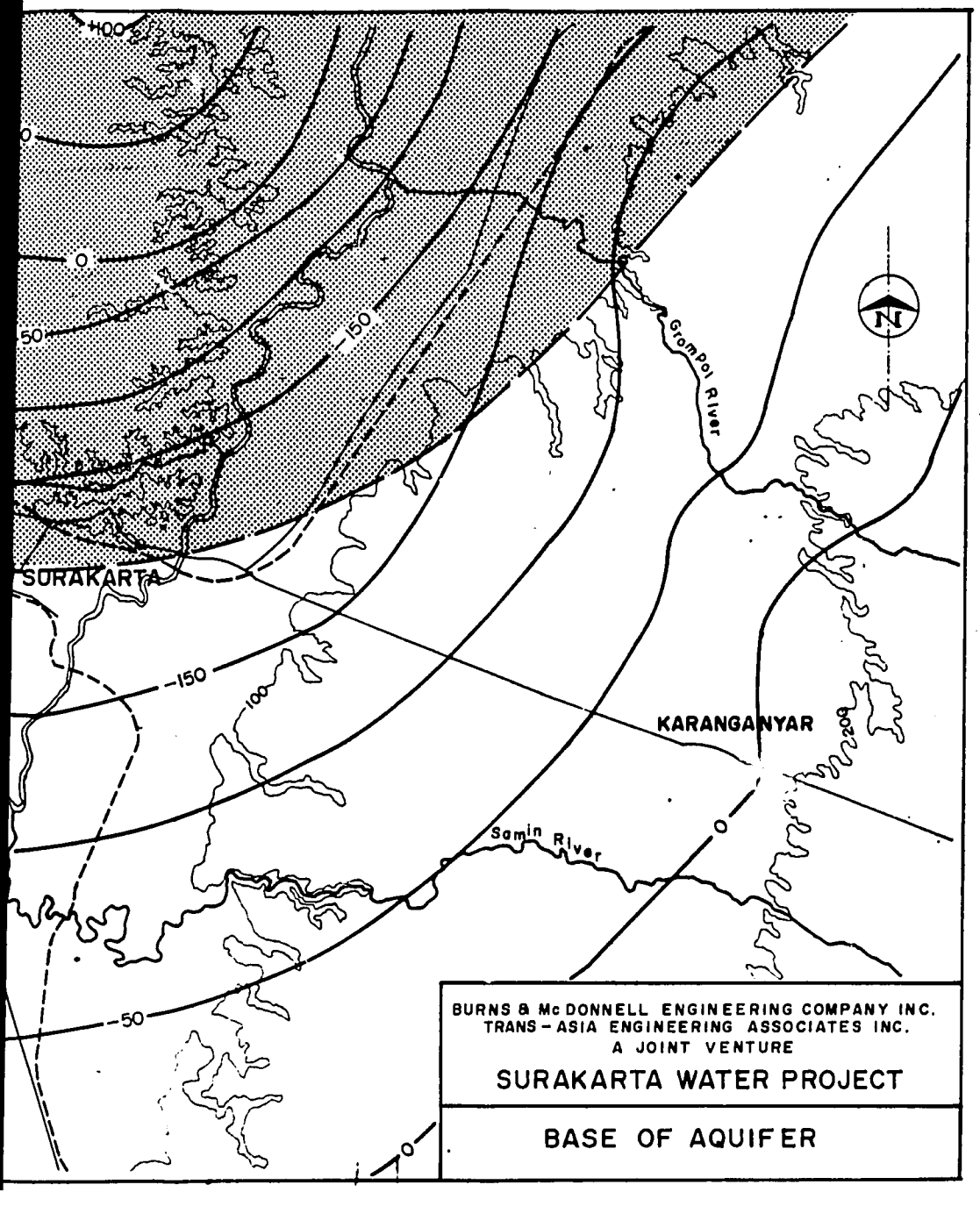
AQUIFER ISOPACHS


Contours at base of Kabuh and Notopuro formation and Younger Volcanic deposits
areas underline by Putjangan fm
areas underline by Tertiary marine fm
Zero contour = mean sea level, contours in meters and approximate
0
2.5
5
7.5
10 Km
+100
+50
0
-50
-100
-150
KARTASURA
approximate location
SURAKAR
Brambang Riv
DELANGGU
Bengawan Solo


+100
0
0
50
-50
-150
SURAKARTA
-150
100
KARANGANYAR
Grompol River
Samin River
0
-50
0
N
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SURAKARTA WATER PROJECT
BASE OF AQUIFER

HYDROGEOLOGY

Ground Water Occurrence and Movement - The Kabuh and Notopuro formations and Younger Volcanics are more or less discontinuously layered and lenticular. Evidence indicates that aquifer layers in these formations have some hydraulic continuity. This would be by seepage through aquitard layers such as "sandy clay" and "tuff" and around aquiclude layers such as "clay" and "breccia".

Confined ground water and unconfined ground water are concurrently present but the occurrence of each cannot be clearly defined. Information from the old Surakarta city wells indicated that static water levels progressively increase in elevation as deeper aquifer layers are encountered. Unconfined ground water is present a few to 10 meters below the ground surface for the most part but is up to 30 meters deep just north of Surakarta.

The unconfined ground water table slopes towards the Bengawan Solo River both from the east and west. The slope generally conforms to the topography. North of Surakarta, in response to high surface elevations, a ground water mound interrupting the general water table slope is present.

From the somewhat sketchy information on the old Surakarta city wells drilled 80 to 90 years ago it can be deciphered that aquifer layers at a

general depth of 50 to 100 meters had a static water level elevation of about 91 meters and the aquifer below 130 meters had a static water level elevation of about 96 meters. The unconfined ground water occurs today at about elevation 85 meters.

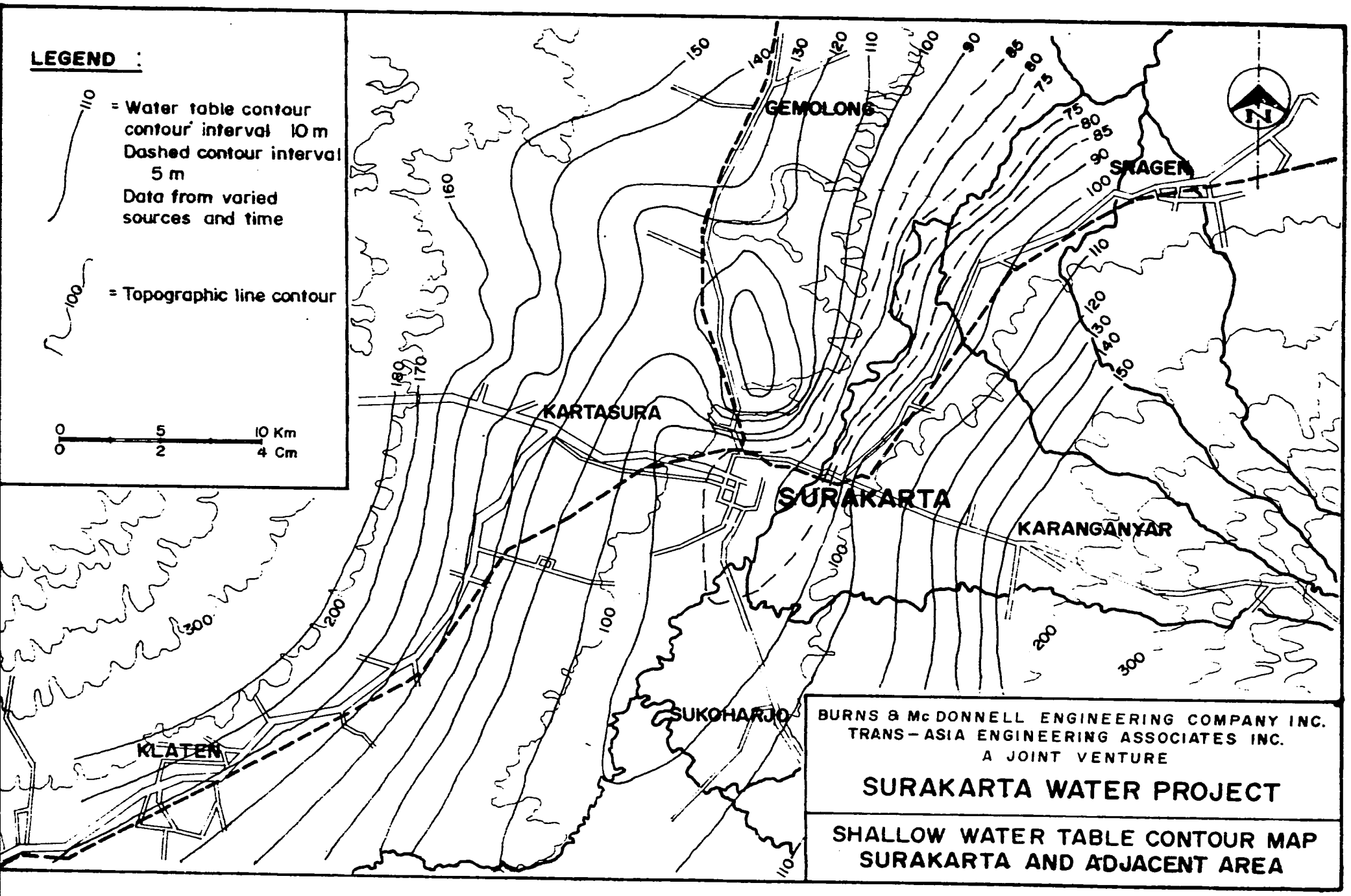
It is possible that a localized depression occurs on the water table in Surakarta and environs. The magnitude may be about two meters. Today only two of the old city wells are known to flow. It seems logical that the casings have rusted away and the holes caved, sealing off the deeper aquifers and their flow rather than a reduction of the piezometric surface. Slope and direction of movement of artesian ground water should be parallel to the unconfined ground water. Approximate equal static water level elevations in these wells seven kilometers apart in the north-south direction tend to support this expectation.

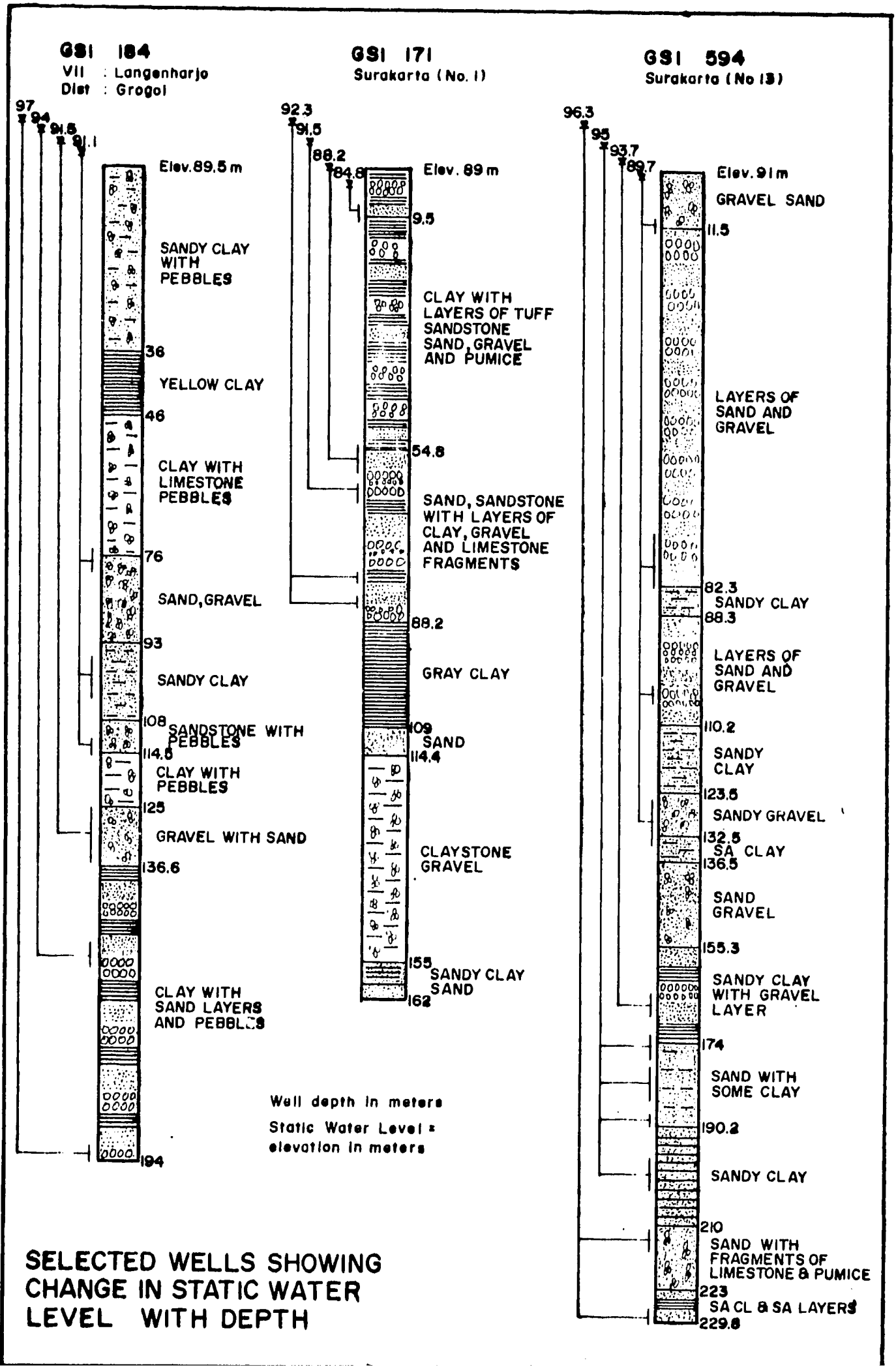
Seasonal Water Level Fluctuation - Annual fluctuation of static water level in shallow wells range from about 1 to 2.5 meters. Low levels occur during the latter part of the year at the end of the dry season while higher levels occur during the early months of the year during and just after the rainy season. Data is not available to compare unconfined and confined fluctuations. Water level fluctuations in shallow wells tend to increase towards Surakarta where the 2.5 meter ranges were common.

Recharge - Geologic character of the sediments and the increasing heads with successive depth of aquifer layers indicate the nature of ground water recharge. The water table aquifers are recharged primarily from nearby rainfall and to a small extent from upward seepage through aquitards in response to greater hydrostatic heads with depth.

Unconfined water moving down slope passes beneath layers of clay, tuff, and breccia and becomes confined. This ground water may pass beneath a number of successive overlapping confining layers gradually working to deeper aquifers while still having static heads relating to its initial source. In general, the deeper the ground water the further away the initial entry into the ground. The age of the ground water is 40-60 years as measured and reported by the Electroconsult - Nippon Koei Study, January 1977. This young age plus static water levels and Transmissivity indicate that confined ground water beneath Surakarta and surrounding areas could have originated less than 10 kilometers distant.

The percent of rainfall infiltrating and becoming part of the ground water supply is unknown. Considering the geologic conditions, topography, rainfall pattern, and land use an estimate of 10 to 20 percent might be appropriate. The Notopuro formation composed of much tuff and tuff breccia will limit infiltration of precipitation to


LEGEND :
= Water table contour
contour interval 10 m
Dashed contour interval
5 m
Data from varied
sources and time
= Topographic line contour
0 5 10 Km
0 2 4 Cm
GEMOLONG
SRAGEN
KARTASURA
SURAKARTA
KARANGANYAR
SUKOHARJO
KLATEN
N
BURNS & McDONNELL ENGINEERING COMPANY INC.
TRANS-ASIA ENGINEERING ASSOCIATES INC.
A JOINT VENTURE
SURAKARTA WATER PROJECT
SHALLOW WATER TABLE CONTOUR MAP
SURAKARTA AND ADJACENT AREA



SELECTED WELLS SHOWING CHANGE IN STATIC WATER LEVEL WITH DEPTH

some degree to the underlying Kabuh formation aquifers. Permeable layers of the Younger Volcanics are contiguous with the ground surface in many places and infiltration into the useable aquifers should be very good.

Pumping test results from well TW-1, Jonggrangan, indicated a vertical hydraulic conductivity of 9.8 gallons per day per square foot of surface for the Younger Volcanics. This obviously cannot be projected extensively but does give some indication of the seepage potential.

Creating a depression on the piezometric surface through ground water withdrawal from storage will enhance recharge, the amount of enhancement depending on the amount of depression.

GROUND WATER QUALITY

Mineral analysis of ground water from wells within the project area are plentiful. In general the analysis indicates Municipal quality water is available for Surakarta water supply.

Iron and Manganese concentrations in the ground water tend to be a bit high in some wells. Most wells, however, indicate Iron is present in less than

0.1 mg/l and Manganese mostly less than 0.2 mg/l. The Iron is present to a level of 1.3 mg/l in a few wells. Several readings such as 15 and 27 mg/l are obviously erroneous. Manganese is present to 0.6 and 0.7 mg/l in a few wells. Neither of these minerals are considered to be a problem or potential problem as the slightly over maximum tolerance presence appears to be in isolated cases.

Saline water is present in Tertiary marine formations that underly the aquifers and was trapped in the sediments at the time of deposition. The particular marine sediments are the upper Kalibeng Beds of Pliocene age and are composed of fossiliferous limestones, claystones and some sandstones based upon outcrops north of Surakarta. Periodic marine transgressions are represented in the Putjangan formation also which could be a source of some saline water. It can be speculated that saline water still present is within low permeability layers or entrapped in isolated lenses otherwise ground water movement would certainly have replaced it with fresh water by this time.

The connate water yields high Chlorides and Dissolved Solids to wells that tap them. These salty zones have been "cemented off" in several cases after they were encountered in wells. The only mineral analysis of this water is from well GSI 1619 at Ceper and has the following mineral constituents:

Dissolved Solids	14,500 mg/l
Sodium	1,750 mg/l
Chlorides	7,840 mg/l

Dissolved Solids ranging from 300 to 600 mg/l are common in mineral analysis regardless of the well depth. These quantities tend to be high, near and above the preferred levels, but still well within the maximum tolerated limits.

Chlorides are commonly present in low 10 to 30 mg/l concentrations except when associated with wells believed to bottom near the saline marine formations as previously discussed.

Records of the mineral analysis from our Surakarta city wells drilled by the Dutch are available. "Zouten" or Dissolved Salts was a standard analysis and values commonly range from 500 to 600 mg/l and occasionally to 1200 mg/l. The few Chloride analyses available from these old wells ranges from 100 to 250 mg/l except well GSI 594 which ranged from 300 to 400 mg/l, from 100 to 215 meters depth and 916 mg/l at the 228 meter deep hole bottom.

Chlorides are consistently and considerably higher than those reported for more recently drilled wells. Whether this is real or some difference in analysis procedure is unknown. The big increase in Chlorides at the bottom of the deepest well in Surakarta is significant in either case and suggests the marine sediments may be nearby. Sodium Chloride was commonly reported with mineral analysis. Concentrations range from 23 to 435 mg/l and show a definite increase with depth. Again relating these 80-90 year old analyses to contemporary analyses is problematic.

Based upon geology, Dutch drilled deep well GSI 184 at Langenarjo is believed to bottom near the connate water bearing formation. Mineral analysis of this well follows:

Aquifer Depth	Chlorides	Na Cl	Dissolved Salts
76 - 78 M	-	-	5280 mg/l
95	-	-	2600
112 - 114	1310 mg/l	-	2494
125 - 136.6	-	1564 mg/l	2080
152 - 157	-	1374	1947
192	1035	-	3507

This well was also known for the healing powers of its mineral waters. Reportely it formerly had an odor and could be ignited.

Quality of ground water from the formations considered for aquifers, namely the Notopuro and Kabuh formations and the Younger Volcanics, is presently suitable for municipal use. To some degree this is

true because more confidence can be placed on recent analysis than analysis performed before 1900. However, the quality of water could deteriorate through migration of connate water to the aquifers after an extended period of ground water withdrawal.

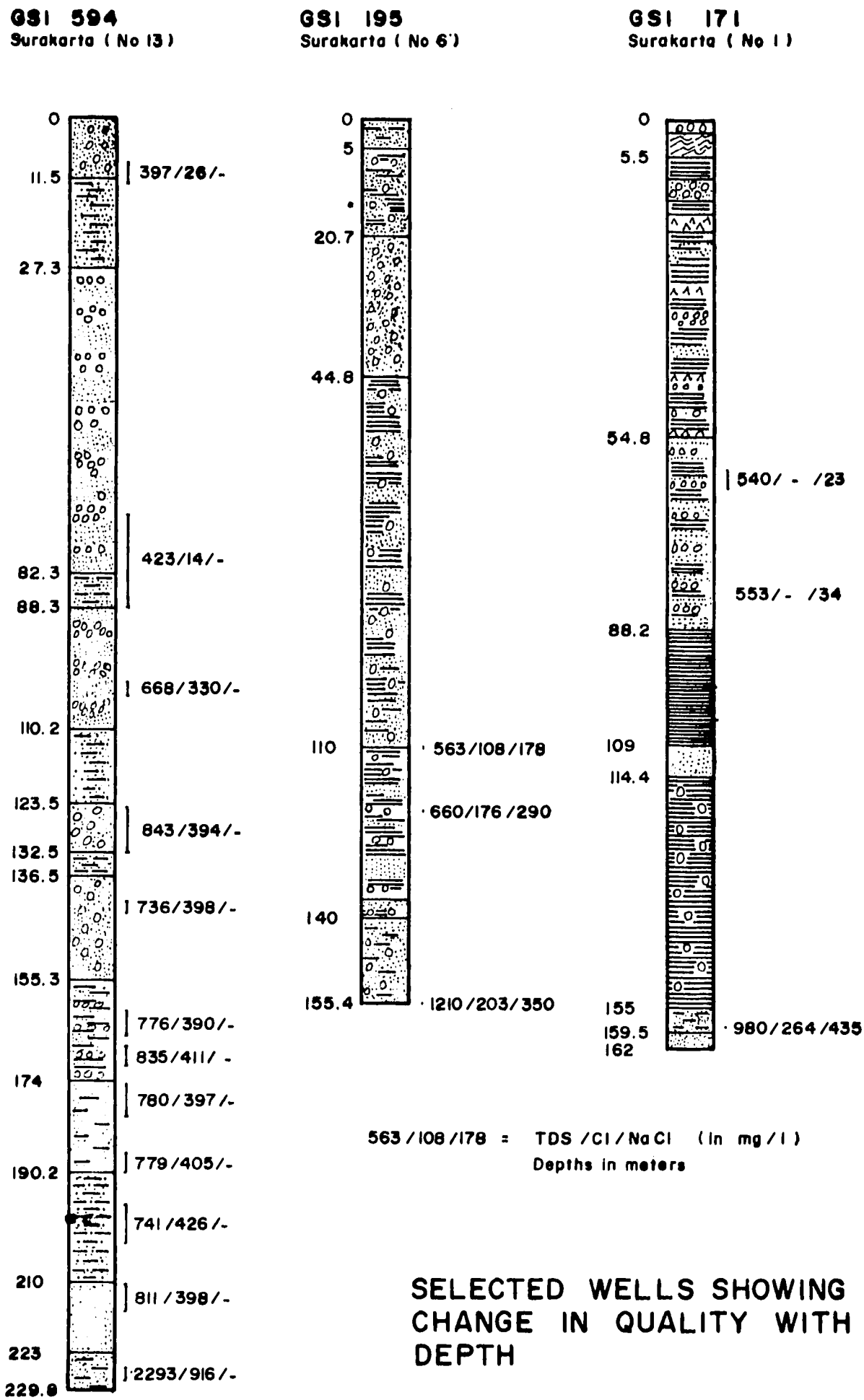
The high Dissolved Solid content makes the water corrosive hence well screens of noncorrosive material should be used.

GROUND WATER CONTAMINATION

Except for saline contamination by connate water, pollution potential appears to be minimal at this time. With future area growth and development this may alter however and problem sources may develop which cannot be identified or predicted at this time. Some potential sources might be batik and textile dyes, waste from pharmaceutical manufacturing, and waste from sugar factories.

Nitrate from fertilizers used in extensive farming areas around Surakarta could be a potential problem. Mineral analysis available indicate concentrations of less than one mg/l with an occasional 2 - 3 mg/l which are well within the recommended limits for municipal water. If fertilizer usage becomes more extensive concentrations of Nitrates will undoubtedly increase.

Future organic waste contamination should be minimal for deep wells tapping artesian aquifers as hydrogeological conditions are favorable providing



SELECTED WELLS SHOWING CHANGE IN QUALITY WITH DEPTH

adequate surface seals are placed on wells. Movement of water through the first one or two meters of soil reduces organic waste matter to almost zero This is particularly true under aerobic conditions and in sands and finer grained material, both of which exist in the project area. The water table is commonly 5 - 8 meters below the surface in Surakarta and 2 - 6 meters below the surface in outlying areas resulting in an opportunity for aerobic conditions to prevail. Water entering the ground must pass through at least 30 to 40 meters of aquitards and aquifers before reaching the upper aquifers that will be utilized by wells.

GROUND WATER POTENTIAL

Aquifer Transmissivity - It appears the Kabuh formation and the Younger Volcanic deposits have generally similar aquifer conditions. Based upon existing information Transmissivities for the Kabuh formation are estimated to be about 500 to 1000 $m^3/d/m$ for 150 meters of formation. Estimated Transmissivities for the Younger Volcanics are 400 to 900 $m^3/d/m$ for 100 to 150 meters of formation.

Transmissivity appears to be proportional to the thickness of the formation utilized for placing well screens in these layered sediments. Wells 150 meters deep would utilize about 110 meters of formation, screening the inclusive aquifers and resulting in a conservatively estimated 500 $m^3/d/m$ Transmissivity. Wells 200 meters deep would utilize

about 150 meters of formation giving a conservatively estimated 700 $m^3/d/m$ Transmissivity.

Well Specific Capacity - Considering the estimated 500 $m^3/d/m$ Transmissivity for 150 meters deep wells and allowing for inefficient entry of water into the well and some partial aquifer penetration effects an average well Specific Capacity of two liters per second per meter of drawdown can be assumed. For wells with 700 $m^3/d/m$ Transmissivity an average well Specific Capacity of 2.5 l/s/m can be assumed.

Prime Aquifer Area - The area of greatest thickness of the Kabuh, Notopuro and/or Younger Volcanic deposits is an east-west oriented strip 7 to 8 kilometers wide with Surakarta and Kartasura along its central axis. This area is at least 30 kilometers long with its ends undefined beyond a practical distance from Surakarta. Thickness of the aquifers beneath Surakarta is at least 230 meters and based on geology projected to 250 to 300 meters depth. Thickness in the Kartasura area is estimated to be about the same or somewhat greater but based on less direct evidence. This strip narrows and bends to the north paralleling the road to Masaran east of Surakarta.

Within this Prime Aquifer Area it appears the western end has a slightly better potential due to greater thickness of aquifer, better recharge possibilities and a somewaht better Transmissivity.

The north half of this Prime Aquifer area is underlined by nonmarine Putjangan formation which offers better protection against the upconning of saline water.

Prime Aquifer Area is defined as the area where the aquifer bearing Notopuro and Kabuh formations and the Younger Volcanic deposits are thickest. The same good aquifers exist where these formations are present outside the prime area but with less total thickness. This will result in wells of less depth and hence lower capacities.

Quality Constructions - The Notopuro, Kabuh and Putjangan sequence and the Younger Volcanics in the project area are underlined by Tertiary marine formations. Several wells drilled into these underlying formations encountered saline water and deeper wells completed within the Kabuh formation encountered increases in Dissolved Solids and Chlorides with depth.

This saline connate water was trapped in the marine sediments at the time of deposition. The extent, concentration and geohydraulics of the connate water is unknown. Finite position and configuration of host sediments is also unknown.

When fresh water overlies saline water a pumping well in the fresh water zone will cause the fresh water - saline water interface to cone upward towards the well due to pressure relief on the interface. The interbedded nature of the

aquifers alternating with aquicludes and acquitards will inhibit the upconning to a great extent however Depending on the ultimate drawdown in the well and proximity of the well bottom to the interface, the undesirable water would eventually find its way to its equilibrium position and into the well.

Mineral analysis for well GSI-195 in Surakarta indicates no discernible quality change after flowing for 27 years. Even though the flow rate was low this could suggest a stable quality condition.

Date	Aquifer Depth	Chlorides	Dissolved Solids
1893	110 m	108 mg/l	563
	121	176	660
	153	213	1210
1920	110 m		
	121	115.5	770
	153		

An alternate situation is possible. Presumably connate ground water remaining after half a million years will be in low permeability fine grained formations and/or in isolated lenses of its host marine formations. Natural movement of ground water under existing hydrogeologic conditions will be imperceptibly slow and mineralization from connate water will continue to be concentrated. Large scale withdrawal of ground water will accelerate movement of water through the aquifers and its replacement with recharge. Ground water

contact time with mineralizing sources will be minimal, hence limiting concentrations. Quality will gradually improve with aquifer use in this case.

Recharge - Based upon the stated need of 13,000 m^3/day from ground water, recharge appears to be more than sufficient. An average of 2157 millimeters of rainfall occurs annually in the Surakarta area. If approximately two percent of this infiltrates into the ground and through the leaky aquitards over the area within which vertical leakage is divertedto the pumping centers of the production wells, recharge will be adequate. Depressing the piezometric level through ground water withdrawal will induce this vertical leakage.

GROUND WATER EXTRACTION

Limited Use of Aquifers - Unless test holes are drilled to define the finite position and character of the saline formations and extent and movement of saline water or until long term monitoring of water quality has proven saline encroachment to be minimal, it appears prudent to limit production well depth to less than half the aquifer thickness.

Well Dimensions - The general maximum thickness of the prime aquifer is estimated to be 250 to 300 meters. 150 meter deep wells would then be appropriate. The typical pumping chamber for such a well would be approximately 40 meters

deep with an available drawdown of about the same as confined static water levels are near ground surface. Accounting for seasonal and annual water level variations, interference drawdown from adjacent wells and some reserve usable drawdown will be about 30 meters. Specific Capacity for this typical well would be about two l/s/m of drawdown after adjustments for well losses and partial penetration.

Well capacity is then: 2 l/s/m x 30 m=60 l/s.

Pump chamber diameter for this capacity well should be 16 inches. An estimated 40 meters of 8 inch diameter, noncorrosive wire wound screen should be utilized intermittently to intercept the layered aquifers.

Wells Required - An additional 13,000 cubic meters of water per day is required to meet the current demand for the city of Surakarta. Five wells producing 60 l/s for half a day can meet this requirement.

An average aquifer Storage Coefficient is required to determine well spacing. Well TW-1 at Jonggrangan utilizing an observation well during an aquifer pumping test produced an apparently reliable Coefficient of 2.6×10^{-3}. Similar values were developed by Electroconsult and Nippon Koei, 1977, in the Sragen area.

The five wells producing 60 l/s on a half time operational basis will withdraw ground water from storage during the non and low recharge

season of approximately five to six months per year. Calculations indicate the wells then should be spaced approximately three kilometers apart. However, the aquifer functions with leaky artesian conditions as suggested by the geologic nature of the aquifers and supported by five of the pumping tests collected from various sources. Leakage of any quantity will reduce the water taken from aquifer storage and offset interference of well drawdowns resulting in the opportunity to space wells closer. An estimated 1½ kilometer spacing between wells is suggested after considering the magnitude of leakage that might be expected. In the future, when additional wells beyond those envisioned in the scope of this report are being installed observation wells should be utilized to collect basic data on aquifer storage and aquitard leakage so well spacing can be refined as it becomes more critical.

Future Considerations - The stated present additional 13,000 m^3 of water per day required will result in four or five production wells being placed to approximately 150 meters depth in an area where the aquifer is considered most productive. These few wells will result in a very modest stress on the aquifer. The potential for quality deterioration exists however and these initial wells should be monitored continuously for quality changes.

In the future there will be a requirement for additional wells to augment the municipal supply. Before additional wells are installed, multiple level observation wells should be placed

to the bottom of the aquifer to monitor saline water movement and possible encroachment. The aquifers being tapped by these wells will produce ample quantities of water but the supply is not unlimited. Industrial, commercial and future municipal wells will continually be added eventually placing a heavy demand that could deplete the quantity and deteriorate the quality of the ground water supply.

Aquifer pumping tests utilizing observation wells should be conducted on as many new production wells as possible so that aquifer storage, leakage, recharge and refined Transmissivities necessary for evaluating optimum exploitation of the ground water can be obtained.

TEST PRODUCTION WELLS TW-1 AND TW-2

General

Two test production wells were installed for the Surakarta Water Project and two more production wells are anticipated to follow. Geological and general hydrogeological investigations carried out during the first phase of the Ground Water Investigation resulted in the identification of two areas with the best ground water potential:

1. North of Surakarta
2. South West of Surakarta

TW-1 was located in the North of Surakarta area and TW-2 was located in the South West of Surakarta area, their finite position based upon resistivity surveys. This also placed TW-1 in the Kabuh and Notopuro formations and TW-2 in the Younger Volcanic deposits, the only formations in the area suitable for aquifers. Results from pumping tests conducted on these two wells produce reliable aquifer coefficients and well Specific Capacities which are believed to be representative for the respective aquifers. These results were utilized to calibrate conclusions derived from evaluation of existing well data.

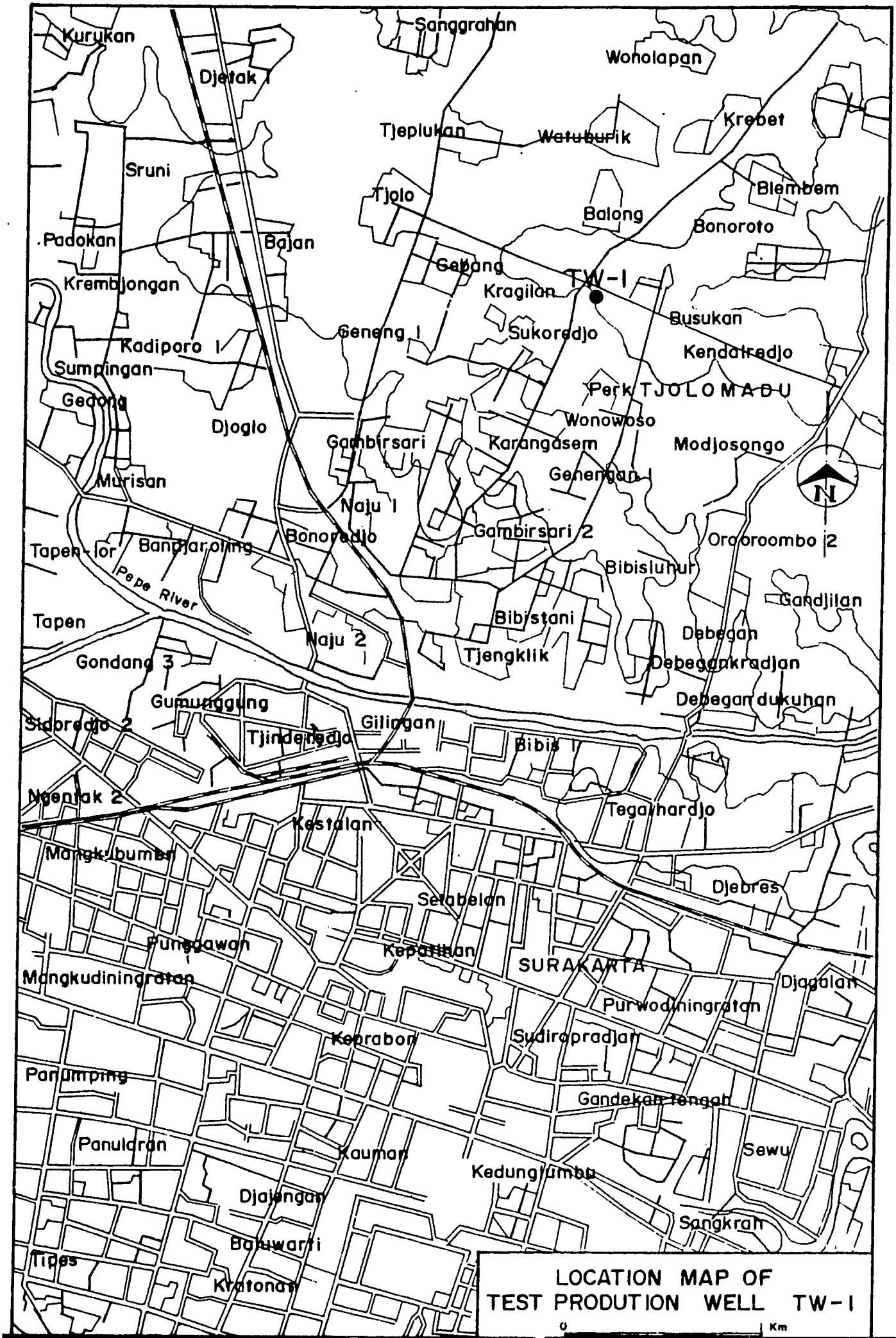
TW-1 Pumping Tests

Three pumping tests were conducted on well TW-1:

January 23, 1981 - Three step for well performance.

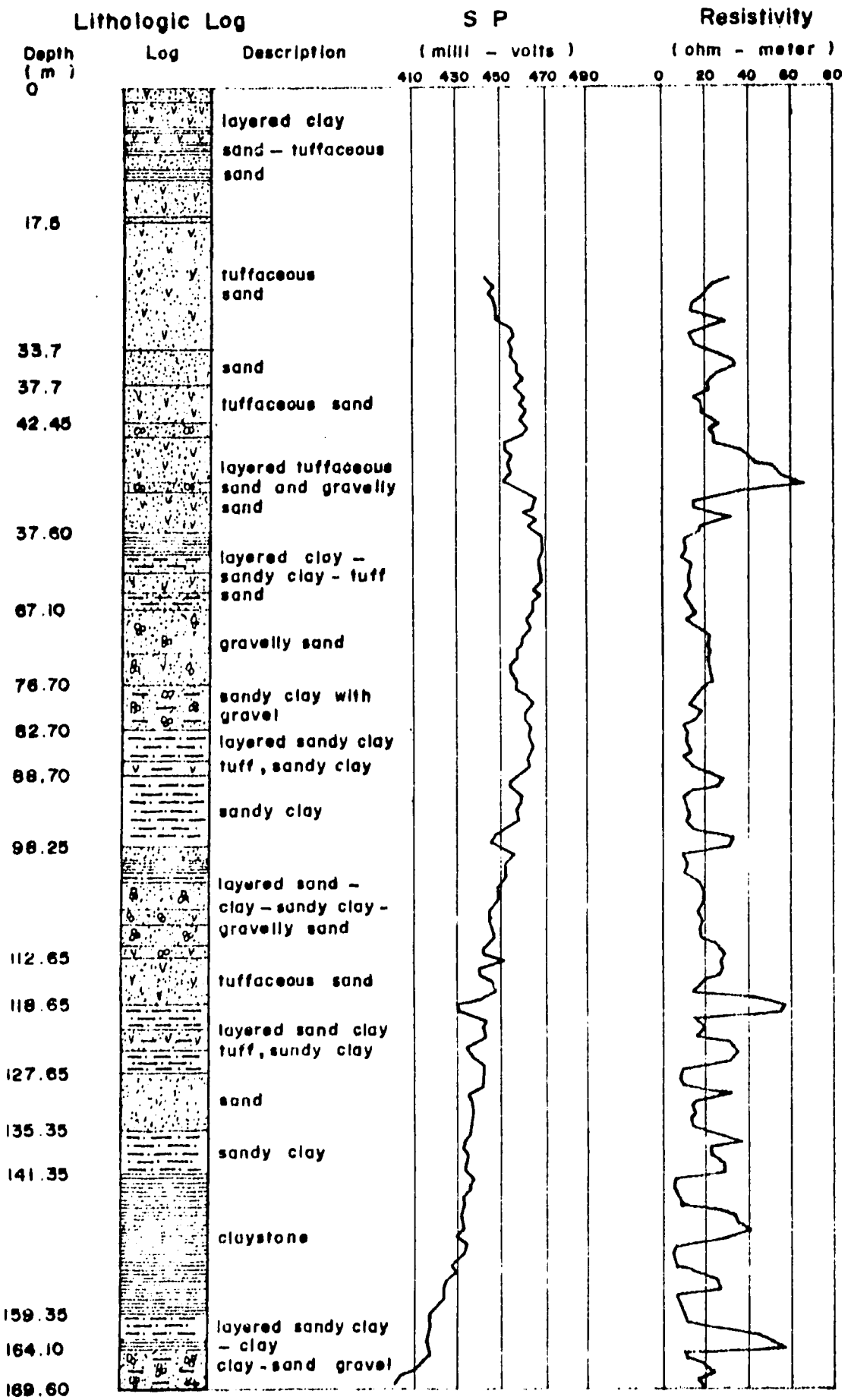
January 27, 1981 - Seven step for well performance.

January 29, 1981 - Constant rate for aquifer characteristics.


Kurukan
Djetak I
Sanggrahan
Wonolapan
Krebet
Tjeplukan
Watuburik
Sruni
Blembem
Tjolo
Balong
Bonoroto
Padokan
Bajan
Gebang
TW-I
Krembjongan
Kragilan
Busukan
Geneng I
Sukoredjo
Kadiporo I
Kendalredjo
Sumpingan
Perk TJOLOMADU
Gedong
Wonowoso
Djoglo
Gambirsari
Karangasem
Modjosongo
Genengan
Murisan
N
Naju I
Gambirsari 2
Bonoredjo
Ororoombo 2
Tapen-lor
Banjaroling
Bibisluhur
Pepe River
Gandjilan
Tapen
Bibistani
Debegan
Naju 2
Tjengklik
Gondang 3
Debegankradjan
Gumunggung
Debegandukuhan
Sidoredjo 2
Gilingan
Tjindenedjo
Bibis I
Ngentak 2
Tegalhardjo
Kestalan
Mangkubumen
Djebres
Setabelan
Punggawan
Kepatihan
SURAKARTA
Mangkudiningratan
Djagalan
Purwodiningratan
Keprabon
Sudiropradjan
Panumping
Gandekan tengah
Panuldran
Kauman
Sewu
Kedungjumbu
Djajengan
Sangkrah
Baluwarti
Tipes
Kratonan
LOCATION MAP OF
TEST PRODUTION WELL TW-I
0
Km

Test Production Well TW - I

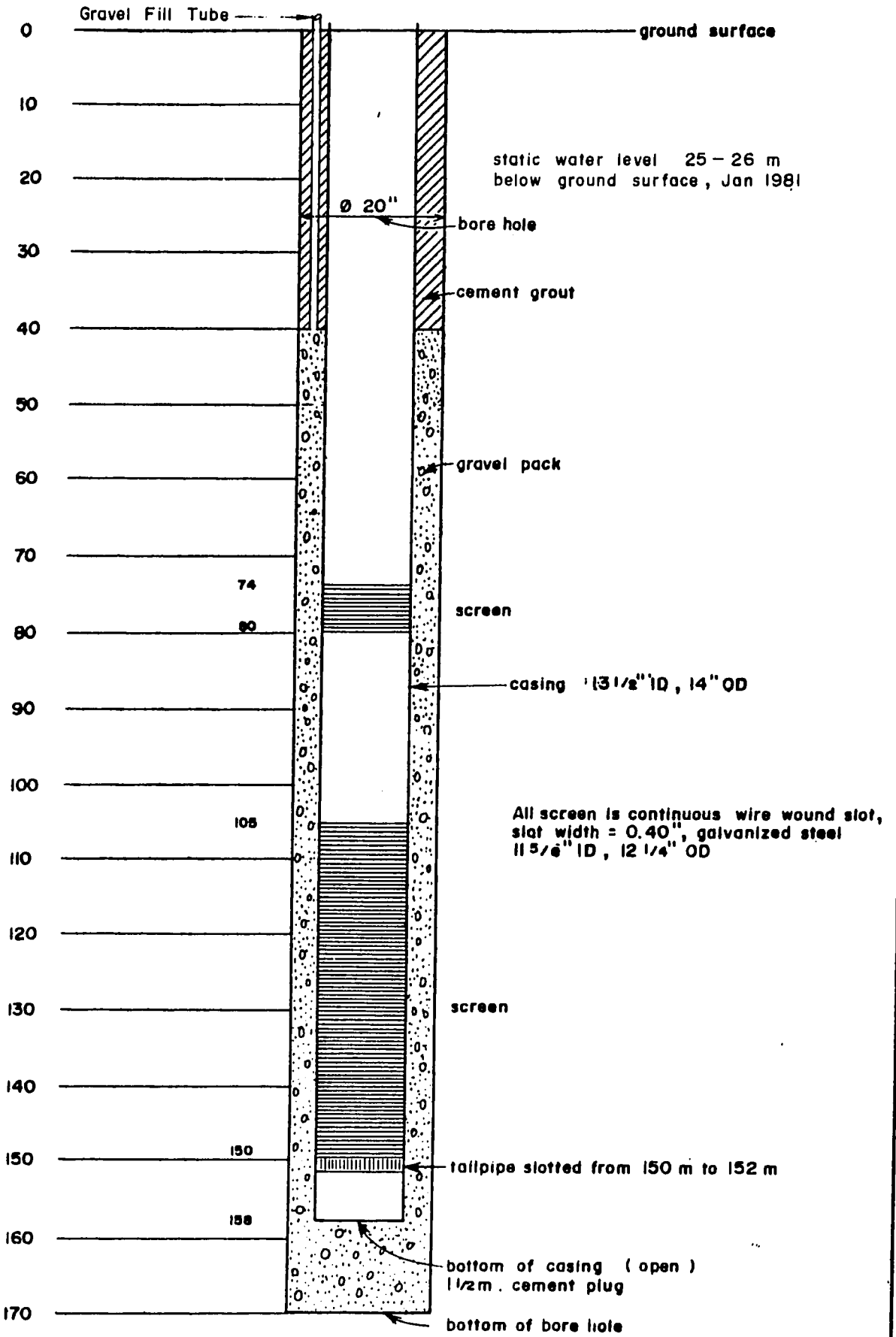
Elevation : ± 125 m
Vil. Busukan
Dist. Mojosongo

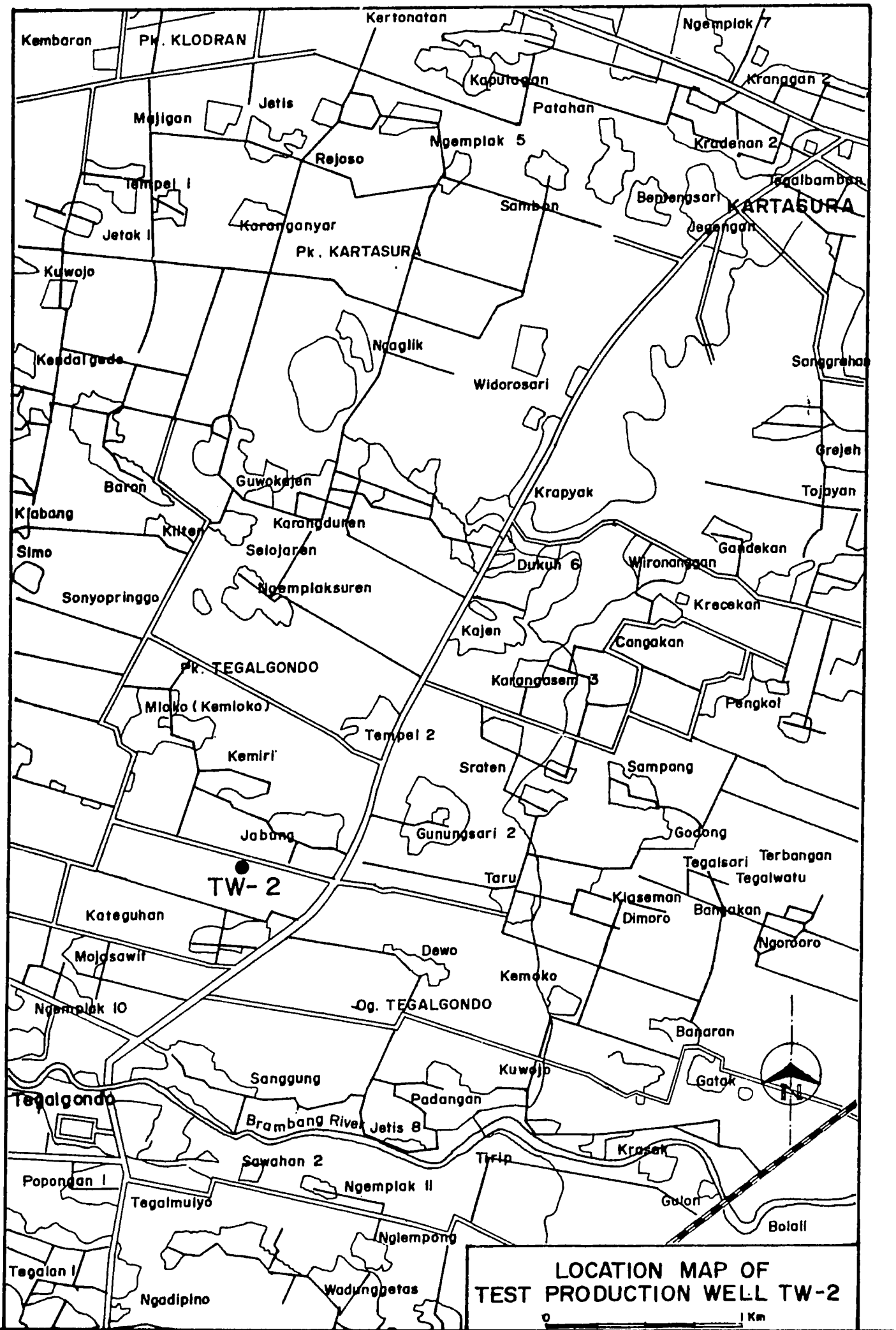


Test Production Well TW-1

Elevation ± 125 m
Vil. Busukan
Dist. Mojosongo

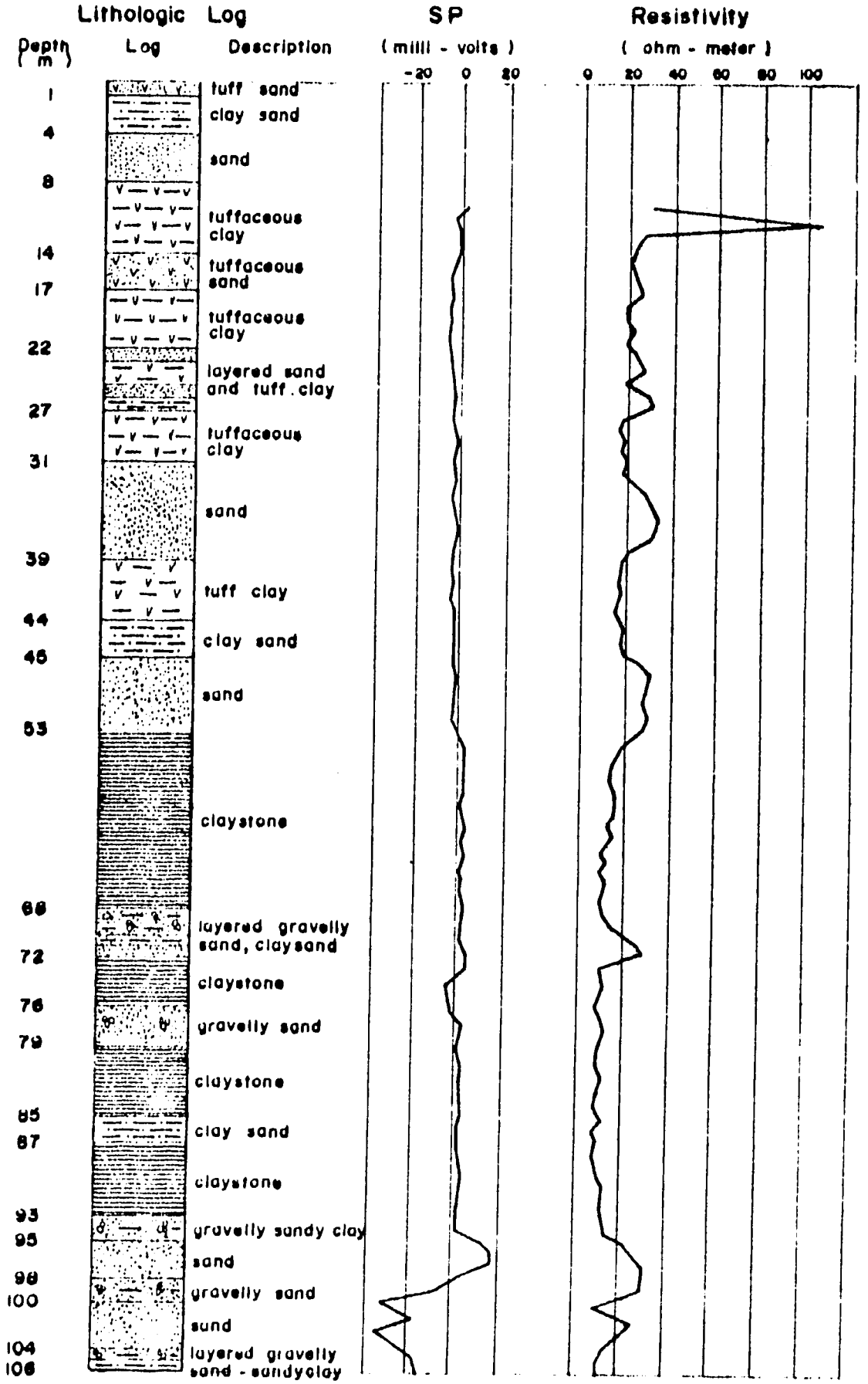
Well Construction




Kembaran
Pk. KLODRAN
Kertonatan
Ngemplak 7
Kaputagan
Kranggan 2
Jetis
Majigan
Patahan
Ngemplak 5
Kradenan 2
Rejoso
Tempel I
Tegalbamban
Bentengsari
KARTASURA
Sambon
Jetak I
Karanganyar
Jegangan
Pk. KARTASURA
Kuwojo
Ngaglik
Kendalgede
Sanggrahan
Widorosari
Grejeh
Baron
Guwokajen
Krapyak
Tojayan
Klabang
Kliten
Karangdumen
Selojaren
Gandekan
Simo
Dukuh 6
Wironanggan
Ngemplaksuren
Sonyopringgo
Krecekan
Kajen
Cangakan
Pk. TEGALGONDO
Karangasem 3
Mlako (Kemloko)
Pengkol
Tempel 2
Kemiri
Sraten
Sampang
Jabung
Gunungsari 2
Godong
Tegalsari
Terbangan
TW-2
Taru
Tegalwatu
Kateguhan
Klaseman
Dimoro
Bangakan
Ngoroboro
Mojosawit
Dewo
Kemoko
Ngemplak 10
Og. TEGALGONDO
Banaran
Kuwojo
Sanggung
Gatak
Tegalgondo
Padangan
Brambang River
Jetis 8
Krasak
Sawahan 2
Tirip
Popongan I
Ngemplak II
Tegalmulyo
Gulon
Bolali
Ngiempong
Tegalan I
Wadunggetas
Ngadipino
N
LOCATION MAP OF
TEST PRODUCTION WELL TW-2
0
1 Km

Test Production Well TW-2

Elevation ± 135 m
Vil. Jabung
Dist. Kartasura

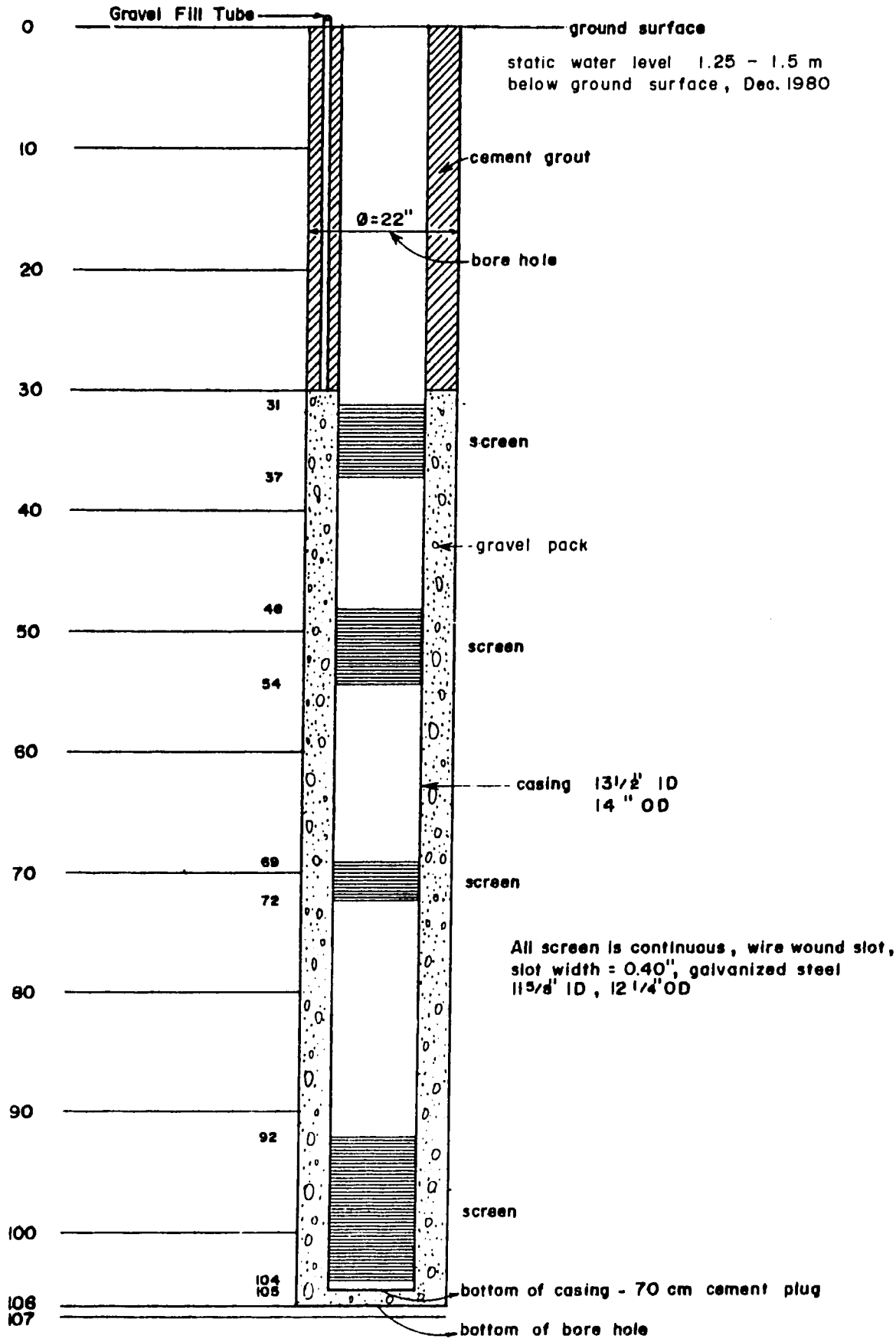


Note . below 50m lithology change maybe 1 - 2 m lower than shown on log

Test Production Well TW - 2

Elevation ± 135 m
Vil . Jabung
Dist. Kartasura

Well Construction



The test pump was initially installed to develop the well by backwashing and overpumping. Pump column available at this time was insufficient for final testing of the well, however. Following some development a preliminary well performance test was conducted on January 23-24 to gain some knowledge of the total pump column required for the final test.

On January 27-28, following deeper settling of the pump intake, a seven step test was conducted at various rates up to the estimated production rate of 63 l/s. This was followed by a continuous uniform rate test to gain information on the aquifer characteristics.

A summary of test results follow:

TW-1		Three Step	Seven Step	Constant Rate
Transmissivity ($m^3/d/m$)	Draw-down	460	550	450
	Recovery	600	500	500
Specific Capacity (l/s/m)	Projected to 24 hours	$\frac{26\ l/s}{6.8\ m} = 3.8$ $\frac{32.2}{9.6} = 3.4$ $\frac{37.6}{11.0} = 3.4$	$\frac{19.3}{4.6} = 4.2$ $\frac{26}{7.2} = 3.6$ $\frac{32.2}{9.8} = 3.3$ $\frac{38.4}{11.6} = 3.3$ $\frac{44.4}{13.5} = 3.3$ $\frac{50.5}{15.5} = 3.3$ $\frac{63.3}{22.2} = 2.9$	$\frac{63.3}{22.0} = 2.9$
	Projected to ten days	$\frac{26}{8.1} = 3.2$ $\frac{32.2}{11.5} = 2.8$	$\frac{63.3}{24.0} = 2.6$	$\frac{63.3}{24.0} = 2.6$

Static water level was 25 to 25.5 m below ground surface during the period of testing.

An average Transmissivity of 500 m^3/day/meter width of aquifer can be concluded from the test results.

Well Specific Capacity after 24 hours of continuous pumping at 63 l/s will be 2.9 l/s/m of drawdown and 2.6 l/s/m after ten days of continuous pumping. An additional 25 meters of drawdown is still available as the top of the well screen is 74 meters below the surface, assuming the pump is placed between the top and second screen.

Well diameter will be the capacity constraint however as the 14 inch OD pump chamber will limit a pump diameter to about 12 inch and approximately 82 l/s. Pumping at a rate of 82 l/s will result in a drawdown of 35 meters below static water level based upon extrapolated pumping test data, leaving an additional 13.8 meters of unused potential.

TW-1 Pump Recommended

Capacity - Maximum that can be placed in the well - presumed to be about 82 l/s.

Settling - 70 meters below ground surface just above the upper well screen.

Head - Delivery head to ground surface should be approximately 60 meters.

In the future if additional drawdown is required, the pump bowls and intake could be placed between the upper and second well screen.

TW-2 Pumping Tests

Four pumping tests were conducted on TW-2.

December 15, 1980	-	Four step for well performance.
December 16, 1980	-	Continuous rate for aquifer characteristics.
December 25, 1980	-	Attempted continuous rate test.
January 13, 1981	-	Five step for well performance.

The test pump was installed and the well initially developed by backwashing and overpumping for several days. On December 15 a four step pumping test was conducted with satisfactory results.

This was followed on December 16 by a long term continuous rate pumping test. Periodic slugs of sand and mud plus loss of gravel pack and settling of the casing during this test indicated the well was incompletely developed. The test results indicated that the well Specific Capacity had improved slightly.

The gravel pack was replaced and retested on December 25. The well developed problems during this testing and the pumping test results indicated a lower aquifer Transmissivity and well Specific Capacity.

The final five step well performance pumping test was conducted on January 13-15, 1981. Slight variations in Specific Capacity between this and other tests suggests the gravel pack has not yet stabilized and additional development with equipment more effective than pump backwashing should be undertaken.

A summary of test results follows:

TW-2		Four Step	Continuous Rate	Discontinued Test	Five Step
Transmissivity ($m^3/d/m$)	Draw-down	395	615	275	490
	Recovery	355	425	--	--
Specific Capacity (l/s/m)	Projected to 24 hours	$\frac{24.8 \text{ l/s}}{7.9 \text{ m}} = 3.1$	$\frac{63.1}{28.0} = 1.9$	$\frac{50.5}{26.8} = 1.9$	$\frac{20.7}{7.5} = 2.8$
		$\frac{33.4}{15} = 2.2$			$\frac{26.0}{10.1} = 2.6$
		$\frac{50.5}{20} = 2.5$			$\frac{31.3}{11.9} = 2.6$
		$\frac{63.1}{31.5} = 2.0$			$\frac{33.4}{14.9} = 2.2$
					$\frac{50.5}{17.9} = 2.8$
	Projected to ten days	$\frac{24.8}{10.2} = 2.4$	$\frac{63.1}{38} = 1.66$	--	$\frac{26.0}{14.0} = 1.9$
					$\frac{31.3}{16.7} = 1.9$

Static water level was one to two meters below ground surface during the testing period.

Aquifer Transmissivity averages about 435 m^3/day/m width of aquifer. A boundary condition is reached after a short period of time resulting in a reduced well Specific Capacity. The 24 hour and ten day projections reflect the reduced Specific Capacity.

Well Specific Capacity at the rate of 50.5 l/s after 24 hours is 2.5 l/s/m of drawdown and after 10 days 1.9 l/s/m of drawdown.

Pumping at the rate of 50.5 l/s for 10 continuous days (or eight hours per day for 30 days) will result in a drawdown of 27.5 meters below the ground surface. The maximum potential is 31 meters below ground surface. The 50.5 l/s will allow for some reserve, seasonal water level fluctuations, and interference from additional production wells.

TW-2 Pump Recommended

Capacity - 50 l/s

Settling - bowls and intake should be placed between the top and second well screen - between 39 and 46 meters depth.

Head - Delivery head to ground surface should be about 28 meters.

Shallow Wells

Pumping at TW-1 and TW-2 resulted in water level decline in vicinity shallow wells. The magnitude of these declines were 5 to 10 centimeters during a day's pumping. Long term use of the new deep wells will most probably result in the loss of adjacent shallow wells. The January 13-17 pumping test at TW-2 resulted in the "drying up" of one shallow domestic well one kilometer distant.

The radius of influence in which shallow well static water levels will be affected is uncertain but will diminish with distance away from the municipal well. Using known and assumed data, zero drawdown and the distance beyond which affect on other wells will be nonexistent can be calculated at about two kilometers. This figure should be refined by observation.

The lowering of static water levels in domestic wells during the pumping tests indicates semi-confined aquifers are tapped by TW-1 and TW-2. This indicates recharge to the deep aquifers will not be a constraint. The assumed 10 continuous days (or 30 days at 8 hours per day) withdrawal of stored ground water prior to reaching equilibrium between withdrawal and recharge is then a valid but conservative assumption.

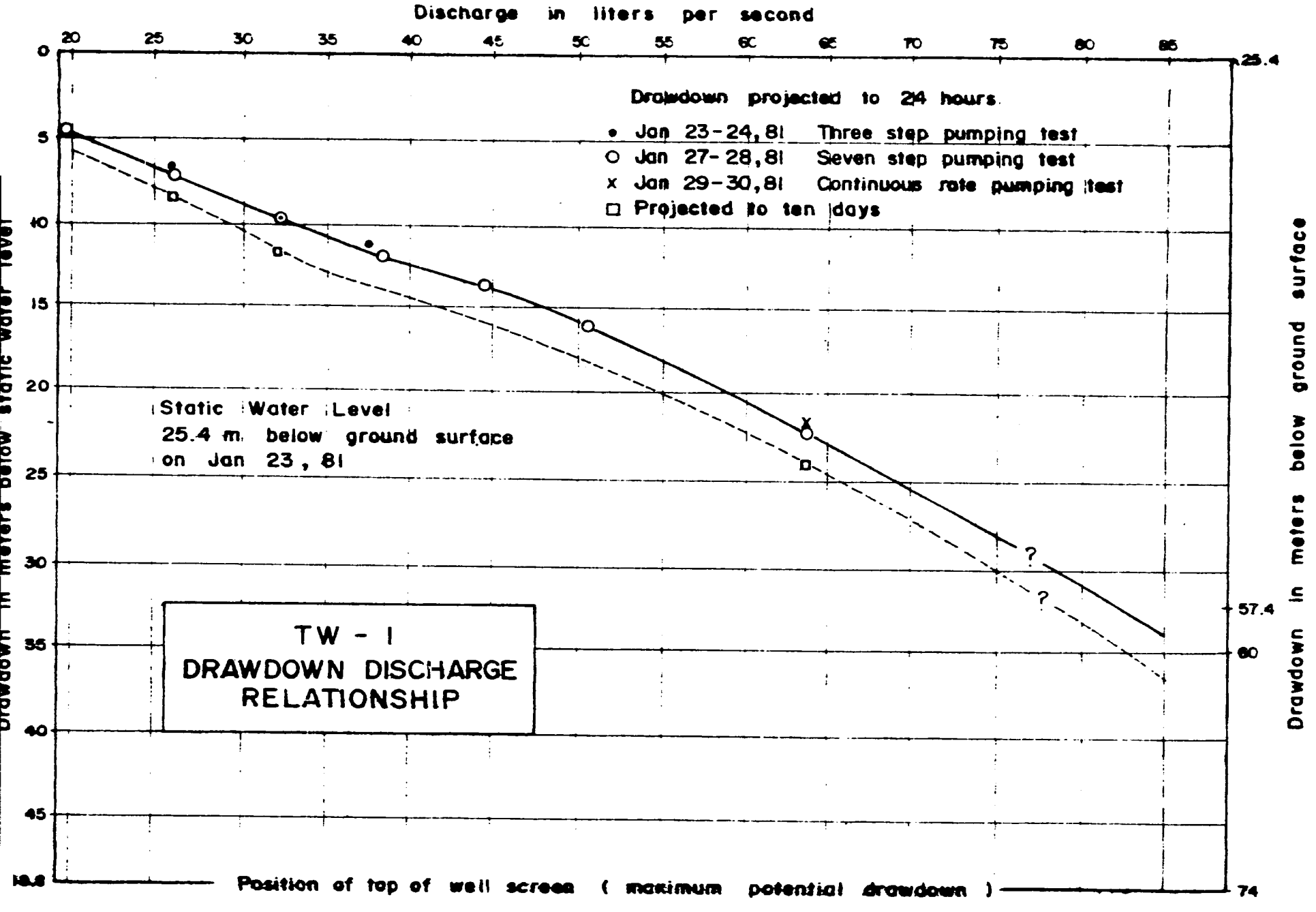
Water Quality

The Sodium content of ground water from both TW-1 and TW-2 appears to be anomalously high at 240 to 245 mg/l. This is particularly true when considering the low Chlorides and Dissolved Solids content.

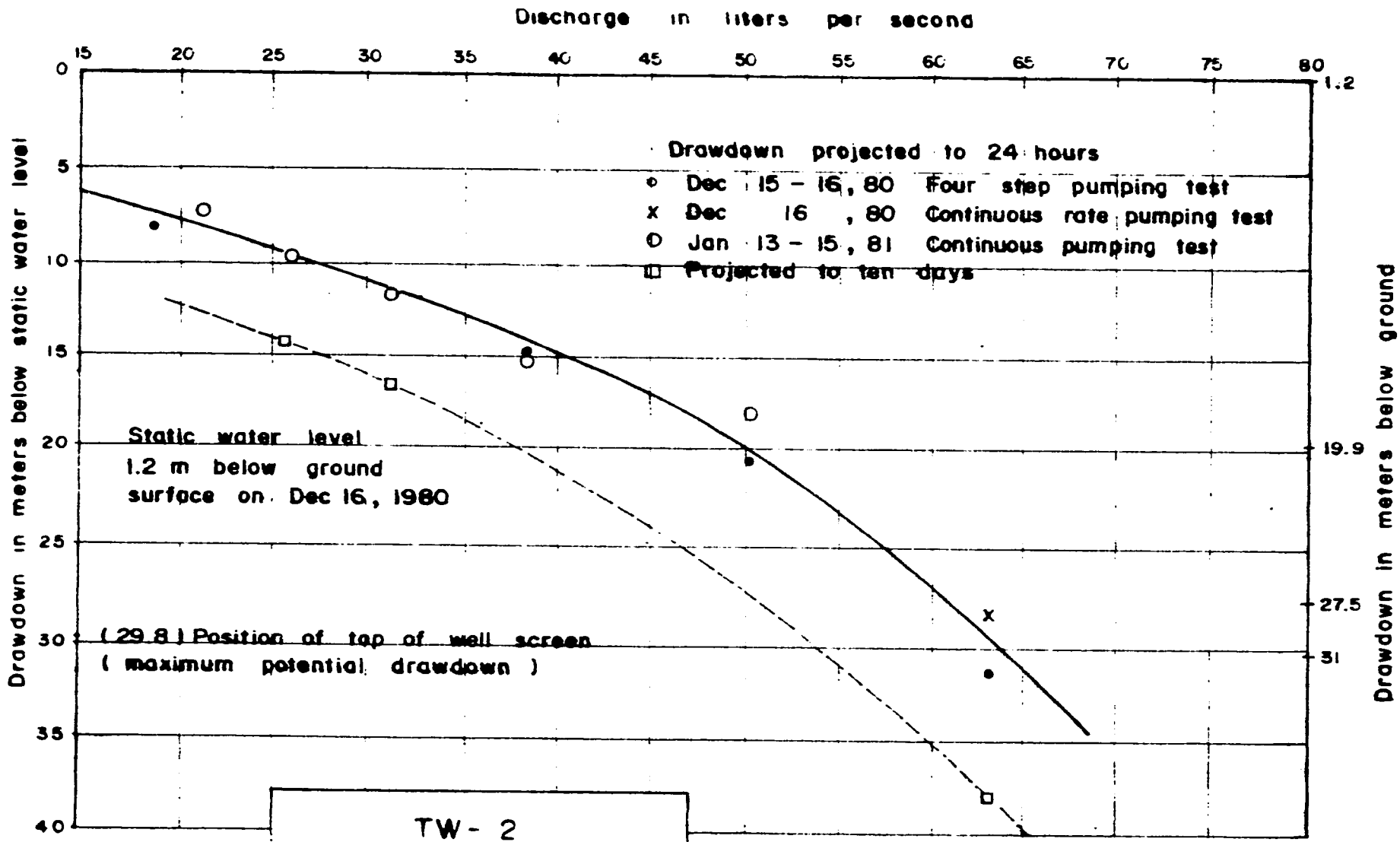
Hardness of TW-2 water exceeds the allowable limit but the water is still considered soft.

Manganese is high in TW-2 and will cause some staining problems if not treated.

Additional Production Well Locations - This second phase of the Ground Water Investigation has resulted in a detailed examination and evaluation of aquifer



SURAKARTA WATER PROJECT



TW- 2

DRAWDOWN DISCHARGE RELATIONSHIP

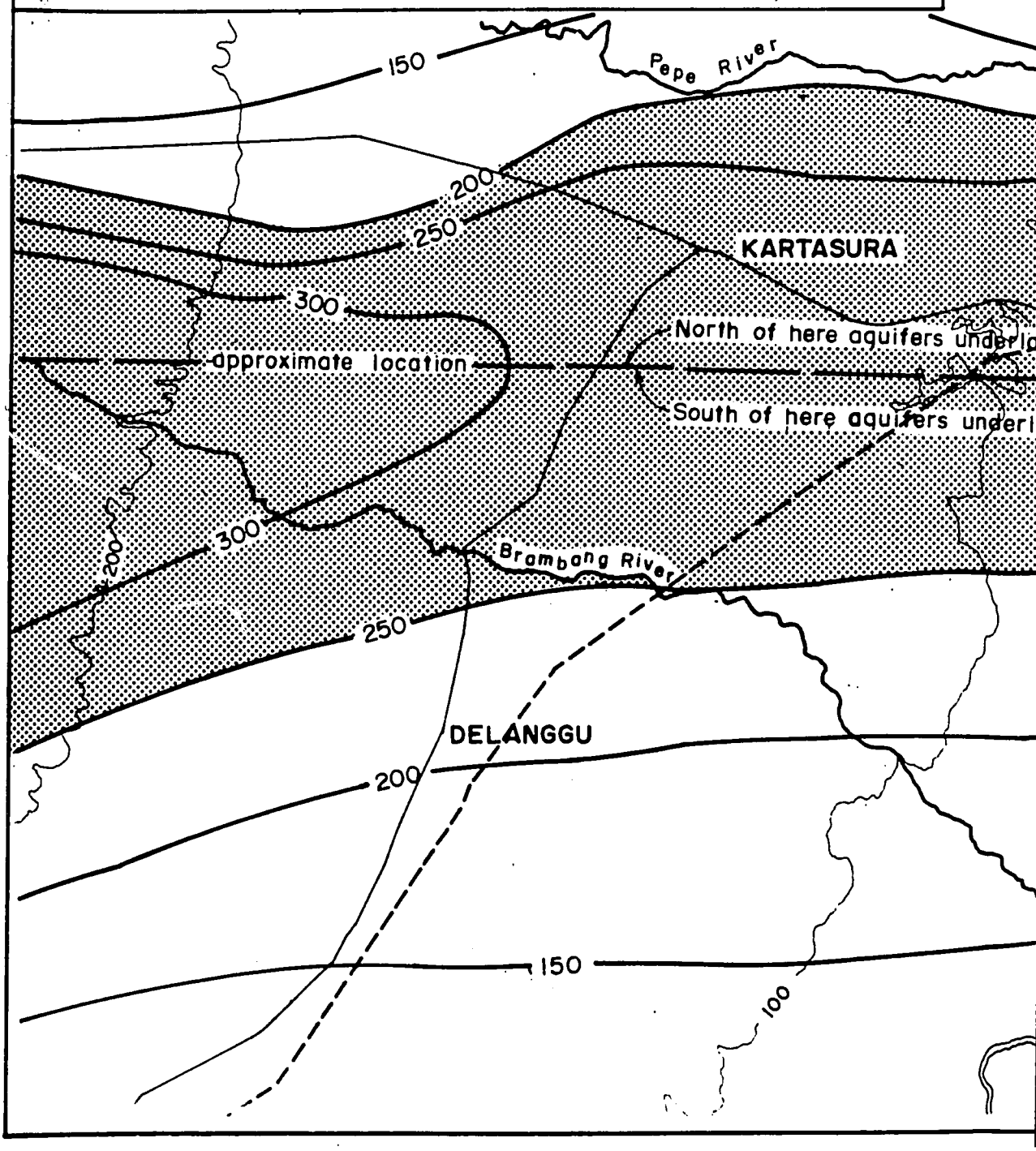
SURAKARTA WATER PROJECT

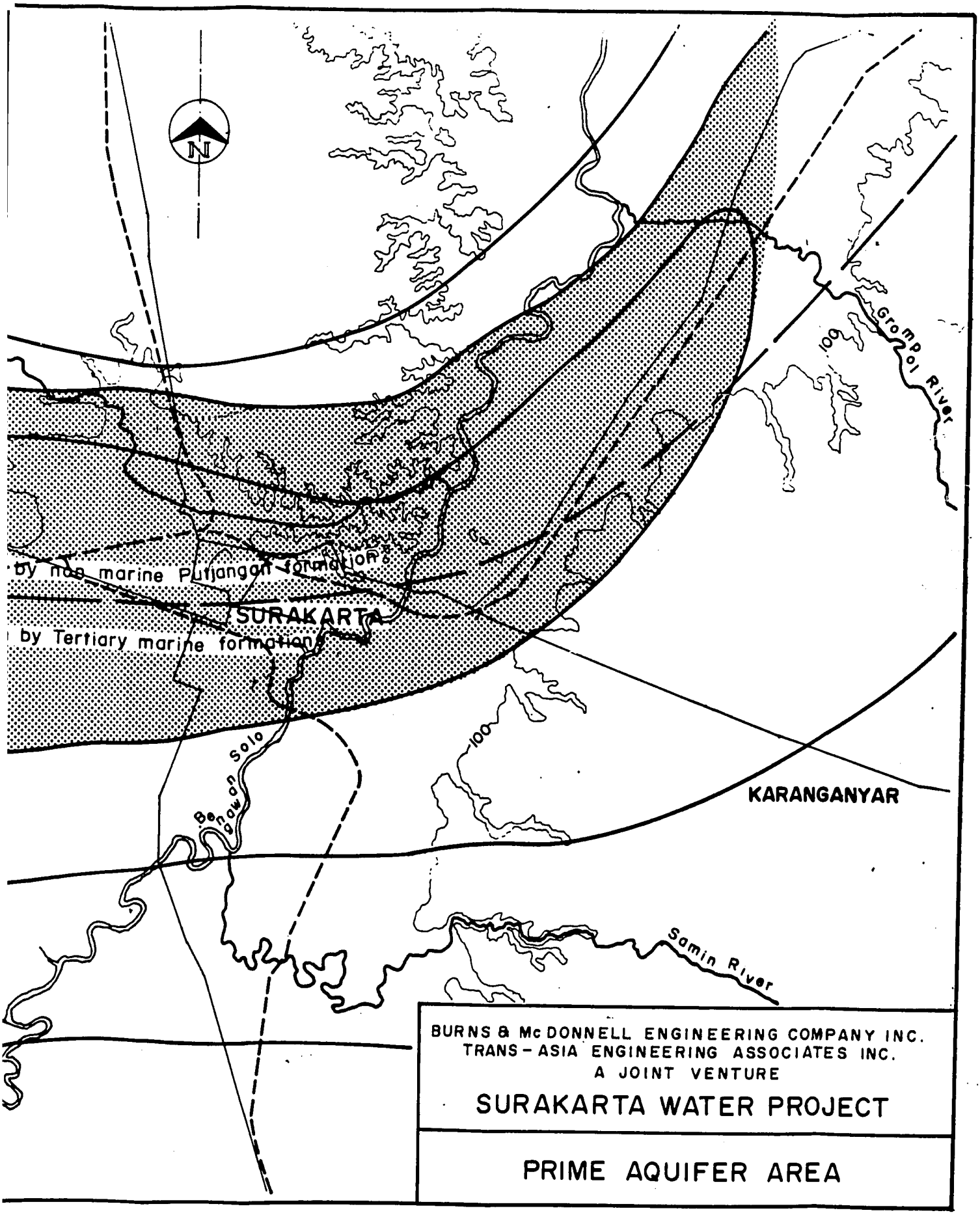
Prime Aquifer-area of greatest useable aquifer thickness

Prime aquifer area

Contours = isopachs of aquifer bearing formations, contours in meters and approximate

0 2.5 5 7.5 10 Km





BURNS & McDONNELL ENGINEERING COMPANY INC.
TRANS-ASIA ENGINEERING ASSOCIATES INC.
A JOINT VENTURE

SURAKARTA WATER PROJECT

PRIME AQUIFER AREA

geology, hydrogeology and ground water quality of the specific aquifers that will be exploited for municipal water wells. A Prime Aquifer Area where the formations and hence inclusive aquifer layers are thickest and where connate water can best be avoided is defined and described herein. Both well field areas recommended in the first phase of the investigation lie mostly within this Prime Aquifer Area. Wells TW-1 and TW-2 are within the area. The conclusion is that production wells can be placed in either of the two areas i) North of Surkarta and ii) South West of Surakarta, or anywhere within the Prime Aquifer Area and expect the same general capacities. Wells outside the Prime Aquifer Area will penetrate the same aquifers but with less total thickness and, therefore, will have a lower Transmissivity and less capacity.

Design of Additional Production Wells - Results from TW-1 and TW-2 should set the pattern for realized capacities, well dimensions and depths and pump equipment for additional future wells. Unfortunately, these two wells have been completed with poor drilling techniques and construction practices that undoubtedly have resulted in losing some of the aquifer potential. Well TW-2 depth was abbreviated in part because drilling techniques were believed to be progressively damaging the aquifer. Drilling equipment would probably have been incapable of completing the well and installing the casing and screen to the contracted depth of 170 meters. Well TW-1 caved three to four times because of work stoppages due to logistic problems and equipment failures.

Hydrogeologic conditions in the Prime Aquifer Area, well capacities expected, drilling equipment used and drilling techniques practiced dictate production well design of using a large diameter pump chamber, reducing to a smaller diameter screen intermittently placed between blank casing. Gravel packed wells should continue to be included in the well design as should a good surface seal.

Capacities of 60 to 100 l/s will require a 16 inch diameter pump chamber. Eight inch diameter wire wound screens will allow adequate entrance velocities and friction loss will be minimal in the alternating blank casing.

Using 8 inch diameter screen and casing will also allow for smaller diameter bore hole and less weight of material being installed. Less gravel pack and drilling mud will be used. This will make construction simpler for contractors as machinery and equipment can be lesser capacity. Cost per well will obviously be reduced.

Well Depths - One hundred fifty meters has been recommended for production well depths, at least until more is known about the geohydrology of the connate ground water. Several other reasons can be advanced for minimizing well depth: 1) Adequate ground water is available within these lesser depths to meet present and immediate future needs, 2) Equipment and drilling technology requirements increase with well depth and 3) Pump sizes and appurtenances increase with well depth.

This could change in the distant future with a better understanding of the connate ground water geohydrology and finite position of host formations, greater capacity wells being required, increased demand on the aquifer and increase in the capacities of drilling contractors. Wells to 300 meters depth and several hundred l/s are conceivable in these aquifers.

Gravel Pack - Screen Slot Size - Gravel pack and slot size ideally should be compatible with and designed following seive analysis of aquifer samples. This, however, becomes impractical because of unavailable "off the shelf" supplies and poor samples collected due to drilling methods used. Some combination or sets of combinations best suited for all expected conditions should be technically determined and incorporated into the well design and construction.

Screen Material - High Dissolved Solids and Chlorides present in the ground water tend to make it corrosive. Screens of suitable noncorrosive material should be selected for installation. Stainless steel would be the most suitable, but it is very expensive.

Artesian Flowing Wells - Wells drilled at lower elevations have encountered aquifers with heads above ground surface. When this is expected, surface casing to the top of the first used aquifer should be cemented into position for control of ground water flow.

<u>Well Development</u> - Development of TW-1 and TW-2 was incomplete and only represented a token effort. The few days of development and the lack of effort to develop within the screen undoubtedly resulted in randomly and partially developed wells. Vigorous development is important for efficient and long lasting wells. Development improves the well by:

1. Stabilizing movement of the gravel pack.
2. Removing fines from the natural formation.
3. Removal of drilling mud from the walls of the bore hole and aquifer.

Best results are obtained with a surge block used in conjunction with cable tool drilling and air lift development used with rotary methods of drilling. Development should commence in the casing above screens until easily removed drilling mud and fines have been developed from the aquifer. This should be followed by developing within the screens directly opposite all portions of the aquifer. Five to eight days will be required to fully and adequately develop wells of the size being installed. Development is an important phase of well construction and is a small percent of the total cost of the well. Development should not be minimized. Very likely both new production wells and in particular TW-2 will have problems and an abbreviated life because of inadequate development.

AQUIFER EXPLOITATION

Previous reports have stated that wells will withdraw ground water primarily from storage and inferred that the supply would be practically exhausted in 40 years. Also, it has been reported that ground water beneath the project area originates high on the flanks of Mt. Merapi. Geologic conditions suggest and pumping test results tend to confirm that the aquifer is semiconfined and will function under leaky artesian conditions. This means that practically all recharge to the aquifers when wells are operating will occur within the area of piezometric depression created by the pumping.

Lowering of the piezometric surface by withdrawing ground water from storage will create a head differential causing unconfined ground water to leak through aquitards. Aquifer layers below those utilized by wells will leak upward through aquitards by similar hydraulic principles. Pumping tests indicate that this will occur within days in some aquifers after commencement of pumping. Depression of piezometric surface will induce lateral flow from all directions toward pumping centers.

The amount of water available to wells over an extended period of time will be controlled by the amount of rainfall that seeps into the ground and is included into the aquifer layers through head differentials.

Drying up the Bengawan Solo and other rivers as previously reported, should not be expected by adjacent deep wells as several semipermeable layers exist between the river and the aquifers. An imperceptible and insignificant loss may occur through sections where the piezometric surface has been lowered however.

Static Water Levels in shallow wells will be lowered as unconfined ground water is induced to leak downward. The amount will depend on several unknowns and cannot be estimated at this time. Provisions should be made to monitor shallow well water levels adjacent to deep municipal wells to gain information on this potential conflict of ground water use.

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APPENDIX "A"

SUMMARY OF WELL DATA

SUMMARY OF WELL DATA

WELL NUMBER LOCATION	DATE CONSTRUCTED	WELL CONSTRUCTION	SWL meters	SPECIFIC CAPACITY (hrs) $\frac{l/s}{m}$ = SC	TRANSMISSIVITY $m^3/d/m$	LITHOLOGY depth in meters	GEOLOGIC FORMATION	COMMENTS
TW - 1 Vil. Jonggrangar Dist. Klaten	1976	0- 24 m/203 mm csg 24-27.5 m. 59.5 - 62.5 m, 66 - 72 m / 105 mm screen bottom csg 75 m Screen is 40 slot	-3.94 / Nov. 76	(24) $\frac{26}{14}$ = 1.9	1028	0 - 3 soil, rock 3 - 15 f - vf sa 15- 18 f - m sa 18- 23 f sa 23- 29 f sa 29- 39.5 agglomerate 39.5 - 47 f sa 47- 55 agglomerate 55- 62 c l w/gvl 62- 65.5 f-m sa w/gvl 65- 75 m sa & gvl	Younger Volcanics	Storage coefficient = 0.0026 Vertical Permeability = 9.8 gpd/ft^2 Leaky artesian condition indicated
TW - 6 Vil. Semono Dist. Sambi	Feb. 1978	0 - 28 m / 8" csg 28.5 - 40.5 m/6" screen 40.5 - 47. 59 - 65 m/6" slotted csg bottom 101 m	- .68/Feb. 78	(3) $\frac{2}{26}$ = .08	rec / 31.6 dd / 15.8	0 - 9.7 tuffaceous cl 9.7 - 25.8 clay tuff 25.8- 47.1 sca, gvl 47.1- 53.2 cl 53.2- 59.3 gvl w/cl 59.3- 62.4 gvl 62.4- 68.5 gvl m-csa 68.5- 95.9 tuffaceous, sa cl 95.9- 99 gvl tuff 99 - 101 sa cl	Kabuh and Putjangar	Boundary condition indicated
TW - 7 Vil. Nogosari Dist. Nogosari	May 1978	1 - 30.1 m/8" csg 39.2 - 45.6, 57.6 - 73.4, 79.4 - 83.3, 92.1 - 98.8 m / 6" screen csg bottom 104.7 m	- 2.5/June 78	(1.7) $\frac{8.5}{14.5}$ = .6 (72) $\frac{8.5}{14.5}$ = .6	rec / 34.6 rec / 36.6 dd / 45.4	0 - 42 volcanic breccia 42 - 60 cl sa 60 - 76 sa 76 - 84 c sa 84 - 92 cl sa 92 - 102 sa 102 - 115 cl	Notopuro, Kabuh and probably Putjangan	
TW - 8 Vil. Jati Dist. Sumber - lawang	May 1978	0 - 18 m /8" csg 18 - 30 m/8" slotted 30 - 47.7, 57.3 - 66 m/6" screen bottom of casing 78.1 m		(72) $\frac{19}{5.1}$ = 3.7	dd / 480	0 - 23 layered f - m sa 23 - 38 m - c sa gvl 38 - 80 sa cl	Kabuh and Putjangan	

WELL NUMBER LOCATION	DATE CONSTRUCTED	WELL CONSTRUCTION	SWL meters	SPECIFIC CAPACITY (hrs) $\frac{l/s}{m}$ = SC	TRANSMISSIVITY $m^3/d/m$	LITHOLOGY depth in meters	GEOLOGIC FORMATION	COMMENTS
TW - 9 Vil. Ngrendeng Dist. Ngemplak	July 1976	0 - 15 m / 8" csg 15 - 30.3 m/8" slotted 30.3 - 38.7 m/6" screen csg bottom 45 m		(72) $\frac{5}{14}$ = .36	dd / 56.5 rec/ 60.8	0 - 10 m c sa & tuff 10 - 16 tuff breccia 16 - 18.5 vc sa 18.5- 28.5 - vc sa 28.5- 41 cl 41 - 44 sa tuff 44 - 84 cl	Kabuh and Putjangan	
TW - 10 Vil. Celengan Dist. Ngemplak	July 1978	0 - 12 m/8" scg 12 - 30 m/8" slotted csg 30 - 33 m/6" scg 33 - 50 m/6" screen 54 - 60 m. 70 - 72 m/6" w/holes 76 - 84. 91 - 99.5 /6" screen csg bottom 118 m	- 2.95 / Aug. 78	(36) $\frac{10}{19.2}$ = .5	dd /60.8 rec/68.7	0 - 10 sa tuff 10 - 13.5 tuffaceous sa 13.5 - 19.5 sa tuff 19.5 - 22.7 breccia 22.7 - 31.8 tuffaceous cl 31.8 - 40.9 breccia 40.9 - 47 sa tuff 47 - 62.3 sa, cl tuff 62.3 - 77.6 tuffaceous cl 77.6 - 95.8 sa, cl, tuff 95.8 - 105. gvl sa 105 - 108 sa tuff 108 - 126 cl	Notopuro Kabuh and Putjangan	Boundary condition indicated
TW - XIII Vil. Sabranglor Dist. Wonosari	1978	—	—	—	—	—	Younger Volcanics to about 50 m, Tertiary marine formations below	Saline water at depth 67 - 85 m based on SP log. Attempted to cement off saline aquifer for testing failed
TW - XIV B Vil. Bulusan Dist. Karang - dowo	1979	0 - 34 m / 8" csg slotted 10 - 22, 25 - 31 m	-.14 Feb 79	(1.4) $\frac{6.65}{4.23}$ = 1.6	dd & rec/130	0 - 3 cl sa 3 - 12 sa cl 12 - 17 cl sa 17 - 25 si, cl, sa 25 - 32 gvl w/cl 32 - 35 tuff & sa	Younger Volcanics	First well csg pulled apart. Well B redrilled and tested. Leaky artesian conditions suggested
TW - 14 Vil. Gawan Dist. Tanon	Oct. 1976	0 - 42.2 m / 12" csg 42.2 - 48.3, 60.4 - 90.7, 121 - 133.1 m/ 8" screen csg bottom 152.3 m	+ 1.5 / Oct 76	(72) $\frac{60}{6}$ = 10	dd & rec / 1186	0 - 19.7 cl w/some tuff and sa layers 19.7 - 27.8 - f sa 27.8 - 38 tuff 38 - 48.1 tuffaceous cl 48.1 - 60.8 tuff & sa tuff	Notopuro-Kabuh	

WELL NUMBER LOCATION	DATE CONSTRUCTED	WELL CONSTRUCTION	SWL meters	SPECIFIC CAPACITY (hrs) $\frac{l/s}{m}$ = SC	TRANSMISSIVITY $m^3/d/m$	LITHOLOGY depth in meters	GEOLOGIC FORMATION	COMMENTS
TW - 14 Vil. Gawan Dist. Tanon (Continued)						60.8 - 68.9 tuffaceous cl 68.9 - 97.4 sa & gvl, tuffaceous si, cl, sa 11.6 - 115.7 tuff 115.7 - 119.7 gvl 119.7 - 129.9 layerd cl & sa tuff 129.9 - 136 sa & gvl 136 - 142 cl 142 - 152.3 layered claystone & gvl		
TW - 15 Vil. Dari Dist. Plupuh	Nov. 1976	0 - 41.8 m/12" csg 47.9 - 54, 60 - 78.2, 84.2 - 102.3 m/8" screen Csg bottom 120.5 m	- 1.29 / Nov. 76	(12) $\frac{59.5}{11}$ = 5.4	dd / 634 rec 474	0 - 6.3 f - c sa 6.3 - 8.3 tuff si 8.3 - 13.3 sa cl 13.3 - 19.1 tuff 19.1 - 23.1 sa cl 23.1 - 39.4 tuff silt 39.4 - 43.5 tuff breccia 43.5 - 51.6 c sa 51.6 - 65.8 sa si 65.8 - 67.7 gvl 67.7 - 79.6 sa 79.6 - 92 layered cl & tuff 92 - 98 tuffaceous si 98 - 103 claystone 103 - 110 cl w/ lime-nodules 110 - 114 sa tuff 114 - 120 sa cl	Notopuro, Kabuh and probably Putjangan Tetiary marine below 103 m	Leaky artesian conditions indicated
TW - XV Vil. Jeron Dist. Nogosari	May 1979	0 - 11.1 m/8" csg 11.1 - 17.2, 23.3 - 29.4/8" slotted 29.4 - 41.7/6" csg 41.7 - 53.9, 72.2 - 84.4 96.6 - 102.7 m/6" slotted csg bottom 108.8 m	- 1.66 / May 79	(72) $\frac{8.23}{10.8}$ = .8 (discharge rate varied) (1.5) $\frac{11}{22}$ = .6	dd / 139.5 rec/ 132.5	0 - 3 cl 3 - 6 m sa 6 - 11 c sa 11 - 22 gvl (or conglo - merate) 22 - 43 missing 43 - 48 cl, gvl, sa 48 - 62 gvl sa 62 - 74 cl sa 74 - 80 sa cl 80 - 85 cl, gvl sa 85 - 98 sa cl 98 - 103 cl, gvl, sa	Notopuro Kabuh and Putjangan	Boundary condition indicated

WELL NUMBER LOCATION	DATE CONSTRUCTED	WELL CONSTRUCTION	SWL meters	SPECIFIC CAPACITY (hrs) $\frac{l/s}{m}$ = SC	TRANSMISSIVITY $m^3/d/m$	LITHOLOGY depth in meters	GEOLOGIC FORMATION	COMMENTS
TW - XV Vil. Jeron Dist. Nogosari (continued)						103 - 128 missing 128 - 135 cl sa 135 - 149.5 cl, sa cl		
TW - 20 Vil. Gabugan Dist. Tanon	Apr 197	0 - 38 m / 12" csg 64.5 - 72.8, 84.8 - 90 96 - 106.3, 124.3 - 132.6, 146.6 - 151.8 m/ 8" screen csg bottom 160 m	+ 1.79 / May 77	(72) $\frac{49.9}{17.5}$ = 2.9	dd / 329 rec/ 493	0 - 8.9 f sa 8.9 - 14.5 c sa 14.5 - 26 tuff w/sa 26 - 102 layered cl & tuff cl, some sa 102 - 105 gvl w/sa 105 - 157 clay w/some gvl sa 157 - 160 tuff breccia	Notopuro Kabuh and probably Putjangan	
E - IV Vil. Gurungan Dist. Ngemplak	August 197	0 - 8 m/6" PVC 8 - 50 m/6" PVC slotted 50 - 70 m/4" slotted csg	- 7.23 / Aug.78	(24?) $\frac{10}{16}$ = .63	rec / 54.5 dd / 57.1 rec / 69.3	0 - 8 tuffaceous sa 8 - 12 cl 12 - 20 sa, tuff 20 - 45 f - m sa 45 - 48 sa cl 48 - 53 cl tuffaceous m sa 53 - 70 sa cl	Kabuh and Putjangan	Boundary condition indicated
Jati Test Well Vil. Jati Dist. Masaran	1972	Test well, no permanent construction	Variable, + .45 to + .85 / ?	46.5 - 52 m aquifer (?) $\frac{5}{2.89}$ = 1.7 52 - 66.8 m aquifer (?) $\frac{1.2}{5.8}$ = 2.1 (?) $\frac{1.6}{1.23}$ = 1.3 (?) $\frac{2.66}{1.67}$ = 1.6 70.8 - 75 m aquifer (?) $\frac{5.1}{3.89}$ = 1.3	36.7 - 38.7 m aquifer 520 52 - 66.8 aquifer 568 70.8 - 75 m aquifer 500 46.6 - 75 m aquifer 251	0 - 14 layered cl, tuffaceous cl 14 - 15.7 tuffaceous f sa 15.7 - 18 tuffaceous cl 18 - 27.3 tuffaceous ss 27.3 - 29.3 m sa 29.3 - 36.7 sa cl 36.7 - 38.7 f ss 38.7 - 41.1 cl tuff 41.1 - 75.1 tuffaceous m-c sa 75.1 - 82.4 cl tuff 82.4 - 84.1 conglomerate 84.1 - 90.4 sa cl 90.4 - 93 tuffaceous cl 97 - 101.5 tuffaceous f sa	Notopuran and Kabuh	Pumping test conducted on open hole below the casing during drilling of the test well

WELL NUMBER LOCATION	DATE CONSTRUCTED	WELL CONSTRUCTION	SWL meters	SPECIFIC CAPACITY (hrs) $\frac{l/s}{m}$ = SC	TRANSMISSIVITY $m^3/d/m$	LITHOLOGY depth in meters	GEOLOGIC FORMATION	COMMENTS
Kemiri Tes: Wei Vil. Kemir Dist. Masaran	1972	Test well, no permanent construction	variable, -.75 to -2.25 / ?	7.6 - 16.4 m aquifer (?) $\frac{1.76}{2.73}$ = .7 20 - 28.3 m aquifer (?) $\frac{2}{2.4}$ = .8 49.7 - 61 m aquifer (?) $\frac{3.2}{2.9}$ = 1.1	7.6 - 16.4 m aquifer 210 20 - 28 m aquifer 152 & 50 49.7-61 m aquifer 27 85 - 95.5 m aquifer 125 & 147	0 - 6.5 tuffaceous m sa 6.5 - 10 cl 10 - 15.4 tuffaceous f ss 15.4- 20.1 vf tuff 20.1- 28.7 sa tuff 28.7- 35.8 sa tuffaceous cl 35.8- 43 cl 43 - 73 tuffaceous f-c sa 73 - 93.3 m - vc sa 93.3- 98.3 f - m sa 98.3- 100.8 tuffaceous f - c sa	Notopuro and Kabuh	Pumping test conducted on open hole below the casing during drilling of the test well
SE - 3 Perum Perumnas Vil. Palur Dist. Karang - anyar	1979	0 - 40 m / 10" csg 51 - 54, 62 - 65, 69 - 72, 75 - 78, 100.5 - 103.5, 106 - 109 m / 6" screen Csg bottom 120 m	- 2.66 / Jan 80	(10) $\frac{10}{18.9}$ = .53 (8) $\frac{15}{33.9}$ = .44 (17) $\frac{15}{34}$ = .44	dd / 61.4 rec/ 155.6 also dd / 22.5 rec/153	0 - 4 tuff sa 4 - 9 breccia 9 - 10.5 tuff cl 17 - 23 ss 23 - 37.5 tuffaceous sa 37.5- 40.5 tuffaceous cl 40.5- 45 tuffaceous sa 45 - 50 cl 50 - 66 tuffaceous sa w/ gvl 66 - 69 sa cl 69 - 80 cl, tuff sa 80 - 100.5 cl 100.5 - 116 tuff & sa, some cl 116 - 124 sa cl	Notopuro and Kabuh	Leaky artesian conditions indicated
Dr. Soeharso Real Estate Vil. Pulukrejo Dist. Karang - anyar	Feb. 1979	0 - 36 m / 4" csg 36 - 42 m / 4" slotted 42 - 60 m / 4" csg 60 - 66 m / 3" csg 66 - 78 m / 3" slotted ?	- 7.9 / Feb 79	(?) $\frac{4}{.6}$ = 6.7	—	0 - 34 cl 34 - 36 hard pan 36 - 42 sa 42 - 63 cl 63 - 66 hardpan 66 - 78 sa	Notopuro and Kabuh	
GSI 1271 Textile factory Vil. ? Dist. Ceper	March 1958	0 - 16 m / 9" csg 20 - 24 m / 4" screen bottom csg 26 m 26 - 38 gravel backfill	- 2.4 /Mar 58 - 3.99 / Nov 57	(?) $\frac{1.6}{1.1}$ = 1.5 (?) $\frac{2.35}{1.89}$ = 1.2	—	0 - 1.5 cl 1.5 - 2.5 hard tuff 2.5 - 5 sa & gvl blocks 5 - 9.7 tuff sa 9.7 - 12 cl 12 - 17 cl & sa	Younger Volcanics	

WELL NUMBER LOCATION	DATE CONSTRUCTED	WELL CONSTRUCTION	SWL meters	SPECIFIC CAPACITY (hrs) $\frac{1/n}{m}$ = SC	TRANSMISSIVITY $m^3/d/m$	LITHOLOGY depth in meters	GEOLOGIC FORMATION	COMMENTS
G S I 1271 Textile Factory Vil. ? Dist. Ceper (continued)						17 - 19 cl 19 - 24.3 f sa 24.3 - 32 cl 32 - 40 tuff gvl & blocks		
G S I 1619 Sugar Factory Vil. ? Dist. Ceper	1973	0 - 35 m / 8" csg 35 - 40 m / 8" screen 40 - 42 m / 7" csg 73 - 83 m, 115 - 121 m / 4" screen bottom csg 126 m	- 6.9 / 73	(5) $\frac{8.3}{9.4}$ = .9 (3.5) $\frac{7}{8.4}$ = .8	—	Hole drilled to 151.7 m	Younger Volcanics sand to 126 m, below this marine Tertiary formations	Saline water below 126 m, hole back-filled w/cement to 126 m
G S I ? Vil. ? Dist. Delanggu	—	Bottom screen 80 m	- 4.5 / ?	(?) $\frac{3}{2}$ = 1.5	—	—	Presumed Younger Volcanics	Dissolved solids 23 ppm
G S I 1336 Military Camp Vil. Jegongan Dist. Karteasuro	—	bottom screen 40 m	- 9.9/ 1962	(?) $\frac{10}{4.02}$ = 2.5 (?) $\frac{4}{4.02}$ = 1.0	—	0 - 2.5 cl 2.5 - 9.8 tuff 9.8 - 16 ss, tuff, gvl 16 - 46.5 tuff w/sa & gvl/ ayers 46.5 - 53.2 cl w/tuff & sa layers	Probably Notopuro and Kabuh	Dissolved solids 495 ppm
G S I 918 Vil. Karang - anyar Dist. Karang - anyer	1923	bottom screen 86 m	- 9.3 /1923 and - 10.2/1923	Aquifer 23.3 - 44.7 SC= 8.3 Aquifer 23.3 - 50.75 SC= 4.2	—	0 - 24 cl sa 24 - 54 gvl 54 - 150 tuff sa, cl 150 - 217.5 tuff sa 217.5 - 229.5 f sa, calcareous cl 229.5 - 289.5 calcareous sa 289.5 - 303 sa, cl 303 - 337.5 calcareous cl	Younger Volcanics above 196 m Tertiary marine formations below 196 m	Well flowing 2.1 /s, Most productive convined aquifer about 70 m
G S I 171 (Well No. 1) Surakarta	May 1889	0 - 75.6 m/ 16 cm 75.6 - 85.6 m / 12 cm 80 - 85 m perforated	6 - 9.4 m aquifer - 4.2 swl 54.5 - 59.2	— SC = .12		0 - 1 gvl 1 - 5.5 laterite 5.5 - 54.8 cl wl tuff layers, ss, sa, gvl, pumice	Notopura and Kabuh	Tests conducted in open hole ahead of casing as well

WELL NUMBER LOCATION	DATE CONSTRUCTED	WELL CONSTRUCTION	SWL meters	SPECIFIC CAPACITY (hrs) $\frac{l/s}{m}$ = SC	TRANSMISSIVITY $m^3/d/m$	LITHOLOGY depth in meters	GEOLOGIC FORMATION	COMMENTS
G S I 171 (Well No. 1) Surakarta (continued)			62.7 – 65.6 + 2.6	sc = .33	—	54.8 – 98.2 sa, ss. w/ layers, cl, gvl layers, ls fragments 88.2 – 109 cl 109 – 114.4 sa 114.4 – 155 sa cl 155 – 159.5 sa		Test after well completed sc (?) = $\frac{3.8\ l/s}{1.38\ m}$ = 2.8
			79.8 – 80.3 + 3.43	sc = .12				
			83.1 – 84.8 + 3.27/1889	sc = $\frac{3.83}{1.89}$ = 2				
G S I 174 (Well No. 2) Surakarta	Aug 1889	0 – 83.5 m/ csg no perforations	53.1 – 54.4 m aquifer + 1.02 swl	sc = .1	—	0 – 18.4 cl w/ls concretions 18.4 – 29.7 sa cl w/gvl & ls fragments 29.7 – 41 cl 41 – 54.4 tuff ss w/ls pebble 54.4 – 71.3 cl w/ls 71.3 – 84.2 sa w/layer of sa cl	Notopuro and Kabuh	Tests conducted in open hole
			73.6 + 1.02 ?	sc = 1.6				
			84.2 + 3.22 / 1889	sc = $\frac{5}{2.1}$ = 2.3 sc = $\frac{6.7}{2.9}$ = 2.3				
G S I 181 (Well No. 3) Surakarta	April 1890	?	26.5 – 32 m aquifer + 1± swl/ 1890	sc = $\frac{6.34}{3 \pm}$ = 2.1	—	0 – 8 cl 8 – 26.5 cl w/ls pebbles 26.5 – 32 gvl 32 – 64 sa cl w/ pebbles 64 – 67 sa gvl 67 – 90 cl w/ pebbles 90 – 92.5 sa	Notopuro and Kabuh	Test conducted in open hole, presumably from most productive confined zone at 28m
G S I 184 Vil. Langen-harjo Dist. Grogol	Oct 1890	0 – 21.2 m /8" csg 21.2 – 75.5 m/6½" csg 75.5 – 102.6 m/5½" csg 102.6 – 153.6 m/4" csg 153.6 – 179.6 m/3" csg 179.6 – 189.5 m/2½" csg	96 – 108 m aquifer + 1.5 swl	sc = .7	—	0 – 36 sa cl w/pebbles 36 – 48 cl 48 – 76 cl w/ ls pebbles 76 – 93 sa, gvl 93 – 108 sa cl 108 – 114.5 ss w/ pebbles 114.5 – 125 cl w/ pebbles 125 – 136.6 gvl w/ sa 136 – 194 cl w/ sa layers & pebbles	Younger Volcanics Notopuro and Kabuh	Test conducted in open hole Final construction unknown
			112 – 114.5 + 1.62	sc = 1.1				
			125 – 136.6 + 1.95	sc = 2.8				
			152 – 157 + 4.52	sc = .6, .7				
			192 – 195 + 7.55 / 1890	sc = $\frac{10}{6.65}$ = 1.5 or sc = 8.2				

WELL NUMBER LOCATION	DATE CONSTRUCTED	WELL CONSTRUCTION	SWL meters	SPECIFIC CAPACITY (hrs) $\frac{l/s}{m}$ = SC	TRANSMISSIVITY $m^3/d/m$	LITHOLOGY depth in meters	GEOLOGIC FORMATION	COMMENTS
G S I 187 (Well No. 5) Surakarta	July 1891	0 – 154 m/2½" 134 – 138, 143 – 148 m perforated open bottom	64 – 70 m aquifer + 1.44 swl	sc = .6	—	0 – 30 cl w/ls fragments 30 – 50 cl w/ stone 50 – 78 sa w/ gvl 78 – 87 ss 87 – 153 sa cl w/ sa & gvl layers 153 – 155.5 gvl 155.5 – 169.2 sa cl w/gvl	Notopura and Kabuh	Test conducted in open hole
			135 – 137 + 5.91	sc = .8				
			144 – 148.5 + 7.19	sc = .16, .25				
			153 – 155.5 + 6.72 / 1891	sc = .13, .25				
G S I 195 (Well No. 6) Surakarta	July 1892	0 – 135 m / 3.6" csg 0 – 123.2 m / 2.5" csg 124 – 155.3 m / 3" csg (open bottom) seal 124 m 110.2 – 112.2, 121.2 – 123.2 m / perforations	110 – 113 m aquifer + 1.99 swl	sc = $\frac{.85}{.84}$ = 1	—	0 – 5 ss, cl 5 – 20 sa cl w/ pebbles 20 – 44.8 gvl w/ sa 44.8 – 110 cl w/ pebbles gvl & ss 110 – 140 cl & pebbles w/ sa layers 150 – 155.4 ss w/ cl & pebbles	Notopura and Kabuh	Tests conducted in open hole
			121 – 125 + 1.8	sc = $\frac{2}{1.6}$ = 1.2				
			153 – 155 + 5.9 / 1892	sc = $\frac{5}{5.5}$ = 9				
G S I 210 (Well No. 7) Surakarta	Jan 1894	85 – 90, 115 – 117, 153 – 156 m / perforations or 100.2 x 2½" csg 67 – 68.7 perforations open bottom	67 – 68.7 m aquifer + . 26 swl	sc = $\frac{.76}{.79}$ = 1	---	0 – 1 sa 1 – 25.2 cl 25.2 – 52.5 sa w/ thin cl layers 52.5 – 77 cl w/ sa layers 77 – 83.8 sa 83.8 – 101.8 sa cl 101.8 – 104.2 sa	Notopuro and Kabuh	Test in open hole
			100.2 – 104.8 + 1.05 / 1894	sc = $\frac{.83}{.74}$ = 1.1				
G S I 213 (Well No. 8) Surakarta	April 1894	85 – 90 , 115 – 117 m / perforated 12 cm csg 153 – 156 m / perforated 2 " csg	85 – 90 m aquifer + 1.69 swl	sc = $\frac{2.8}{1.29}$ = 2.2	—	0 – 19 sa cl 19 – 36 cl w/ pebbles 36 – 64 cl 64 – 84 sa cl w/ pebbles 84 – 90.5 sa, gvl 90.5 – 115 sa cl w/ pebbles 115 – 117 sa, gvl 117 – 153 sa cl 153 – 156 sa	Notopuro and Kabuh	Test in open hole.
			115 – 117 + 1.78	sc = $\frac{1.7}{1.5}$ = 1.2				
			153 – 156 + 5.79 / 1894	sc = $\frac{2}{5.2}$ = .4				

WELL NUMBER LOCATION	DATE CONSTRUCTED	WELL CONSTRUCTION	SWL meters	SPECIFIC CAPACITY (hrs) $\frac{l/s}{m}$ = SC	TRANSMISSIVITY $m^3/d/m$	LITHOLOGY depth in meters	GEOLOGIC FORMATION	COMMENTS
G S I 218 (Well No. 9) Surakarta	August 1894	?	+ 7.65 / 1894	sc = $\frac{3.13}{6.53}$ = .5	—	0 - 2 cl 2 - 25 ss w/ cl & pebbles 25 - 30 sa 30 - 96 cl 96 - 106 sa cl 106 - 120 ss 120 - 180 hard cl w/ pebbles 180 - 197 sa w/ pebbles 197 - 218.5 sa w/ cl & pebbles	Notopuro and Kabuh	Test in open hole, presumably in most productive confined layer at 218 m.
G S I 594 (Well No. 13) Surakarta	May 1911	0 - 44.66 m/6.6" csg - 0 - 111.62 m/5.5" csg 0 - 225.23 m/3.6" csg 73 - 76 m / 5.5" perforation 78 - 81 m/ 125 - 128 m /3.6" perforation 129 - 132 m/ 169 - 172 m 174 - 177 m 178 - 181 m 187.5 - 190.0 m 210.5 - 211.5 m 214 - 216 m 3.6" perforation Depth of seal 134 m	8 - 11.5 m aquifer - .83 swl 70.8 - 82.3 - 1.2 100.3-102.5 -+.35 123.5-132.5 - .35 160.6-165.5 + 2.74 168.8-172 + 4.1 174 - 181.5 + 4.02 187.5-190.2 + 3.06 196.5-203.5 + 4.04 210 - 214.5 + 5.33 226.8-228.5 + 5.2 / 1911	sc = .8 sc = .1 sc = 1 sc = 1.2, 2.3 sc = .4 sc = .3 sc = $\frac{4.17}{3.26}$ = 1.3 sc = .7 sc = .1 sc = 7.7 sc = .3	---	0 - 11.5 gvl, sa 11.5- 27.3 sa cl 27.3- 82.3 layered sa & gvl 82.3- 88.3 sa cl 88.3- 110.2 layered sa & gvl 110.2 - 123.5 sa cl 123.5 - 132.5 sa gvl 132.5 - 136.5 sa cl 136.5 - 155.5 sa, gvl 155.5 - 174 sa cl w/gvl layers 174 - 190.2 sa w/ some cl 190.2 - 210 sa cl 210 - 223 sa w/ ls & pumice fragments 223 - 229.8 layered sa cl & sa	Notopuro and Kabuh	Tests in open hole Water above 134 m removed by pump Water below 134 m flowing
G S I 708 (Well No. 14) Surakarta	Jan 1916	?	- 3.5 / 1916	(?) $\frac{.42}{1.0}$ = .4	---	0 - 70 sa cl w/ some ls & gvl 70 - 106 cl w/ ls & magnatite 106 - 118.3 pumice stone w/ cl & ls 118.3 - 171.4 sa cl w/ ls & magnatite	Notopuro and Kabuh	Test conducted in open hole, presumably from most productive confined zone at 140 m.

WELL NUMBER LOCATION	DATE CONSTRUCTED	WELL CONSTRUCTION	SWL meters	SPECIFIC CAPACITY (hrs) $\frac{l/s}{m}$ = SC	TRANSMISSIVITY $m^3/d/m$	LITHOLOGY depth in meters	GEOLOGIC FORMATION	COMMENTS
G S I Sari Petojo Ice Fact. Well Surakarta	Oct 1969	——	- 2.75 / 69	——	——	0 - 2 limestone, sa 2 - 12 sa 12 - 31 limestone, sa 31 - 53 sa 53 - 74 sa cl, lime - stone 74 - 84 sand		
Kusuma Sahic Prince Hote Wel Surakarta	1978	——	- 3.5 / Oct 78	(?) $\frac{2.67}{4.5}$ = .6	17.7	——	Probably Recent Alluvium overlying Notopuro and / or Kabuh	Encountered water 25 - 28 m Leaky artesian conditions indicated

APPENDIX "B"

SUMMARY OF QUALITY ANALYSIS

SUMMARY OF QUALITY ANALYSIS

WELL NUMBER LOCATION	DATE OF ANALYSIS	Physical Characteristic		Chemical Constituents (in mg / l)																					pH	Lime Water	Comments
		Turbidity	Colour	K	Na	Ca	Mg	Fe	Mn	Cu	Zn	Cl	SO_4	H_2S	NH_4	NO_3	NO_2	As	Pb	Cr	F	HCO_3	$KMnO_4$	TDS		(°D)	
TW - 1	-	25			17.3	25.8	8.2	1.3	.7			17.6	4			.5						136.5	0.9	188		6.26	SiO_2 2.8 mg/l; $CaCO_3$ 111.9 mg/l
Vil. Jonggrangan		4			13	29.2	3.3		traces			12.6	1.30			.4						97.5	traces	212		4.5	17.5 mg/l; 80 mg/l
Dist. Klaten		3			12.5	26.7	2.9		.1			10.5	4			16						100.6	traces	120		4.62	10 mg/l; 82.5 mg/l
		5			12	25.6	2.8	traces	.2			11.9	7			1						93.9	traces	208		5.24	18 mg/l; 77 mg/l
TW - 6	August 14, 1978	77	10	4.15	112.5	60	31.62	.06	.0	.0		22.5	10		.0	.0	.0			.01		635		576	7.65		
Vil. Semono Kidul																											
Dist. Sambi																											
TW - 7	August 14, 1978	55	10	2.65	.45	25	15.2	.32	.0	.0	.0	7.5	2		.0	.30	.0			.0		19		96	6.25		
Vil. Nogosari																											
Dist. Sumberlawang																											
TW - 8																											
Vil. Jati	August 14, 1978	51	7.5	27.5	40	90	4.86	.19	.02	.0	.0	10	3		.02	.9	.0			.0		395		128	6.35		
Dist. Sumberlawang																											
TW - 9																											
Vil. Ngrendeng	August 14, 1978	94.5	7.5	16.50	168	57.5	30.76	.7	.0	.0		32.5	4		.80	.24	.39			.006		430		1.008	7.30		
Dist. Gemolong																											
TW - 10																											
Vil. Ngrendeng	August 14, 1978	81	5	16.6	88.5	52.5	36.24	.06	.0	.0		15	10		.0	.12	.004			.0		510		489.6	7.75		
Dist. Ngemplak																											
TW - 14																											
Vil. Gawan	-	15		8.20	41	69.71	29.63	.83	.0			34.80	.0		.01	.01	.01					640		520	7.60		Hardness 296; B = .26 mg/l; C = 600; PO_4 = .01 mg/l
Dist. Tanon																											
TW - 15																											
Vil. Dari	-	129		6.40	25	61.04	31	15.50	.0			13.90	.0		.02	.11	.01					555.10		450	7.55		Hardness 280.00; B = .34 mg/l; C = 460; PO_4 = .02 mg/l
Dist. Plupuh																											
TW - XV																											
Vil. Jeron	May 19, 1979	2	5			35.80	26.68	.08	.2	.0	.3	40.5	.0	.0	.42	.17	.0	.0	.015	.0	.3		1.770	580		10.2	Cd = .0 mg/l; Phenol = .0 mg/l; Hg = .0 mg/l
Dist. Nogosari																											

WELL NUMBER LOCATION	DATE OF ANALYSIS	Physical Characteristic		Chemical Constituents (in mg / l)																					pH	Lime Water (+D)	Comments
		Turbidity	Colour	K	Na	Ca	Mg	Fe	Mn	Cu	Zn	Cl	SO_4	H_2S	NH_4	NO_3	NO_2	As	Pb	Cr	F	HCO_3	$KMnO_4$	TDS			
TW - XV (continued)	June 9, 1979			11.8	118																	491.9		570			B = .0 mg/l CO_3 = .0 mg/l
TW - 20 Vil. Gabugan Dist. Tanon	---	10		7	41	75	28	.50	.2			18	5		.10	.01	.0					465		450			Hardness 302.50 C = 595 PO_4 = 1.5 mg/l B = 6.5 mg/l
Jati Test Well Vil. Jati Dist. Masaran	---	clear			67.6	73.5	22.22	.0	.0			20	.0				.0					481	3.7		7	15.4	Depth 11.20 - 11.70 m
		clear			109.5	36.4	14.7	.0	.2			24	.0				.0					434.1	3.2		7	8.5	Depth 16.45 - 22.25 m
		clear			87.4	34.6	13.9	.0	.0			24	.0				.0					427.5	2.7		7	8.1	Depth 27.25 - 29.30 m
		clear			118.7	36.7	11.3	.0	.0			28	.0				.0					434.2	2.7		7	7.7	Depth 36.65 - 38.65 m
		clear			110.2	35.5	12.8	.1	.0			29	.0				.0					420.8	3		7	7.8	Depth 36.60 - 52 m
		clear			36.1	70	27	.0	.0			18.3	.0				.0					43.7	2.5		7	1.6	Depth 51.07 - 67.75 m
		clear			97.3	34.5	12.4	.1	.0			28	.0				.0					387.4	2.5		7	7.7	Depth 70.75 - 78.95 m
		clear			97.3	51.1	13.4	.0	.0			29.3	.0				.0					402.4	4		7	10.2	Depth 85 - 85.40 m
		clear			45.4	72.1	24.2	.0	.1			25.6	.0				.0					418.5	2.5		6.5	15.7	Depth 93 - 96.50 m
Kemiri Test Well Vil. Kemiri Dist. Masaran		clear			22.1	64.7	13.4	.0	.2			14	.0				.0					299.3	3		6.8	12.2	Depth 8.75 - 16.85 m
		clear			16.3	40.8	11.5	.0	.0			14	.0				.0					202.8	2.7		6.8	8.4	Depth 20 - 28.3 m
		clear			28.5	36.4	10.3	.1	.2			14	.0				.0					212.6	6.7		6.8	7.5	Depth 33.85 - 37.75 m
		clear			18.8	40.6	10.3	.1	.0			14	.0				.0					202.8	3		6.8	8.1	Depth 49.66 - 61 m
		clear			50	27	5.2	.0	.0			12.8	.0				.0					246.5	3.4		7	5	Depth 61 - 85.45 m
		clear			18.4	34.3	6	.1	.0			16.6	.0				.0					183.6	5		6.5	6.2	Depth 91.30 - 100 m
SB - 3 Perum Perumnas Vil. Palur Dist. Karanganyar	Jan. 31, 1980	2.6	5	.0	.0	10.39	5.47	.0	.0	.0	.05	10.2	7.5	.0	.02	.4	.0	.0	.0	.0	.6		5.8	546	7.7		Cd = .0 mg/l Hg = .0 mg/l BQ = Good

WELL NUMBER LOCATION	DATE OF ANALYSIS	Physical Characteristic		Chemical Constituents (in mg / l)																					pH	Lime Water (°D)	Comments
		Turbidity	Colour	K	Na	Ca	Mg	Fe	Mn	Cu	Zn	Cl	SO_4	H_2S	NH_4	NO_3	NO_2	As	Pb	Cr	F	HCO_3	$KMnO_4$	TDS			
Dr. Soeharso Real Estate	Feb. 28, 1979	4.1	5		.0	37.3	11	.0	.2	.0		5.1	2.5	.0	traces	2	.0	.0		.0	.1		1.2	412	7.5		BQ. Good Cd = .0 mg/l Hg = .0 mg/l
Vil. Putukrejo Dist. Karang – anyar	May 01, 1979	.0	.0		.0	38.91	14.19	.0	.2	.0		7.09	2.5	.0	.0	.8	.0			.0			3.79	125.8	7.4		--
Joho Test Well	April 10, 1980	4.4	10	.0	.0	55.38	16.82	.04	.20	.0	.18	31.6	10	.0	.0	2.06	.0	.0	.0	.0	.25		1.84	558	7.3	11.79	BQ. Good Cd = .0 mg/l Hg = .0 mg/l Phenol = .0 mg/l
Vil. Joho Dist. Sukoharjo	June 11, 1979	2	5	.0	.0	35.80	28.86	.08	.02	.0	.03	40.5	.0	.0	.42	.17	.0	.0	.15	.0	.30		1.70	580		11.20	Cd = .005 mg/l Hg = .0 mg/l Phenol = .0 mg/l
Batik Keris Factory	Feb. 4, 1977	.07	none			47.12	21.07	1.15	.0			28.4	48		.0	.0	.0					298.9	6	291.4	7.10	11.50	Well No. 1 CO_2 = 33 mg/l
Vil. Cemani Dist. Grogol	March 22, 1977	.0	none			51.41	9.25	.10	1			33.225	8		.0	.0	.0					283.65	9.16	312.01	7.40	9.35	Well No. 2 CO_2 = 26.4 mg/l
(All wells are 90 m deep)	April 12, 1977	.0	none			37.13	13.33	.0	.30			59.58	32		.0	.0	.0					8.85	8.85	282.08	7.40	8.10	Well No. 3 CO_2 = 8.8 mg/l
	April 15, 1977	.0	none			35.50	12.04	.0	.10			56.80	48		.0	.8	.0					326.35	9.16	304.08	7.60	7.8	Well No. 4 CO_2 = 6.6 mg/l
	April 18, 1977	.0	none			63.19	28.81	1.5	1.60			163.30	10.25		.0	.0	.0						11.70	554.10	7	15.55	Well No. 5 CO_2 = 24.20 mg/l
	April 21, 1977	.0	none			43.91	25.16	.0	.50			140.23	13.75		.0	.0	.0						7.27	446.10	7.80	11	Well No. 6
	April 25, 1977	.0	none			60.35	27.95	.85	.30			127.80	20		.0	.0	.0					298.90	6.04	475.50	7.40	15	Well No. 7 CO_2 = 17.60 mg/l
	May. 30, 1977	.0	none			87.11	16.99	.0	.10			51.48	20		.0	.0	.45					372.10	8.85	351.16	7.40	16.15	Well No. 8 CO_2 = 30.8 mg/l
	June 3, 1977	.90	none			65.69	19.57	.75	.80			88.75	12.50		.0	.0	.0					244	6.32	376.12	6.80	13.75	Well No. 9 CO_2 = 22 mg/l
	Feb. 25, 1977	.25	none			17.85	8.60	.05	.20			92.30	48		.0	.0	.0					118.95	7.58	322.90	7.60	4.5	Well No. 10 CO_2 = 4.40 mg/l
	June 3, 1977	1.20	none			64.97	27.74	.95	1.10			92.32	10		.0	.0	.0					305	11.38	394.12	7.60	15.55	Well No. 11 CO_2 = 15.40 mg/l

WELL NUMBER LOCATION	DATE OF ANALYSIS	Physical Characteristic		Chemical Constituents (in mg/l)																					pH	Lime Water	Comments
		Turbidity	Colour	K	Na	Ca	Mg	Fe	Mn	Cu	Zn	Cl	SO_4	H_2S	NH_4	NO_3	NO_2	As	Pb	Cr	F	HCO_3	$KMnO_4$	TDS		(°D)	
G S I 1271 Textile Factory Vil. ? Dist. Ceper			none					.0	.0			9	16											260	6.7		Depth 6 - 9.7 m
			little					.2	.9			14	11											305	6.8		Depth 16.45 - 23.25 m
			little					.1	1			19	10											306	6.7		Depth 19 - 24 m
G S I 1619 Sugar Factory Vil. ? Dist. Ceper	—				51							10												200	7.4		Depth 75 - 83 m. C = 320
					51							23												230	7.1		Depth 111 - 126m. C = 360
					1750							7840												14,500	7.3		Depth 127.6-150m.C = 23,000
					300							573												1,100	8		Depth 115 - 120 m.C = 1,970
G S I ? Vil. ? Dist. Delanggu			-																					230			TSD only
G S I 1338 Military Camp Vil. Jegongan Dist. Kartosuro	—																							495			TDS only
G S I 171 (Well No. 1) Surakarta	Sept. 10, 1889		depth	52 - 65 m																				540			Temperature 30° C SiO_2 = 80 mg/l Na Cl = 23 mg/l Ca CO_3 = 208 mg/l Na_2CO_3 = 257 mg/l
			depth	86 m																				553			Temperature 30° C Si O_2 = 73 mg/l Ca CO_3 = 60 mg/l Na Cl = 34 mg/l Na_2CO_3 = 405 mg/l
	Oct. 2, 1893		depth 159.5 m		473	19	22					264												980			Si O_2 = 65 mg/l Na Cl = 435 mg/l Ca CO_3 = 35 mg/l Mg CO_3 = 46 mg/l Na_2CO_3 = 413 mg/l

WELL NUMBER LOCATION	DATE OF ANALYSIS	Physical Characteristic		Chemical Constituents (in mg / l)																						pH	Lime Water (°D)	Comments
		Turbidity	Colour	K	Na	Ca	Mg	Fe	Mn	Cu	Zn	Cl	SO_4	H_2S	NH_4	NO_3	NO_2	As	Pb	Cr	F	HCO_3	$KMnO_4$	TDS			
G S I 174 (Well No. 2) Surakarta	May 19, 1895	depth		34.2[illegible] m																				550			Temperature 30° C SiO_2 = 80 mg/l $CaCO_3$ = 120 mg/l NaCl = 47 mg/l Na_2CO_3 = 302 mg/l $MgCO_3$ = 33 mg/l
G S I 184 (Well No. 4) Vil. Langen-harjo Dist. Grogol	July , 1891	depth		76 - 78 m																				5280			SiO_2 = 80 & 100 mg/l CO_2 = 196 mg/l CaO = 123 mg/l MgO = 247 mg/l NaO = 897 mg/l NaCl = 1564 & 1696 mg/l $MgCl_2$ = 57 & 380 mg/l $MgCO_3$ = 187 & 220 mg/l $CaCO_3$ = 220 mg/l
		depth		95 - 96 m																				2600			
		depth		112 - 114.5 m								1310												2494			
																								2080			
		depth		192 - 195 m								1035												3507			CaO = 253 mg/l
G S I 187 (Well No. 5) Surakarta		depth		70 - 72 m																				484			$CaCO_3$ = 219 mg/l $MgCO_3$ = [illegible] mg/l Na_2CO_3 = 72 mg/l Na_2SiO_3 = 136 mg/l NaCl = 24 mg/l
		depth		135 - 137 m																				581			
G S I 195 (Well No. 6) Surakarta	Dec. 30, 1892	depth 110 m		337	237	63	12					108												563			SiO_2 = 85 mg/l NaCl = 178 mg/l $CaCO_3$ = 113 mg/l $MgCO_3$ = 25 mg/l Na_2CO_3 = 153 mg/l CO_2 = 210 mg/l
		depth 121.50 m		350	260	79	20					176												660			SiO_2 = 98 mg/l NaCl = 290 mg/l $CaCO_3$ = 141 mg/l $MgCO_3$ = 42 mg/l Na_2CO_3 = 82 mg/l CO_2 = 232 mg/l
	Jan. 7, 1893	depth 153 m		332	548	58	30					213												1210			P_2O_5 = 49 mg/l SO_3 = 16 mg/l SiO_2 = 80 mg/l NaCl = 350 mg/l $CaCO_3$ = 84 mg/l $MgCO_3$ = 63 mg/l Na_2CO_3 = 501 mg/l $NaPO_3$ = 113 mg/l

WELL NUMBER LOCATION	DATE OF ANALYSIS	Physical Characteristic		Chemical Constituents (in mg/l)																			pH	Lime Water	Comments
		Turbidity	Colour	K	Na	Ca	Mg	Fe	Mn	Cu	Zn	Cl	SO_4	H_2S	NH_4	NO_3	NO_2	As	Pb	Cr	F	HCO_3	$KMnO_4$	TDS		(+D)	
G S I 195 (Well No. 6) Surakarta (continued)																											(continued) Ca SO_3 = 27 mg/l; CO_2 = 60 mg/l
	Oct. 20, 1920		clear									115.5			present								none	630 / 770			S = present; CO_2 = present; KAl $(SO_4)_2$ = present; I = none; Odor = none; Taste = good; Hardness = 10.75
G S I 210 (Well No. 7) Surakarta	Feb. 24, 1895	depth 69 m																						535			Na Cl = 41 mg/l; Si O_2 = 85 mg/l; Ca CO_2 = 42 mg/l; Mg CO_2 = 31 mg/l; Na_2CO_3 = 347 mg/l
		depth 101.8 m																						570			Na Cl = 23 mg/l; Si O_2 = 95 mg/l; Ca CO_3 = 170 mg/l; Mg CO_3 = 71 mg/l; Na_2CO_3 = 223 mg/l
G S I 213 (Well No. 8) Surakarta	August, 1893	depth 153 m		443	31	25						255												960			Si O_2 = 65 mg/l; Na Cl = 420 mg/l; Ca CO_3 = 55 mg/l; Mg CO_3 = 52 mg/l; Na_2CO_3 = 377 mg/l; S = trace
G S I 594 (Well No. 13) Surakarta	Nov. 23, 1911	depth 8 - 11.5 m										26												397			Taste = good; Odor = good
		depth 70.8 - 87.3 m										14												423			
		depth 100.3 - 102.5 m										330												668			
		depth 123.5 - 132.5 m										394												843			
		depth 142 - 143.4 m (average from 6 analysis)										483												736			
		depth 160.6 - 165.5 m										390												776			
		depth 168.8 - 172.03 m										411												835			
		depth 174 - 181.5 m										397												780			
		depth 187.5 - 190.2 m										405												779			
		depth 196.9 - 203.5 m										420												741			

WELL NUMBER LOCATION	DATE OF ANALYSIS	Physical Characteristic		Chemical Constituents (in mg / l)																					pH	Lime Water (°D)	Comments
		Turbidity	Colour	K	Na	Ca	Mg	Fe	Mn	Cu	Zn	Cl	SO_4	H_2S	NH_4	NO_3	NO_2	As	Pb	Cr	F	HCO_3	$KMnO_4$	TDS			
G S I 549 (Well No. 13) Surakarta (continued)	Nov. 23, 1911	depth 210 - 214.15 m (average from 5 analysis)										393												811			
		depth 226 - 228.5 m										916												2293			
G S I ? Sari Petojo Ice Fact. Well Surakarta	May 5, 1973	37	5			44.9	12	.2	.6			33	12.9		.1	.05	.4				.51		4		7.9	90	
Campus Well Surakarta	Nov. 1, 1978	2	10			74.1	27.1	.0	.7			11	2.8									567	3.16	435	7.1	16.7	Well No.1 C = 670 CO_2 = 45 mg/l
	Nov. 1, 1978	3	10			47.1	22.8	.0	.25			12.9	5.6									562	.85	450	7.1	11.8	Well No.2 C = 690 CO_2 = 35 mg/l

NOTE :

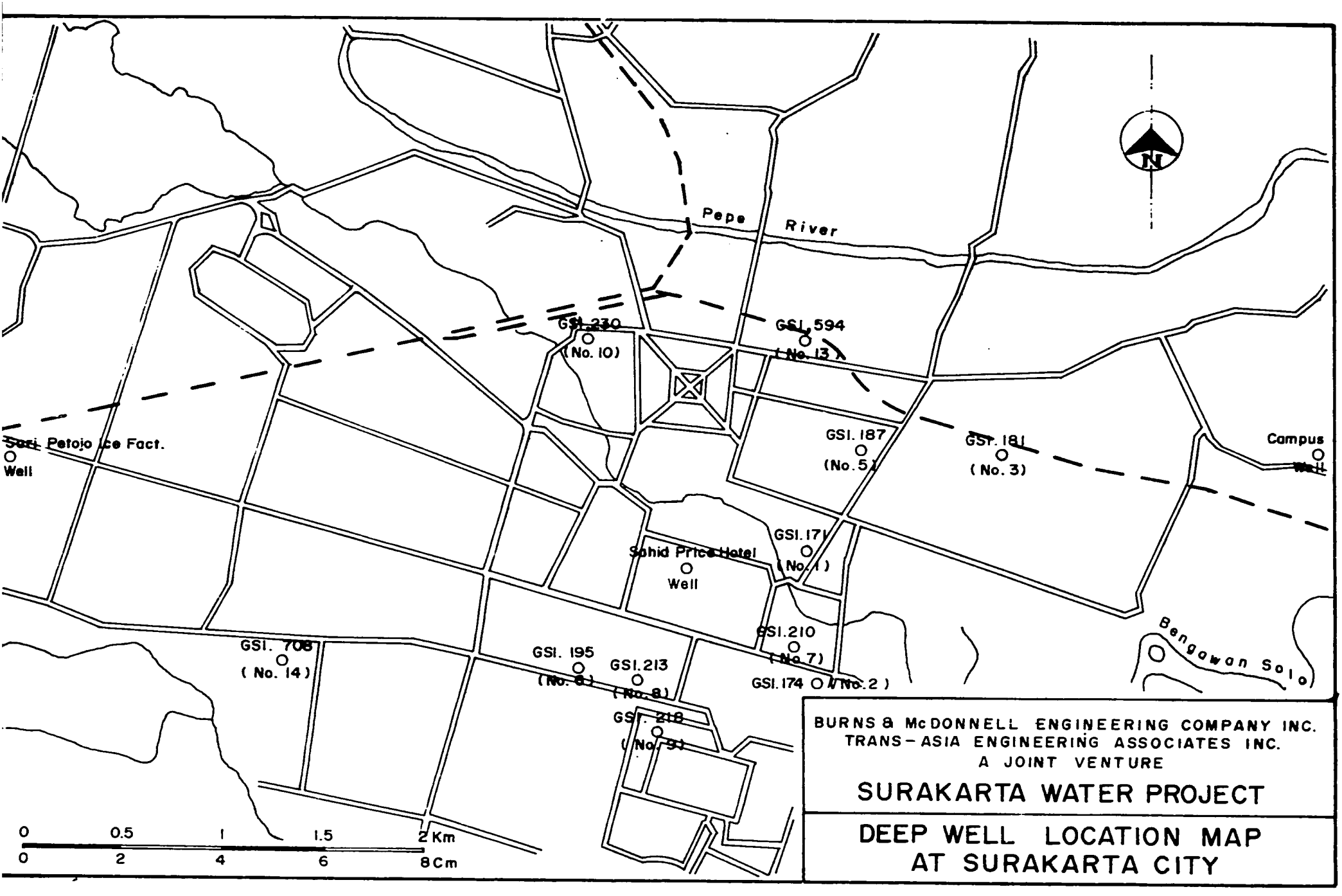
Turbidity = mg/l SiO_2 — 1° D = 10 mg/l Ca O

Colour = pt - Co scale — BQ = Bacterial Quality

C = Conductivity (micromhos/cm)

APPENDIX "C"

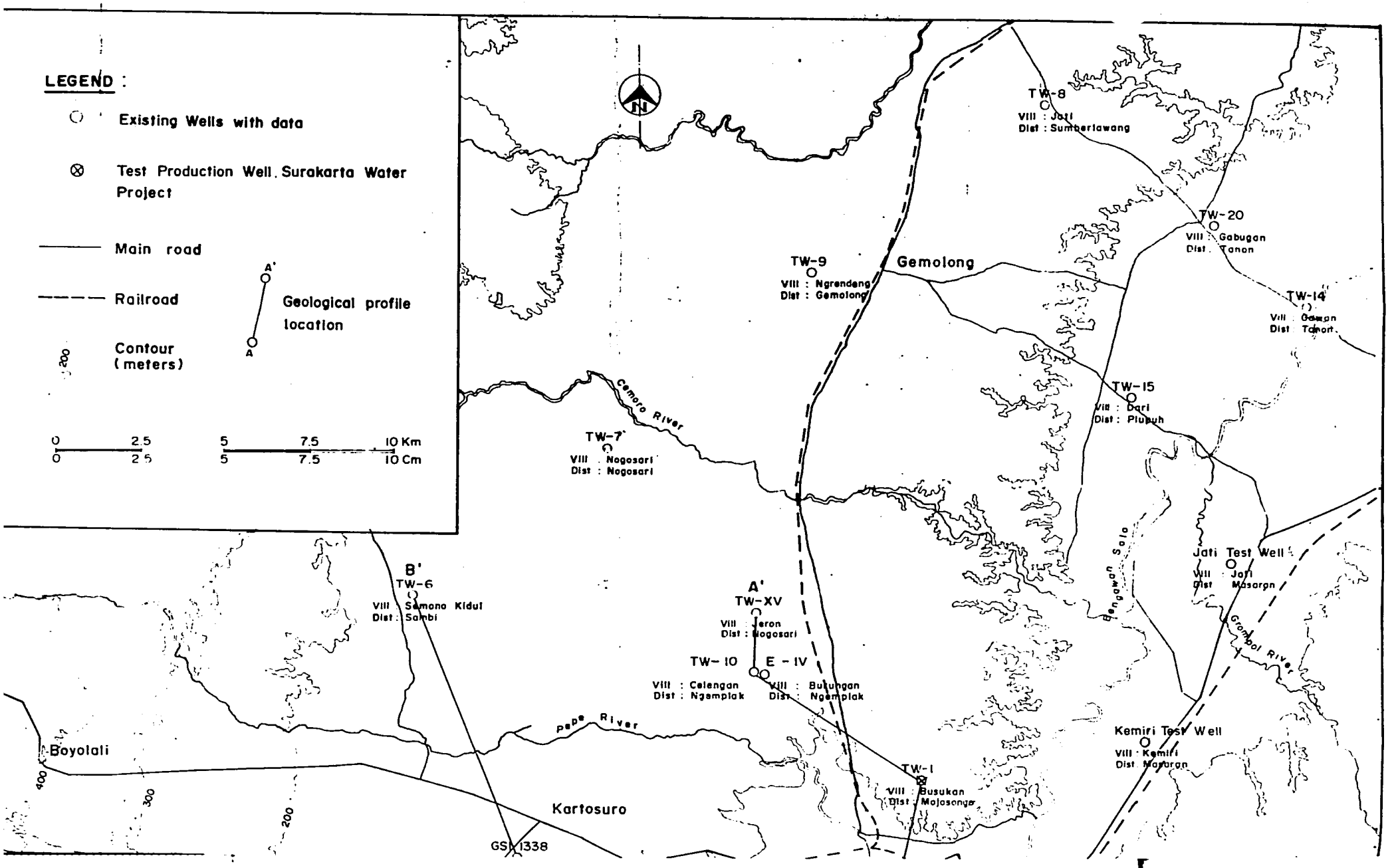
LOCATION MAPS

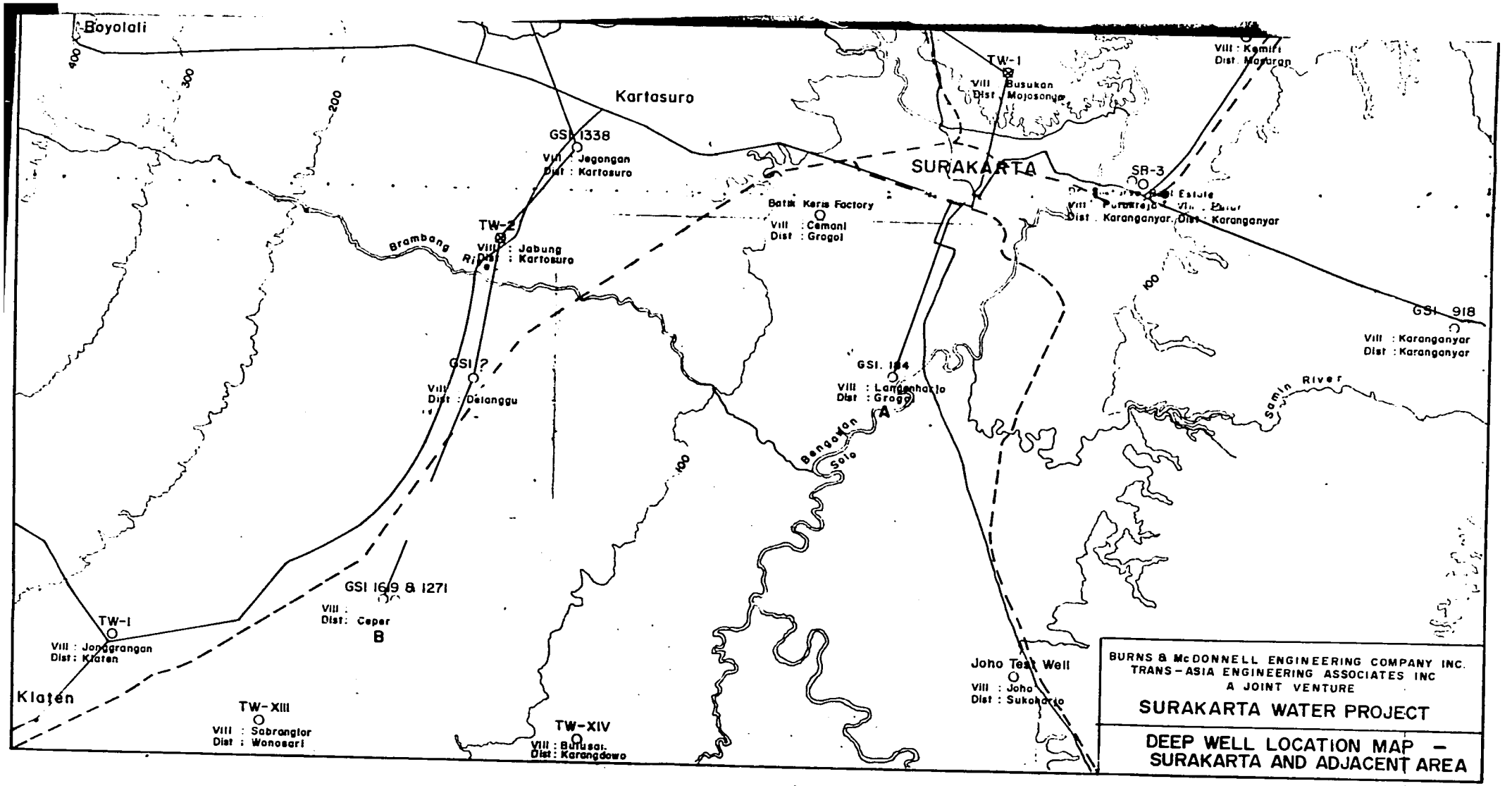


BURNS & McDONNELL ENGINEERING COMPANY INC.
TRANS-ASIA ENGINEERING ASSOCIATES INC.
A JOINT VENTURE

SURAKARTA WATER PROJECT

DEEP WELL LOCATION MAP
AT SURAKARTA CITY


LEGEND :
Existing Wells with data
Test Production Well, Surakarta Water Project
Main road
Railroad
Geological profile location
Contour (meters)
0 2.5 5 7.5 10 Km
0 2.5 5 7.5 10 Cm
N
TW-8
Vill : Jati
Dist : Sumberlawang
TW-20
Vill : Gabugan
Dist : Tanon
TW-9
Vill : Ngrendeng
Dist : Gemolong
Gemolong
TW-14
Vill : Gawan
Dist : Tanon
TW-15
Vill : Dari
Dist : Plupuh
Cemoro River
TW-7
Vill : Nogosari
Dist : Nogosari
B'
TW-6
Vill : Samono Kidul
Dist : Sambi
A'
TW-XV
Vill : Jeron
Dist : Nogosari
TW-10
Vill : Celengan
Dist : Ngemplak
E - IV
Vill : Butungan
Dist : Ngemplak
Bengawan Solo
Jati Test Well
Vill : Jati
Dist : Masaran
Grompol River
Pepe River
Kemiri Test Well
Vill : Kemiri
Dist : Mantan
TW-1
Vill : Busukan
Dist : Mojosongo
Boyolali
Kartosuro
GS 1338
400
300
200


Boyolali
400
300
200
Kartasuro
GSI 1338
Vill : Jegongan
Dist : Kartosuro
TW-2
Vill : Jabung
Dist : Kartosuro
Brambang River
GSI ?
Vill
Dist : Delanggu
GSI 1619 & 1271
Vill :
Dist : Ceper
B
TW-1
Vill : Jonggrangan
Dist : Klaten
Klaten
TW-XIII
Vill : Sabrangtor
Dist : Wonosari
TW-XIV
Vill : Butuset
Dist : Karangdowo
Batik Keris Factory
Vill : Cemani
Dist : Grogol
SURAKARTA
GSI. 1?4
Vill : Langenharjo
Dist : Grogol
A
Bengawan Solo
100
TW-1
Vill : Busukan
Dist : Mojosongo
Joho Test Well
Vill : Joho
Dist : Sukoharjo
SR-3
Vill : Purwarejo
Dist : Karanganyar
Vill : Kemiri
Dist : Mojoroan
GSI 918
Vill : Karanganyar
Dist : Karanganyar
Samin River
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A JOINT VENTURE
SURAKARTA WATER PROJECT
DEEP WELL LOCATION MAP –
SURAKARTA AND ADJACENT AREA