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REPUBLIC OF INDONESIA
MINISTRY OF PUBLIC WORKS
DIRECTORATE GENERAL OF HOUSING BUILDING
PLANNING AND URBAN DEVELOPMENT (CIPTA KARYA)

MEDAN URBAN DEVELOPMENT, HOUSING, WATER SUPPLY AND SANITATION PROJECT

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TECHNICAL MEMORANDUM NO. 32

GROUNDWATER RESOURCES

This is a draft of Appendix D-1 of the Master Plan Report for Water and Sanitation

NOVEMBER 1979

ENGINEERING - SCIENCE, INC. • SINOTECH ENGINEERING CONSULTANTS, INC
A JOINT VENTURE
in association with
PADCO and P.T. DACREA

MEDAN URBAN DEVELOPMENT, HOUSING, WATER SUPPLY AND SANITATION PROJECT

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Our ref.: 79/1201/MUDS/313 9 November 1979

Director General Cipta Karya
Ministry Of Public Works
Jalan Pattimura 20
Kebayoran Baru
Jakarta Selatan

Subject: Technical Memorandum No. 32,
Groundwater Resources

Dear Sir:

Attached are 20 copies of the subject Technical Memorandum for your information and review. The material contained in this memorandum constitutes submission of Appendix D-1 of the draft Master Plan for Water Supply and Sanitation Report.

Yours faithfully,

John M. McGill
Project Representative

C.C.: Ir. Ruslan Diwiryo, Director of City & Regional Planning
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DACREA - Jakarta

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LIST OF TECHNICAL MEMORANDA PREVIOUSLY SUBMITTED

Report No.	Title	Date Submitted
1.	Preliminary Site Selection Criteria for Perumnas Medan III, SSCH/LCH Project	March, 1979
2.	Work Plan for Water Supply and Sanitation Master Plans and Feasibility Studies	April, 1979
3.	Policy Issues for Project Guidance	March, 1979
4.	Drainage - Principal Rivers and Rainfall Analysis	May, 1979
5.	Preliminary Evaluation of Sunggal Water Treatment Plant	May, 1979
6.	Public Health Considerations	July, 1979
7.	The Present Drainage System	August, 1979
8.	Recommended Drilling Program	August, 1979
9.	Medan Household Income/Expenditures	August, 1979
10.	Existing Land Use in Medan	August, 1979
11.	The Regional Functions of Medan	August, 1979
12.	Existing Solid Wastes Systems and Projected Solid Wastes Characteristics	August, 1979
13.	Evaluation of Medan Master Plan	August, 1979
14.	Physical Constraints to Urbanization	August, 1979
15.	Development in Health Care in Medan	September, 1979
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17.	Developments in Education	October, 1979
18.	Existing Water Supply and Sanitation Systems	October, 1979
19.	Public Health and Environmental Aspects	October, 1979
20.	Alternative Solid Wastes Management Systems	October, 1979

LIST OF TECHNICAL MEMORANDA PREVIOUSLY SUBMITTED (CONTINUED)

Report No.	Title	Date Submitted
21	The Distributed Investment Strategy Plan (DISP)	October, 1979
22	Recommended Solid Wastes Management System	October, 1979
23	Recommended Drainage Management System	October, 1979
24	Alternative Water Supply Management Systems	November, 1979
25	Water, Wastewater, Stormwater and Solid Wastes Systems	November, 1979
26	Alternative Wastewater Management Systems	November, 1979
27	Design Criteria and Bases for Cost Estimates	November, 1979
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APPENDIX D-1

GROUNDWATER RESOURCES

D-1.1. INTRODUCTION

D-1.1.1. Past Experience

Deep water wells were first drilled in the 1880s and 1890s and provided water supplies to the coastal areas of Labuhan and Belawan. Shallow wells provided much of the water supply in the central Medan area, while the poor water quality of the shallow groundwater table in the coastal area required deep wells in order to provide usable water supplies. Deep wells were concentrated in the coastal area until after 1945, when several wells were drilled in Medan in order to provide substantial production of good quality water. This trend of general dependence upon deep groundwater in the coastal area and individual deep wells for major institutional, commercial and industrial users has continued to the present; most deep groundwater production remains concentrated in Belawan, although deep groundwater use has expanded in Medan.

D-1.1.2. Potential and Objectives

The long, historic use of the deep groundwater has clearly indicated the potential for greater, controlled use of the groundwater for potable water supplies. The Geological Survey of Indonesia has recommended that non-artesian groundwater wells should be limited to production of about 40 m^3/h (960 m^3/d, 11 l/s) in order to reduce the potential for overdrafting of the deep aquifers and to maintain acceptable water quality. Some trends in Medan would support such a recommendation, while most existing wells have not maintained such production for a significant time. The groundwater potential and recommended objectives appear to be similar if not identical in the Medan area. The investigation of the Medan groundwater resources has focused on verification of the production objective and assessment of the effects of such well production when extended over very large areas (e.g. 160 km^2 with an average of 1.3 wells per km^2).

D-1.1.3. Data Base

Data for the deep groundwater aquifers is limited to production

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and water quality information from the Port of Belawan and P.A.M. Tirtanadi wells in Belawan and to general information regarding private wells in Belawan and Medan. Detailed well reports were available for only wells in Belawan, and no report was made available for the wells in Medan. Lithological logs of wells were provided for many Belawan wells and for many older wells within Labuhan and Medan from the Geological Survey and Port of Belawan. Monthly and daily production records were provided for the Port and Tirtanadi wells in Belawan. Most private deep wells are operated without flow meters, pressure gages, or electric metering. Most estimates of production have usually been made from the original reported production rather than from existing production levels. Production tests and monitoring of water levels in the wells have been done only in Belawan.

Some regional geological information was available from the well logs of Pertamina and a general geological review for the Belawan area. A ground resistivity survey was conducted for P.A.M. Tirtanadi along the east side of Medan and near the Deli River (near Titipapan), and the report estimated the thickness of the aquifer and potential production yields. Unfortunately, this resistivity survey was made without any well log control to the surface indications.

Water quality data were available for several wells in the Port of Belawan, and monthly records were available for the major Tirtanadi wells in Belawan. Single chemical analyses were reviewed for several private wells. Field analyses for iron were made on water from five wells. More complete analysis was conducted on a well water sample taken from the Garuda Plaza Hotel, Singamangaraja St., Medan. The relatively poor data base has been supplemented by study surveys of water levels, drawdowns and water temperatures.

D-1.2. GEOLOGY

D-1.2.1. General Stratigraphy

The geological stratigraphy within the Medan area consists of more than 2000 metres of Tertiary marine formation below complex quaternary and Tertiary volcanic and alluvial deposits. Detailed

geological studies of this area have been restricted to exploration wells of Pertamina and to surveys of particular areas of the volcanic highlands. The general soil report for northern North Sumatra has also indicated the different underlying geological deposits. These studies in addition to the lithological logs of some water wells form the data base for the description of the geology of the region. The general geology and stratigraphic sequence within the study area and vicinity is shown in Figure D-1.1.

The "basement" formations of the study area consist of pre-Tertiary marine and coastal sediments. These formations are well-consolidated, metamorphosed, and folded. The eroded surface of the pre-Tertiary basement forms a depressed basin into which the later Tertiary sediments were deposited. This basin, or Medan Depression, is oriented from southeast to northwest and expands and slopes downward to the northwest.

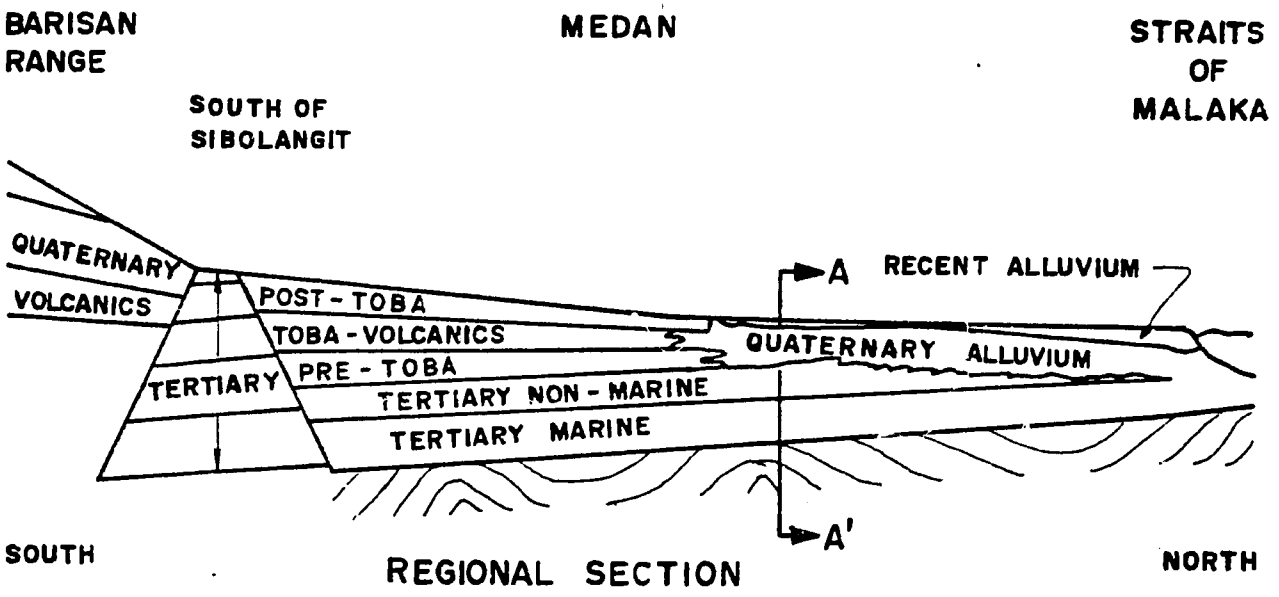
During the Tertiary, thick marine shales and limestones formed over the basement formation. As the basin filled, coarse sands and some gravels were deposited in the basin. These formations thicken and are inclined toward the axis of the basin. During the late Tertiary, fresh water deposition expanded and then fluctuated accros the basin. Volcanic debris first appears in the Seurula formation. Tertiary formations are exposed along the upper Percut river, 30 kilometres south of Medan and north of the Wampu river 40 kilometres north of Medan.

D-1.2.2. Groundwater Stratigraphy

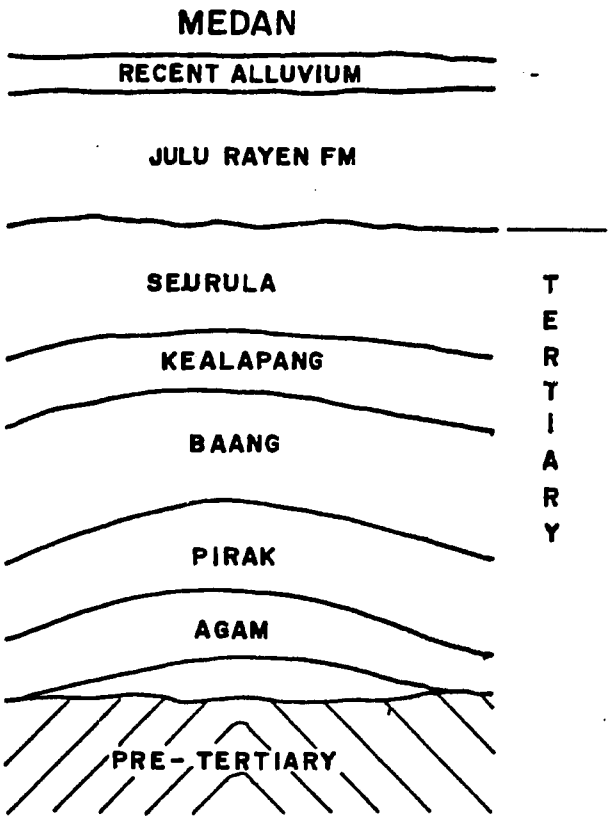
Within the Medan region, Pertamina has drilled three wells through the Quaternary, and lithologic logs for 40 wells of at least 100 m depth have been used to construct more detailed stratigraphic correlations (Figure D-1.2.). Two ground resistivity surveys of east and north Medan and the general geological study of the Belawan area have also been used in the following analyses.

The division between the Tertiary and Quaternary in North Sumatra is poorly defined. Pertamina has defined the Seurula formation as belonging to the Tertiary (Figure D-1.1.), and it indicated the top of this formation at about 250 metres below surface at Tanjung

GENERALIZED CROSS-SECTIONS OF STUDY AREA

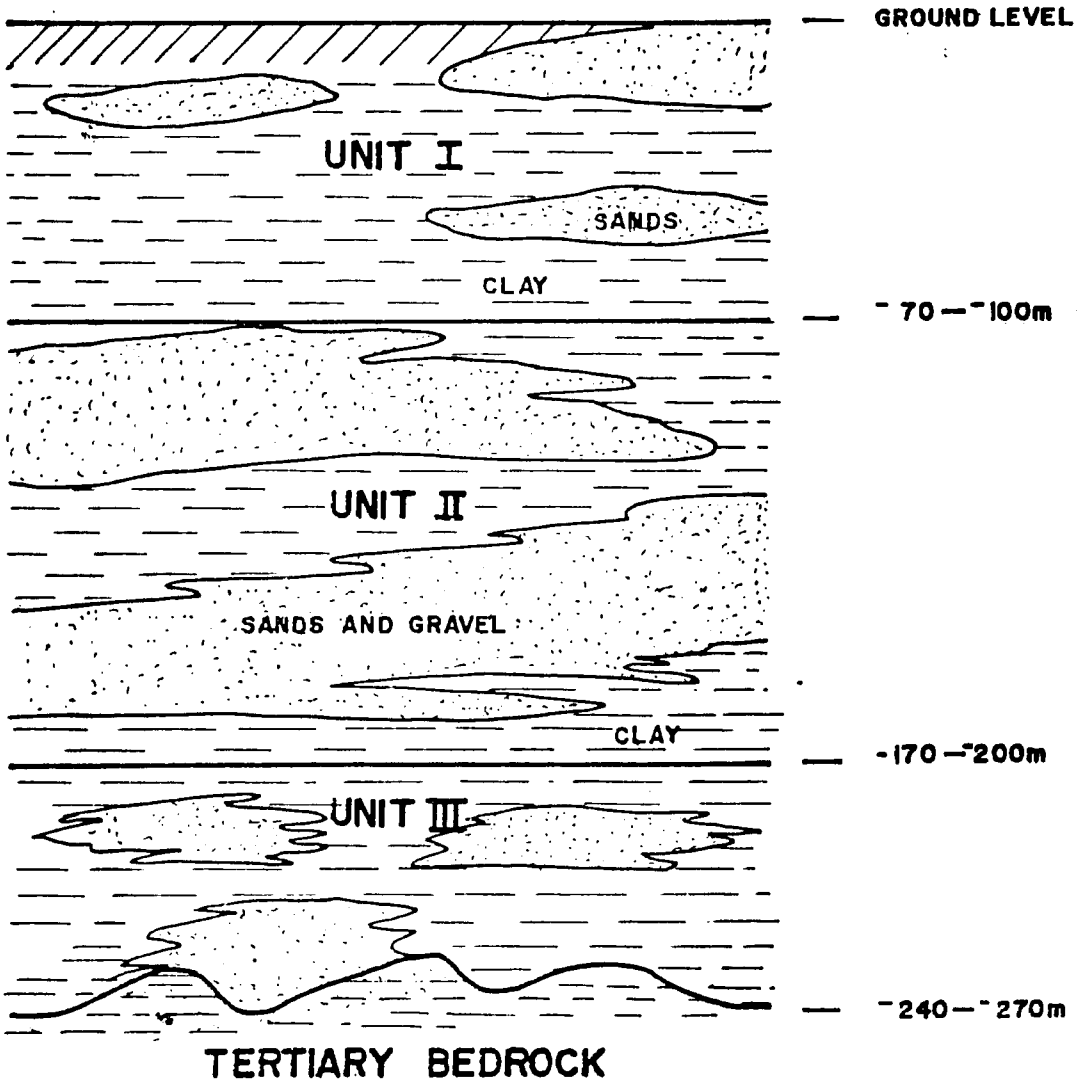


REGIONAL SECTION



DETAILED SECTION A—A'

GENERALIZED GEOLOGIC CROSS-SECTION OF QUATERNARY UNITS IN MEDAN AND BELAWAN



Morawa, 235 m at Diski (west of Medan), and 100 m at Pantai Pakam (southwest of Belawan). In the Tanjung Morawa well, the division between the Julu Rayeu and the Seurula formations was characterized by an increase in the electrical resistivity and spontaneous potential between 200 and 220 m below the surface. This would reflect an increase in compaction of the formations below this zone. In all three wells, the Seurula formation is characterized by a thick standstone, while the overlying sediments of the Julu Rayeu are dominated by interbedded sands and clays.

The contact between the more compacted Tertiary bedrock and the looser overlying Quaternary sediments should be indicated by marked differences in the movement and capacity of the groundwater aquifers in the Tertiary Seurula and Quaternary Julu Rayeu formations.

The general structural trends of the Tertiary formations indicate that a series of small anticlines and synclines are aligned from northwest to southeast but flatten towards Medan. These structures may significantly affect the relief of the contact surface between the Tertiary and Quaternary formations and the movement of deep groundwater across the surface. Since Tertiary formations are elevated well above sea level north of the Wampu River and lie 100 to 200^{+} m below ground level under Medan, the general inclination of the Tertiary/Quaternary contact is only 0.5 percent. This contact could direct regional groundwater movement from the Wampu River southward.

Similarly, the contact of the Tertiary strata with the thick volcanic sediments to the south of Medan is steeply inclined towards Medan. Surface exposures of Tertiary strata occur between 80 and 400 m elevation 25 to 35 km south of Medan, where the strata are 150 to 250 m below the surface; the inclination of the contact of Tertiary and volcanic strata is greater than 1.5 percent.

As indicated above, the Quaternary deposits include part or all of the Julu Rayeu formation which overlies more compacted Tertiary sediments. This formation includes a series of alluvial deposits with gravels, sands, and clays, and these form the major groundwater

aquifers of the coastal zone. Sands and gravels in the Julu Rayeu formation are derived from volcanic deposits, and the relationship of the thick Quaternary volcanic deposits in southern Medan and further south and the Julu Rayeu formation must be complex. In Tanjung Morawa, volcanic tuff overlies the Julu Rayeu formation, while north of Medan and at Pantai Pakam and Daski, no tuff strata was found in shallow or deep wells. River bank exposures on the Percut, Deli, and Belawan, indicate that tuffs disappear from the surface within a few kilometres north of Medan's city center.

At Medan and to the south, the volcanic tuffs cannot be easily distinguished from many alluvial deposits. Compacted terrace sands and clays closely resemble volcanic tuffs which have been weathered deeply in the tropical climate and high rainfall. To the north of Medan, many well logs record volcanic sandy-clay and clay sands with pumice stone; such strata may be either weathered volcanic tuffs or eroded alluvium from volcanic tuffs. Therefore, the Julu Rayeu formation must be considered an alluvial equivalent to the three recognized volcanic units: Pre-Toba, Toba and Post-Toba volcanics. The continuity of the volcanic formation into the alluvial formations may also suggest that groundwater moving downslope in the volcanic deposits may discharge into the Julu Rayeu formation under Medan.

In Belawan, three general sedimentary units have been defined, and these may be distinguished in the Medan City area. Correlations of particular sedimentary strata however cannot be made between Belawan and Medan without more precise lithological analyses and closer spacing of wells. The Quaternary geology of any coastal area is aften complicated by the repeated movements of river, delta, and coastal marine deposition which may have moved back and forth across the study area in response to the rise and fall of sea level during the last three million years. Similarly, the Medan coastal plain deposition should reflect a complex history, which is further complicated by volcanic eruptions and tectonic movement.

Presence of marine shells in sands beneath Belawan and somewhat more prominent sands and gravels in Belawan, compared to Medan, may indicate that some aquifers along the coast may be old beach deposits rather than filled stream channels. If the existing

physiography bears any relationship to those during the Quaternary, aquifers to the north would be expected to be longer in an east-west aligment, while those the south under Medan could be longer in north-south aligments. Some interconnections between these aquifer would be expected although probably further towards Medan than under Belawan.

Most Belawan wells penetrate three lithological units, and most groundwater may come from intermediate units(a series sand and gravel aquifers). Silts and clays dominate the overlying unit (unit I) and appear to seal off the intermediate aquifers from possible contamination by sea water. Historic well water levels indicate that the intermediate aquifers of Unit II were confined under greater pressure than that expected by an aquifer with broad contact with the overlying, shallow aquifers. Some aquifers in Unit III occur below Unit II but are separated by a series of clay and silt strata. Such may completely separate the aquifers of the Unit III from those of Unit II.

The general groundwater geology of Belawan has been reported in a general survey (1977) and indicated that the sands and gravels may follow the same trends as the overlying Deli and Belawan Rivers. This trend indicated that thin aquifers should be found in the central area of Belawan. However, several wells have been drilled and produce significant groundwater within this central area. Widespread occurrence of the sands and gravels within Unit II may suggest that its deposition may have occured in a more widespread beach and sand bar environment rather than a more limited and variable river channel environment.

Particular sand and gravel strata cannot be confidently traced into the Labuhan area (5.0 km to the south), the general three-part sequence of Unit I: clay-silt, Unit II: sand and gravels, and Unit III: mixed clays and sands can also be found in Labuhan. Many wells penetrated only the upper portion of Unit II (down to - 10^{0} m) and do not provide a complete log of Units II and III.

Within Medan and Glugur, only 8 well records have been reviewed, but these generally indicate a similar three part division of the

Quaternary sedimentary units. General comments from drilling contractors also suggest a three-part separation of the Quaternary.

Any separation of three lithological units in Belawan and Medan must recognize that the strata were probably deposited under water and that river and ground surface slopes may have been similar to or steeper than those today. If this is so, strata in Unit II should be at more than 20 m higher elevation in Medan than in Belawan.

Drilling records for the Medan study area are generally concentrated along the north-south line from Belawan to Medan and should not be entirely representative of the region (e.g. winding ancestral river valleys and alluvial fans would be expected beneath Medan). Furthermore, the effects of large volcanic eruptions can be seen south of Medan, (i.e. Medan lies on volcanic formations), and volcanic debris has been reported in many well logs. Geomorphic development in eruptive volcanic areas often involves complete filling of ancestral valleys by an eruption and initiation of entirely new drainage basins. Therefore, geological interpretations based upon the central alignment ecords should not indicate the total stratigraphic sequence.

D-1.2.3. Geology and Infiltration

The recharge of groundwater involves the infiltration of surface waters through the soil or bedrock or from river beds into the shallow aquifers and from the shallow aquifers into the deep aquifers. Geological data are insufficient to locate the areas of surface or river recharge for the deep aquifer in Medan. Several possible areas do exist, however:

1. Volcanic hills and mountains to the south,
2. River valleys above 40 m,
3. River floodplains and irrigated terraces, and
4. Deep river channels of the Wampu and Ular rivers.

The very high rainfall in the Barisan Ranges to the south of Medan offer many suitable areas for infiltration of rainfall. Rainfall of more than 5 m on well-vegetated slopes would allow deep infiltration. The springs of Sibolangit may represent a portion of the discharge of shallow to intermediate depth groundwater derived

from infilterated rainwater. As the groundwater follows the structural and stratigraphic trend of the volcanic deposits, the groundwater is eventually discharge into alluvial deposits which were formed along the northern edge of the old volcanic deposits. Once in the alluvial deposits, the groundwater would tend to follow the thicker and coarser lenses of sand and gravels.

Many river terraces and basins may be found at about 50 and 75 m elevation with steeper grade between the basins. These terraces and basins often have thick deposits of sand and gravel. Rain water and river water many infiltrate through these coarse deposits and enter the coarse, older deposits which or the bottom of the basins and terraces. Such areas may be seen near Deli Tua on the Deli River and Tuntungan on the Belawan River.

Many smaller terraces and basins can be found below 50 m elevation. Upstream of the Sunggal Plant, thick sand and gravel deposits occur and hold groundwater. Between the Babura River and the Belawan River, terraces are cultivated for rice and may provide numerous sites for groundwater infiltration where sands reach the surface. Water levels in shallow groundwater table wells indicate that the finer terrace deposits are charged with groundwater. However, below 50 m elevation, the groundwater table overlies known producing deep aquifer, and the water pressure in wells within the deep aquifers is different from those of adjacent shallow wells. Therefore, infiltration into the deep aquifers may not occur below of south of the 50 m elevation. Similarly, water levels in Belawan are different from sea level and surficial groundwater tables.

Two major rivers, the Wampu to the west and Ular to the east, have wide, deep channels. Such channels can lose considerable water from their beds by infiltration into surrounding sands and gravels. These rivers may contribute the groundwater infiltration into the deep aquifers of the coastal zone. East-west movement of groundwater is not thought to be great but such movement could occur with increased withdrawal from the deep aquifers.

D-1.2.4. Geological Structure

The study area extends across the axis of the deeply buried Medan depression which has formed between the Asahan Ridge (beneath the Straits of Malaca) along the northeastern margin and the Barisan Range along the southwestern margin. A buried ridge separates the Medan Depression from the Siantar Deep to the south, while the Medan depression joins directly with the Tamiang depression on the north. Compression between the Asahan Ridge and Barisan Range has produced a series of smaller anticlinal-synclinal folds in upper Tertiary and Quaternary deposits with the Medan Depression oriented southeast-northwest. Earlier compression formed similar folds with more north-south orientation. North of the Wampu River, a large syncline in late Tertiary (including Seurula and Julu Rayeu) bedrock is oriented so that an extension of its axis would lie along the southern margin of the study area. To the northeast, an anticline near Tanjung Pura may be extended southward to Medan city or to the north.

Geological survey of the Medan-Langkat area indicates the surface exposure of the Tertiary formations at about 500 elevation. This formation is known from more than 1,000 m below Medan and the resulting differential movement of 1,500 m has occured between the edge of the Barisan Range and the Medan peidmont. Northwest-southeast oriented faults near Sibolangit indicate uplift on the southwest side, although the amounts of uplift from faulting and folding cannot be separated. The edge of the faulting cannot be accurately estimated but probably has occured several times over the last 2,000,000 years. The faults are also associated with volcanic intrusive rocks and may have formed weak spots in the earth's crust along which lava was forced to the surface and formed volcanoes. Prominent terraces at +5.0 m have been interpreted to indicate recent (last 10,000 years) uplift of the coastal areas.

D-1.2.5. Seismicity

Active volcanoes lie only 50 kilometres south of the study area and they indicate the seismically active setting of the study area. Geological uplifts of more than 1000 metres during the last three million years, major faults along the central axis of Sumatra,

and occurrences of seismic epicentres within Sumatra and southeast Asia further testify to the moderate to high potential for significant, damaging earthquakes in the area. The general level of seismic hazards is only moderate with no structural damage, additional considerations should be made with regard to the high water table and to the poor structural support which the clay soils of the coastal plain and tidal zones can provide. Damage could be expected where high water table occurs in clay to sandy soils, and near relatively steep, unconfined slopes.

D-1.3. THE GROUNDWATER TABLE

D-1.3.1. Distribution

Groundwater near the surface in the soil and alluvium is called the groundwater table (the shallow, unconfined aquifer). The groundwater table is supplied by rainfall directly, by infiltration from surface waters (e.g. rivers, canals, ponds, etc.), and by deeper groundwater aquifers. In many places in Medan, artifical canals, ponds, lakes, and sewage infiltration fields also contribute to the shallow groundwater. The groundwater table provides the only local water supply to many thousands of people in Medan and is a valuable asset.

In many other places, the high level of the groundwater may provide convenient water supply, but greatly constrains the use of many areas for some agriculture and urban land use without substantial and continuing costs for drainage and fills or pilings. Urban and transportation developments have also modified the natural groundwater table and either caused the shallow groundwater to rise to the surface or have deprived the groundwater of natural recharge which has caused a decline in the groundwater table surface.

In the coastal tidal zone (below 5 m elevation above sea level), the groundwater is very close to the surface and is often continuous with ponds, marshes and other water-logged soils. The very low gradients reduce drainage and increases infiltration of the 2000 mm of rainfall each year and the surface water flowing into the area from higher elevations. Stagnation of the groundwater table and

surface waters and the tidal intrusion of sea water causes contamination of the water, and in many areas other potable water supplies must be found (e.g. the Port of Belawan drilled deep wells as early as 1888 in order to support the port development). Deep excavations must be artifically drained, and most construction requires about one metre of clean fill and pilings.

Along the major rivers and between +5 m and +25 m elevation, the groundwater table is quite high and usually lies within one metre of the surface. On the west side of the Deli River, agriculture development has drained the shallow groundwater, and the groundwater table may be more than one metre below the surface. Along the Belawan-Medan Road, the natural levee development of the Deli River provides slightly higher and dryer ground than further east, and this supported the early development of the railroad, road, and structural development of the corridor.

The small drainage area and the low gradient of the Kera River appears inadequate to carry the large runoff from the eastern area of Medan City, and the flooding and slow drainage increases rain infiltration into the groundwater table. Generally, the groundwater table is higher on the eastern side of the Deli than on the west, even at the same ground elevations.

Between +15 and +25 m elevation, human activities strongly influence the actual depth to the groundwater table which is generally within 0.5 to 1.5 of the surface. Natural movement of the shallow groundwater is towards the rivers, especially during droughts. When roads and widespread structural development occurs across the slope of the groundwater table, the groundwater accumulates on the higher side, and the level of the groundwater table rises, often to the surface as ponds and waterlogged lands. Congested drainage canals and septic tank infiltration fields contribute additional water to the groundwater tables and produce artifically high water table levels.

Above +25 m elevation, groundwater may often be deeper than 1.0 to 3.0 m from the surface. The level of the rivers and other surface waters reflexts the lower-most level of the groundwater table.

Because of the relatively slow movement of the groundwater table towards the rivers and open channels, the level of the groundwater table above +25 m depends upon the distance from an open channel and the amount of rainfall or irrigation. During dry periods of less than 60 mm rainfall per month, the groundwater table near the river will fall more rapidly than the level near the higher ground, or divides between the rivers. Wells within 100 m of the Deli, Belawan, or deeper channels of the Percut and Babura often decline faster during the dry periods than lands more than 1000 m from the channels. The water levels may change from 1.0 m to 6.0 below surface in a few months.

Between the Percut River and the Babura branch of the Deli River, and at a ground elevation of +35 m to +50 m, the groundwater table may lie at least 2.0 m below the surface. The steep ground gradients and close proximity of the deep open channels in this elevational range allow rapid runoff of rainfall and small streams accelerate the flow of the shallow groundwater towards the open channels. Since the Babura branch lies across the north side of the hills, the open channel collects most of the shallow groundwater and decreases the level of groundwater immediately north of the stream. North and west of the Babura branch and up to the Belawan River, the low gradients of the ground and the small streams reduce the rate of runoff and increases the natural infiltration of rainfall to the groundwater table. Irrigation of many crops in this area further increases the amount of water reaching the groundwater table and tends to maintain higher water levels in the wells and excavations. Within 200 metres of the Belawan River, many streams drain into the Belawan channel and their steeper gradients reduce infiltration and increases the natural discharge from the groundwater table.

A prominent terrace or plain occurs along the rivers and between 50 and 75 m elevation, and ground slopes and stream gradients are low, and the drainage is poor. Cultivation of irrigated crops further interferes with rapid drainage and tends to maintain a high groundwater table (within 2.0 m of the surface).

D-1.3.2. Water Table Development Constraints

As indicated above, the groundwater table has benefited the Medan residents by providing usable water supplies. Development and construction, however, will be constrained or restricted by the shallow groundwater in many areas. The Medan Urban Development Study has recognized the following groundwater table constraints and guidelines.

D-1.3.2.1. Belawan

The poor quality of the groundwater table and its shallow depth hinder the efficient development of the port and residential areas of Belawan and Labuhan. Roads and general urban development must be properly filled and diked to protect developments from water logging and flooding. Additional expenses for filling and other special measures increase the costs and may limit efficient land uses except for high value industry and commerce.

D-1.3.2.2. Medan-Belawan Corridor

The combination of flooding and high water tables constrains development to a narrow corridor along the Belawan Road and the railroad or to special projects which can afford the high costs of excavations, fills, deep doundations, and flood protection from both the Deli and Kera rivers. Embankments for the railroad, the Medan-Belawan public road, and the proposed Belawan toll road may provide barriers to groundwater movement in east-west directions. If the toll road is properly aligned and filled, lands in the corridor between the railroad and toll road become more suitable for development with the partial flood protection offered by the embankments. The embankments will also reduce movement of shallow groundwater from the Deli and Kera River channels into this corridor. Properly aligned east-west dikes between the railroad and toll road embankments would close the flood protection and shallow groundwater barrier. Such enclosure would allow use of less fill and smaller drainage facilities compared to those required for a fully exposed site.

D-1.3.2.3. Upper Kera Basin

The Kera River drains much of eastern Medan, and the large volume of water, low channel gradients, and slow runoff increase the flooding and the infiltration of surface waters into the shallow groundwater table. Future flood protection facilities may deepen the channel and improve drainage for the groundwater table. These facilities may also compact the shallow soils and line channels which will reduce the drainage and increase or maintain the existing high water table.

D-1.4. WELL FACILITIES

D-1.4.1. Groundwater resources and Facilities of PAM Tirtanadi, Belawan

The records and facilities for the groundwater wells at Belawan have been reviewed and are described in Section 2. Analysyes of the available data indicate that existing production wells can supply the existing and short-term requirements of the Belawan area without significant imports of water from the Medan distribution system. Even if connection percentage and total demand increased over the next five years at the same rate as in Medan city, the existing supply facilities, with some changes in operations and equipment, could supply the itermediate phase through 1985. The major requirement appears to be storage for continuous production from existing and renovated wells.

D-1.4.2. General Well Design

Production wells in Medan,Belawan have used three types of designs which have reflected the types of pumps and water levels in the wells. Changes in well pumps and declines of groundwater levels have caused modifications of the older designs. Transferral of several wells from the authority of the Port of Belawan to P.A.M. Tirtanadi also involved renovation of the old well design and several additions which are not commonly found in other wells.

D-1.4.2.1. Old Well Type

Early well designs in Belawan, Labuhan, and Medan depend upon artesian pressure which carried the water to within a few metres of

ground surface or actually above the ground surface. Water from the well spilled over into a reservoir from which it was extracted by hand pump or bucket. These wells provided local domestic water supply. As the port expanded, these small capacity wells were replaced by larger facilities with larger capacity, but the basic design remained similar. All wells in Belawan, except Well No. 19 and 20, were originally constructed with a tank system into which well water would flow under artesian pressure about 25 m below surface. Pumps would then draw water from the underground tanks and transmit the water into the distribution system. Thus most wells were not directly pumped (except Wells No. 3, 7, and 8).

D.1.4.2.2. Modified Old Well Type

The older artesian-tank type well provide most water demands before 1950. As groundwater levels fell between 1950 and 1979, production for the old type wells declined (e.g. POB No. 10). Water could not flow, passively, into the tanks at sufficient rates to equal required pumping from the tanks. In order to maintain production, the old type of well with tanks have been slowly modified, replaced, or abandoned (only Well No. 1 remains on the passive system). The major modification involved the mounting of a 7-15 HP submersible pump within the casing of the old well with discharge into the underground tank or into the distribution system. Even the newer POB Wells No. 16,17, and 18 included the underground tank and surface pumping stations and now have been modified by installation of submersible pumps.

Tirtanadi has renovated several of the wells (wells No. 5, 9, 11, and 12) for which they assumed control. The underground tank was removed from the well operations. This exclusion reflects the high capacity submersible pumps being used and the use of pressurized sand filters before water passes directly to the distribution system.

With the modifications of the old type artesian-tank system, all operational wells but well No. 4, 6, 7, and 10 are now pumping directly from the well casing, and wells 4 and 10 will be modified and operated with a submersible. These modifications largely reflect the drawdown of the deep aquifer to below the artesian inflow eleva-

tion to the old type tanks (about 2.5 m below ground surface) rather than increasing demands.

D-1.4.2.3. New Well Type

The "new-type" wells generally consist of the well and a submersible pump with an outflow pipe going either to a storage tank, pressure/gravity filter, or the distribution system. In Belawan, POB Wells No. 19 and 20 with submersible pumps produce more water than any other groups of wells in the entire Medan-Belawan area. The water is pumped directly to an industrial user's storage tank and then to processing units.

Other new wells in Belawan and Medan have submersible pumps which serve industrial or commercial users and treatment of the water depends on eventual use. For industrial use, including food processing, water is used from storage tanks with little treatment. For hotel and hospital use, well water passes through pressure/gravity filters and then is chlorinated before flowing into storage tanks. Many hotels provide separate water supplies for drinking and well water for general washing and swimming pools. No facility was found to reduce iron in the well or surface waters, and many use municipal water for drinking.

D-1.4.3. Operations

General operations of major wells within the Medan study area reflect the agencies and users of the wells, and control and centralized operating procedures extend over less than 10 wells at the Port of Belawan and P.A.M. Tirtanadi in Belawan.

Operations of the Port of Belawan provide 24 hour/day operators for each well, while large private users may have one or more technicians responsible for water and other utilities. Some smaller users may only have technicians inspect and repair wells, pumps, treatment facilities and electrical supply, when some component has failed or shows signs of potential failure.

The port records flows and electrical consumption on a daily basis and has water quality analysed on a monthly basis for some wells or common storage tanks. Most other operators do not appear

to make any meaningful records. As long as the wells produce water, little concern is directed towards maintaining their operating efficiency.

Back up power supply was available only for the wells in the Port of Belawan and at a few major hotels and industries which maintain on-site generators. Other well operators, including Tirtanadi, depend on common electrical distribution systems. Line voltage varys widely, especially for 3-phase equipment, and generally is well below the required 220/380 volts for optimal pump efficiency.

A common problem with many wells is loss of production or disruption of service due to the pump losing suction as the well water level falls to the level of the pump. Such losses or disruptions usually involve reduction of the effective screen opening. Sand sometimes passes through the gravel pack and screen; the sand then falls to the bottom where it eventually accumulates and begins to cover the screen openings. Although some operators may abandon wells due to loss of production, others, like Tirtanadi, periodically clean the screen of the deep well. This, most often, involves removing the accumulated fine sand from the bottom of the well.

Well cleaning most commonly uses a high pressure air compressor to inject air through a long pipe which reaches to the bottom of the well casing and screens. An injected air bubble under 200 m of water begins to rise and carrys both water and sand up and out of the well. Air lifting may be conducted for several hours or days depending on the amount of sand to be cleaned from the well. Once the casing has been cleared of sand and debris, swabbing may be done to clear material which has clogged the screen itself. Sometimes high pressure water jets may also be used. No air is injected through the screen and into the gravel pack.

Cleaning of the casing and clearing screens can immediately increase the production capacity of the well, improve efficiency, and reduce well draw down. If the production does not significantly increase, under water video viewers with lights can be lowered through the casing for visual inspection of the screening for obstructions. This has not been done in Medan nor have any reports of its use in Indonesia been received.

D-1.4.4. Well Drilling Practises and Designs

Poor production and frequent cleaning usually indicates poor designs or drilling/development of the well. All wells in the Medan area have been constructed in accordance with local well drilling practice and with locally made equipment. During this study an inspection was made of most of the existing public water wells. In addition to inspecting each well, the construction of a new well was observed drilled for the Polonia Hotel to augment their present supply. This well was drilled by the rotary method by a local contractor. The drilling equipment was very obviously a one-of-a kind, locally made rig and was capable of drilling to about 240 m and to a bore diameter of about 300 mm. Conversations held with the drilling foreman indicated that this or similar equipment was generally used for well construction in the greater Medan area. Because of these limitations, test well design will have to consider the contractors ability to perform the required work.

The current method of well construction depends to a large extent on the reduction of casing diameter as the well is deepened. A surface casing perhaps 300 mm in diameter is the largest diameter used. At depths of 150 to 175 meters, the casing is normally sequentially reduced to 100 mm. This scaling down of casing with depths is necessitated because the mud pump on the rig is not capable of moving the large volumes of cuttings against high heads (180 to 200 m) that would be the case in larger diameter boreholes.

Many private or older wells not only have small diameter casings but do not include any type of conductor casing normally provided to preclude the entrance of surface or shallow subsurface waters. Moreover, the submersible pump, which is typically used, is hung in the well by a clamp affixed to and supported on the production casing. In most instances the casing extends no more than 0.3 m above ground surface. Electric wires connected to the motor cross the ground from the power source and are unprotected either against the elements or damage by vehicular or foot traffic.

Rotary drilled wells are purported to be gravel packed, but no evidence of the gravel pack was seen. No gravel feed pipe or water level monitoring pipe exists at the top of the casings. Often, the

casing is not sealed or only partially sealed by concrete and steel caps.

No inspection is made during the well construction, and no independent verification of the gravel packing was made on any well. At some wells, settlement of ground around the surface casing suggests that compaction had taken place, but it is unknown whether compaction occured in the gravel pack or in loose fill placed around the casing. In one proposed design, a contractor provided a drawing with the gravel pack extended to the surface, while others indicated that the volume of gravel pack was not calculated nor measured when placed.

Local drillers have concluded, based on information presently unavailable to us, that groundwater in the upper and intermediate aquifers, the zone lying between the surface and 170 meters, contains an unusually high iron content. For this reason, they have connvinced well owners that the minimum well depth should be in the order of 200 m. It is interesting to note, however, that the upper water-bearing zone in these gravel packed wells is either only partially or not sealed-off thereby allowing hydraulic continuity to to exist between and among all the water-bearing strata.

Designs of the wells often appear to reflect minimal initial costs and limitations of equipment. Some design elements would suggest that proper development of the standard well cannot be done even if proper techniques were used.

Well discharge and water level drawdown generally relate to the transmissivity of the aquifers. In any given area where aquifer constants are similar, all wells should exhibit the same rate of discharge with the same drawdown. If extreme differences exist (e.g. Belawan: 4 to 36 m drawdown), such differences usually reflect construction practices rather than variations in the aquifers ability to produce equivalent quantities of water.

The rotary method of drilling injects drilling mud into the wall of the well bore and the mud forms an inherent barrier to properly developing the well. In large diameter casings, tight-fitting swabs and prolonged reciprocating action of the drill stem causes the

drilling muds and other fine-grained sediment in the wall to move through the gravel pack into the perforated casing where it is removed. Local well designs use progressively smaller diameter well casing with depth, and this precludes efficient well development. Some well designs install only one section of screen or several small sections. Without prolonged development, small screens do not allow clearing of drilling mud from the well bore. Only those sections near the screens or those along the gravel pack with the loosest compaction will release the drilling mud, while other less permeable but larger aquifers will remain clogged.

As a result of different degrees of effectiveness wells drilled in the same formation will exhibit different performance. Most probably, well efficiency in the greater Medan area is less than 50 percent, if that high.

D-1.5. WELLS, LOCATIONS, AND PRODUCTION

More than 80 deep wells have been drilled in Medan and the Belawan corridor since 1889. Unfortunately, few records are available for the design, construction, operation, and production of these wells. The Geological Survey of Indonesia (Bandung, 1973) prepared a preliminary list of 68 wells within the Medan study area (Table D-1.1.) and several hundred for all of North Sumatra. Most of the wells were summarized from old Dutch records still extant in the GSI files. A few well reports from private drillers and data supplied by PAM Tirtanadi and the Port of Belawan or the only other sources.

Deep wells are concentrated between Central Medan and the Port of Belawan, inLabuhan to Titipapan, and in central Medan (Figure D-1.3.). Many wells listed by the GSI appear to be located at the sites of existing wells in Belawan, but the description of the wells suggest that two or more wells have been drilled at the same sites. No site had any indication of more than one well nor did Port of Belawan staff report any earlier wells. Where possible, notes have been added to the well list as to which numbered well corresponds to a well operated by PAM Tirtanadi (PAM) and the Port of Belawan (POB). Several wells were known to have been drilled in the Medan-Belawan area but their locations were not known. Some wells had also been abandoned.

TABLE D-1.1

LISTING OF KNOWN WELLS IN THE MEDAN AREA

No.	Name	Date	Depth/m
Wells Drilled by Department of Mining/Directorate of Geology			
8	Labuhan I	1887	75
9	Labuhan II	1887	87
10	Labuhan III	1887	87
11	Labuhan IV	1887	90
12	Labuhan V (not located)	1888	98
13	Labuhan VI	1888	218
14	Medan I	1889	195
17	Belawan Deli II (= PAM 8)	1894	76
18	Labuhan VII	1894	98
22	Belawan Deli III	1911	81
24	Labuhan VIII	1911	90
26	Hamparan Perak	1911	65
28	Pulau Sicanang	1914	119
29	Belawan Pelabuhan I (= PAM 3)	1915	233
30	Belawan Pelabuhan II (= PAM 4)	1916	235
34	Titi Papan	1919	134
37	Bagan Deli	1921	116
38	Sisir Gunting	1922	144
39	Belawan Pelabuhan III (= PoB 2)	1926	153
43	Sunggal	1931	223
44	Percut	1932	168

WELLS REGISTERED WITH DEPARTMENT OF MINING/DIRECTORATE OF GEOLOGY

1	Bulu Cina	1904	224
2	Bulu Cina	1904	112
40	P. Brayan I	-	-
43	P. Brayan II	1916	226
44	Bulu Cina	1918	224
45	Labuhan	-	-
49	Belawan Pelabuhan IV (= PoB 15)	-	-
76	Belawan Pelabuhan V (= PAM 5)	1950	120
77	Belawan Pelabuhan VI (= PAM 6)	1951	112
78	Medan A.V.R.O.S. (= RISPA)	1952	121

PRIVATE WELLS, NOT REGISTERED

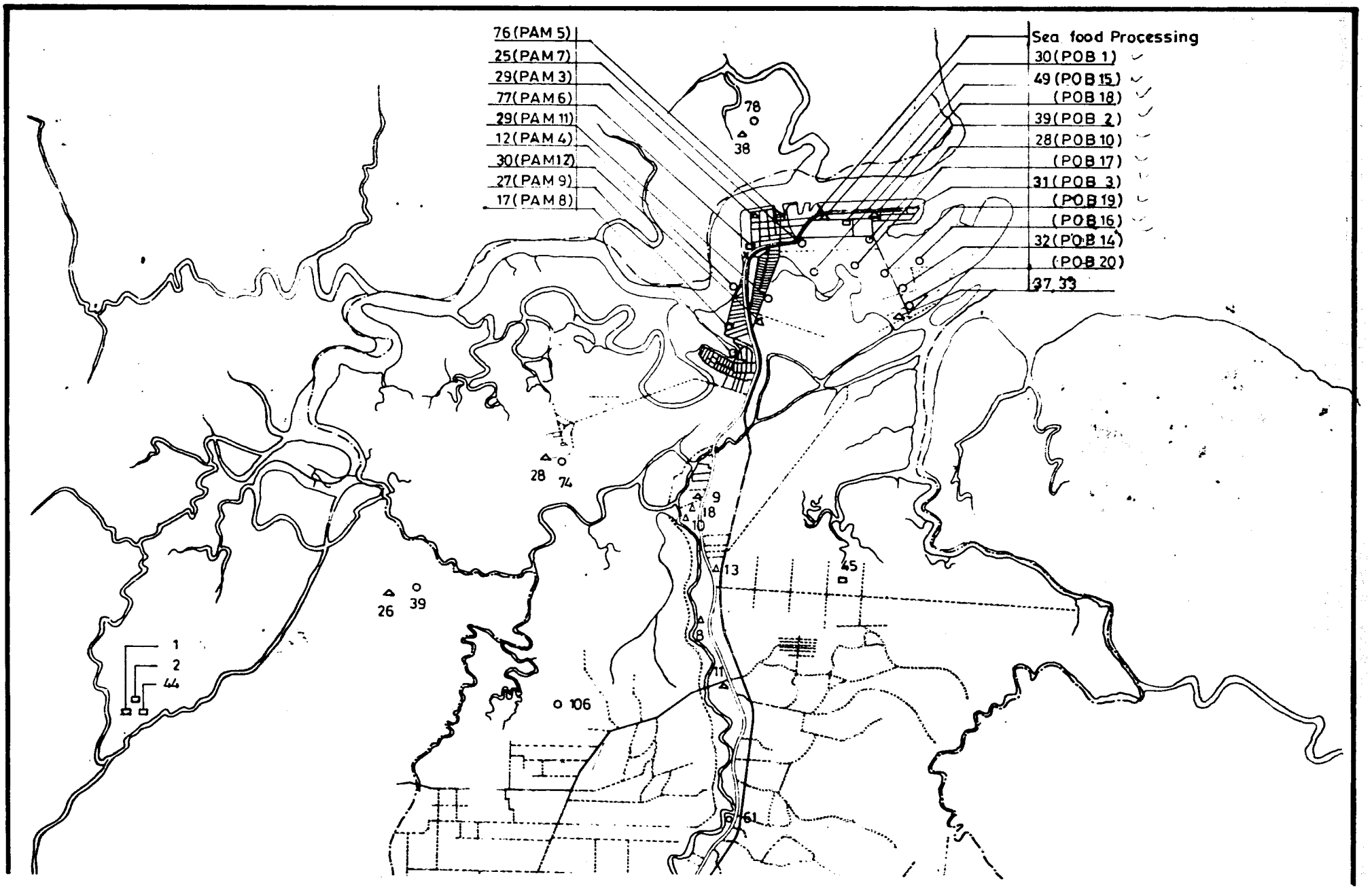
25	Belawan: Jl. Kuburan VI (PAM 4)	1961	130
26	Belawan: Pardede (P.T. Surya Sakti)	-	-
27	Belawan: Dept. Fish (PAM 9)	1962	130
28	Belawan: Jl. Ujung Baru (PoB 10)	1970	160
29	Belawan: Jl. Cipanas (PAM 11)	1971	106
30	Belawan: Kp. Salam (PAM 12)	1971	110
31	Belawan: Gudang 201 (PoB 3)	1971	116
32	Belawan: Bagan Deli (PoB 16)	1971	120
33	Bagan Deli	-	-
39	Hamparan Perak	1970	40
74	Pulau Sicanang	1954	85
78	Sisir Gunting	-	-
88	Tuntungan: Golf Course	-	235
89	Tuntungan: Horse Racing Track	-	-
106	Terjun	-	-
107	Titi Papan	-	-
46	Medan: Tirta Sari (Ice Factory)	1969	140
47	Medan: Mabar (Ice Factory)	1977	126
48	Battalion	-	-
49	Pardede I	1956	-
50	Pardede II	1970	126
51	Pardede III	-	-
52	Pardede A: Food Factory	-	-
53	Pardede B: Shrimp Factory	1971	180
54	Pardede C	-	-
55	Petojo I (Ice Factory)	1920	170
56	Petojo II (Ice Factory)	1959	-
57	Petojo III (Ice Factory)	1968	110
58	University - Engineering School	1946	87
59	Pardede (Shrimp Factory I)	1971	120
60	Pardede (Shrimp Factory II)	1977	210
61	Coca Cola (Battling Factory)	1971	118
62	Tj. Mulia - Mabar	1977	130
63	Danau Toba Hotel I	1972	120
64	Danau Toba Hotel II	1972	140
65	Bank B.D.	-	-
66	Hospital P.N.P. IX	1964	74

PRIVATE WELLS, NOT REGISTERED. RECENT ADDITIONS

Intan Nasional Iron 1	1974	140
2	1978	170
United Rope Co.	1970	135
Asrama Police Barrack	1963	83
Indra-Deli Seafood Factory No. 3 (59 B)	1977	193
Dharma Deli Hotel	1978	200
Garuda Plaza Hotel	1977	210
Polonia Hotel 1 (Abandon)	1977	114
2	1978	200
3	1979	240 e
Medan A.V.R.O.S. (RISPA) No. 2 (78 B)	1977	220
Pemuda Tingkat I Sumut	1978	200

PRIVATE WELLS - SITES UNKNOWN

Leligune Baru Belawan	1962	105
Sebelum Perang	-	200
Jln. Hanafiah (PAM 3)	1966	114
Jln. Langkat (PAM 4)	1950	130
Jln. Sumatra (PAM 6)	1951	130
Leeoni	1952	120
Belawan Km 14	-	1-12


76 (PAM 5)
25 (PAM 7)
29 (PAM 3)
77 (PAM 6)
29 (PAM 11)
12 (PAM 4)
30 (PAM 12)
27 (PAM 9)
17 (PAM 8)
Sea food Processing
30 (POB 1)
49 (POB 15)
(POB 18)
39 (POB 2)
28 (POB 10)
(POB 17)
31 (POB 3)
(POB 19)
(POB 16)
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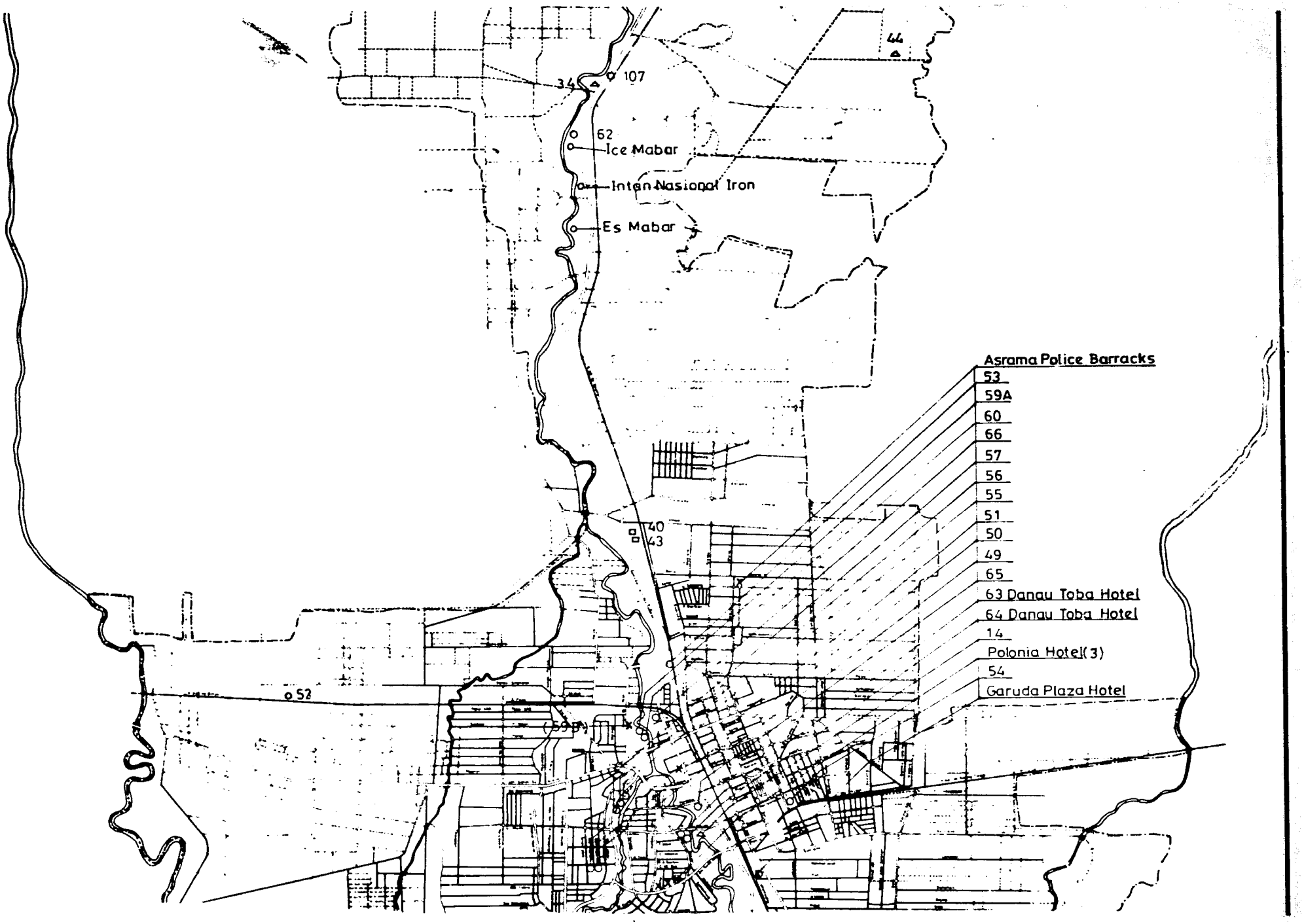
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(59A)
Asrama Police Barracks
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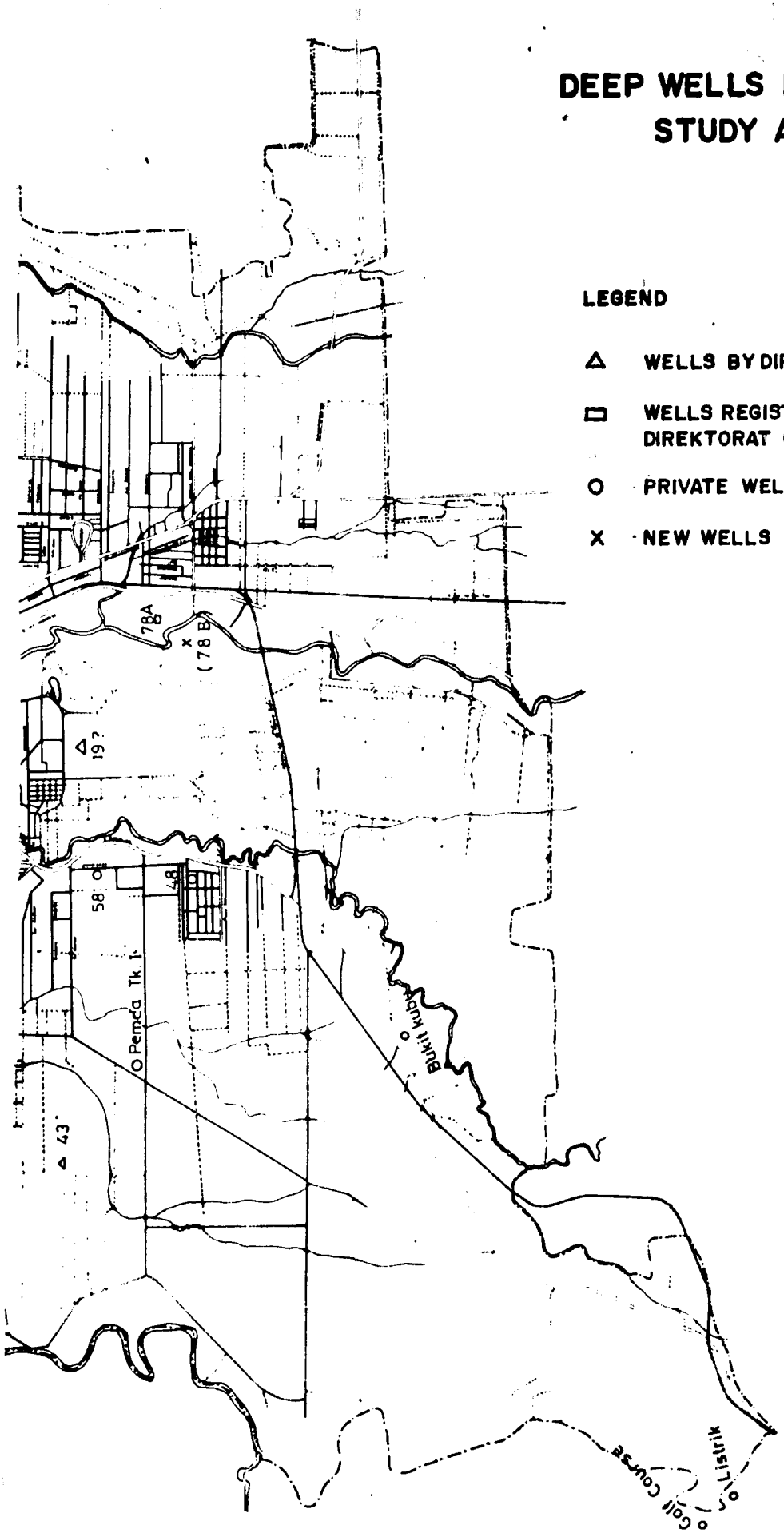
50
49
65
63 Danau Toba Hotel
64 Danau Toba Hotel
14
Polonia Hotel(3)
54
Garuda Plaza Hotel



DEEP WELLS IN MEDAN STUDY AREA

LEGEND

- △ WELLS BY DIREKTORAT GEOLOGI
- ▭ WELLS REGISTERED WITH DIREKTORAT GEOLOGI
- O PRIVATE WELLS (NOT REGISTERED)
- X NEW WELLS (NO NUMBERS)

Total groundwater development may be generally reflected by the number or distribution of known wells, although interviews and review of existing data indicate several factors which strongly influence estimates of production. The only available records of wells production are those of PAM Tirtanadi and the Port of Belawan. The last seven years of production records were reviewed and may demonstrate general trends reported for other wells. Wells generally produce the most water during their first years of operation and then gradually decline in production. Such decline can result from poor construction which causes clogging, inflow of sand, and collapse of the gravel pack. Therefore, initial production estimates will be higher than production after a few years.

Production varys widely by day and hour. Tirtanadi and POB wells are shut off when demand is small (e.g. night-time or holidays), while power failure and low powerline voltage can interupt or reduce production. Among private operators, demand changes, storage tank capacity, poor power supplies, and other factors cause more frequent disruption or reductions in production. Therefore, both the initial estimated production and the pump capacities measures only the maximum well production which may bear little resemblance to actual production.

Production of wells now operated by Tirtanadi has been presented in Section 2 of the Main Report on Water Supply and Sanitation and average monthly production is presented in Table D-1.2. Five operating wells out of six show declines in monthly production, except in 1977 when the wells had been renovated and transferred from the Port to Tirtanadi. After 1977, PAM wells No. 9 and No. 12 continued declines although starting from a higher capacity. Even with an average daily production of 3,000 m^3 or more, the port has provided an additional daily supply of about 1,200 m^3 in order to serve the non-port users in Belawan. This transfer equals about 25 percent of the total water supplied by Tirtanadi and 30 to 50 percent of the production of the port wells, excluding POB No. 19 and 20 which are solely for industrial use.

TABLE D-1.2

AVERAGE MONTHLY PRODUCTION FROM THE
P.A.M. TIRTANADI WELLS IN WESTERN BELAWAN
WELLS AND MONTHLY PRODUCTION (x 1000 m^3/month)

Year	5	6	7	9	11	12	Total
1972	9.2	7.1	3.8	36.0	36.0	30.5	92.10
1973	6.1	5.7	3.2	32.2	18.3	27.7	93.2
1974	6.1	5.5	4.1	31.5	14.6	24.7	86.5
1975	-	4.7	3.8	32.6	15.4	22.6	79.1
1976	5.5	2.1	3.5	33.8	8.9	19.5	73.3
1977[a]	5.1/16.5	0/0.4	3.9/3.6	30.1/27.9	26.9/27.6	18.3/28.8	189
1978	22.2	-	4.1	22.5	28.6	25.7	103
1978	22.8	-	4.8	19.6	29.4	20.0	96.6
Average Daily Production 1979 (m3/d)	760	-	160	653	980	667	3,220 (2,890)[b]
Hourly Production on 18 hour Operation (m3/hr)	42	-	8.9	36	54	37	-

a. 1977 was the year for transfer to PAM Tirtanadi and renovations, only Wells No. 9 and 12 continued similar production.

b. 2,890 is the average daily production for 1972-1976 and 1978.

The Port of Belawan has operated nine wells since 1977 and 14 wells between 1972 and 1977. These wells have produced 70 to 90,000 m^3/month up to 1977 (Table D-1.3.), when production was increased to 180 to 195,000 m^3/month, largely by addition of POB wells 19 and 20 producing about 100,000 m^3/month. Although recent production has remained relatively constant, the level of production has been maintained by adding new wells rather than by increasing or maintaining production from existing wells. Seven of the Port wells have declined in production or have been abandoned. Even wells 16 and 17 have increased production by adding submersible pumps while water levels have declined.

Total Tirtanadi and Port production is now at about 290,000 m^3/month or about 9,350 m^3/d. This is roughly distributed as 3,000 m^3/d by the Tirtanadi wells, 3,000 m^3/d smaller Port wells, and 3,350 by the Port's wells 19 and 20. Over seven years, total production was relatively constant until 1977 when the transfer of wells to Tirtanadi occured.

Review of available data and interviews of technicians working for private well operators indicate that no well is operated at the production approaching that of the larger Port of Belawan well 20 (100 m^3/hr; 2000 + m^3/d. The largest reported initial pumping rate was 60 m^3/hr or 1,440 m^3/d, and most wells were reported to produce 10 to 25 m^3/hr or 240 to 600 m^3/d. Many wells were reported to produce only 3.0 to 5.0 m^3/hr or 36 to 120 m^3/d. Four major hotels, four seafood/food-beverage processing plants, three ice plants, and at least five institutions may have a combined pumping capacity of about 15,000 m^3/d. However, many of these wells are not operated on a 24 hour basis. Production may vary from 3,000 to 9,000 m^3/d (averages of 4 to 14 hour operating schedule).

The combined production of Tirtanadi, Port of Belawan, and other private/institutional wells probably lies between 12,000 and 18,000 m^3/d. An intermediate value of 15,000 m^3/d would equal 5.48 M m^3/yr or about 174 l/s. This production, however, is restricted to a narrow development corridor of 3 km (E-W) and 25 km (N-S) between Medan and Belawan. This area would have an average annual production rate

TABLE D-1.3

AVERAGE MONTHLY PRODUCTION FROM PORT OF BELAWAN WELLS

WELLS AND MONTHLY PRODUCTION (x 1000 m^3/month)

Year	1[a]	2[a]	10[a]	13[a]	14[a]	16	17	18	19	20	Total
1972	12.3[b]	2.8	23.9	40.0	3.1	-	-	-	-	-	82
1973	7.0	3.7	14.6	26.8	18.7	-	-	-	-	-	71
1974	13.0	5.3	21.5	18.7	23.4	-	-	-	-	-	82
1975	12.6	3.1	18.1	30.0	20.0	6.1	-	-	-	-	90
1976	8.6	3.8	20.0	17.0	16.4	4.3	-	-	-	-	70
1977[b]	7.4	-	16.7	15.8	11.4	24.4	15.3	15.1	-	-	190
1978	9.6	-	6.2	5.3	6.8	26.8	23.1	10.1	37.3	62.3	193
1979	7.0	-		6.1	8.4	30.8	30.3	5.4	33.5	71.4	193
Average Daily Production 1979 (m^3/d)	236	-	-	200	280	1,027	1,010	180	1,117	2,380	6,430

a. Wells 1 and 2 began pumping in 1952, 10 in 1971, and 13-14 in 1972. Other wells began production in years of first record.

b. Total includes 84,000 m^3/mo from five wells during three months before wells were transferred to Tirtanadi.

c. Wells 10 and 18 are to be fitted with submersible pumps.

of about 73,000 $m^3.yr/km^2$ or 73 $l.yr/m^2$. No average or modal rates can be estimated for all the wells in Medan and Belawan, but most wells produce less than 50 m^3/hr (1,200 m^3/d).

D-1.6. GEOHYDROLOGY

D-1.6.1. Water Levels and Specific Capcity of Wells

The water levels in the well casings indicate the pressure acting upon the groundwater in the deep aquifers. Differences between the static and pumping water levels is called drawdown and the amount of drawdown per volume withdrawn from the aquifer gives an indication of the permeability and storage of the aquifer. A small volume per metre drawdown indicates that the aquifer is either small or has a low permeability, or both, while a very small drawdown indicates that the aquifer holds a large volume of water which can move rapidly through the aquifer.

Regional water levels indicate the direction of flow in the aquifer. much as pressure levels in a water pipe indicate the direction of flow (Figure D-1.4.). Differences of water level elevations will also indicate the head loss or amount of energy lost in flowing water from one point to another in the aquifer. Long-term regional records may indicate the effects of large scale production, droughts, and possible changes in the hydraulic conditions of the aquifers.

Water levels in Medan and Belawan have not been recorded systematically over the entire region nor at any well over a long period. Some initial and existing values, historic records, and physical structures suggest some trends in well production and the condition of the aquifer. No record of long-term production is available for the entire basin, although most long-term production has occured in Belawan.

During the early part of this century, well drilling logs indicated well water levels in Belawan rose to above ground level +0.5 to +1.5 m). Drillers have reported that coastal aquifers to the north presently have artesian flows above ground level. Well No. 20 was reported to have had a +0.25 m water level above ground

GROUND SLOPE STATIC WATER LEVELS AND REPRESENTATIVE PUMPING WATER LEVELS FROM MEDAN TO BELAWAN

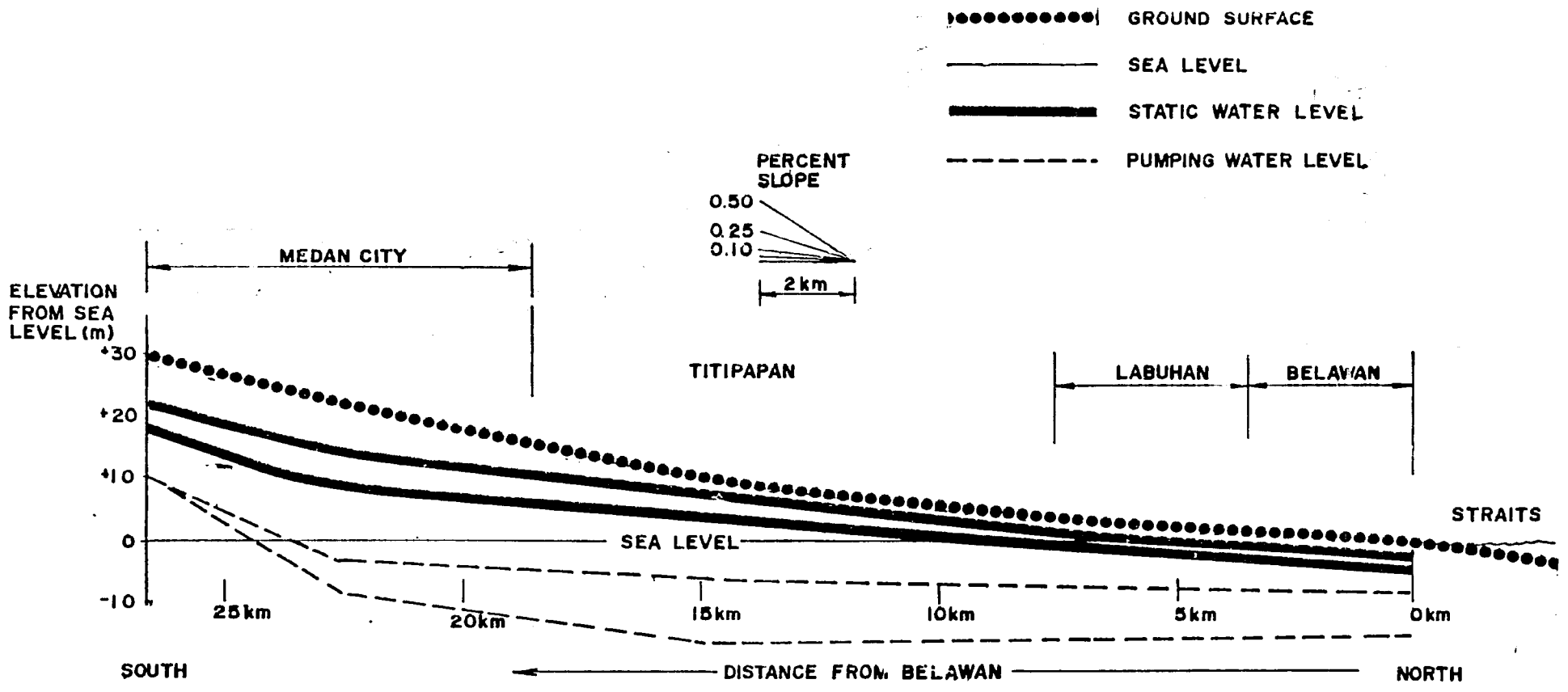


FIGURE D-1.4

level in 1977. Early designs of Belawan and two Medan wells used artesian flows to fill underground tanks from which water was pumped, and the elevations of these structures suggest that artesian flow occured from +0.5 to -3.0 m from ground surface. No well in Belawan or Medan had well water levels above ground surface, although some were within a few metres of surface. Therefore over a span of 30 to 80 years, the water levels from the deep aquifers has fallen from ground level or above down to about 3 m below ground level.

This loss could occur from withdrawals of well water at a rate higher than the rate of recharge, from reduction of rainfall recharge ("droughts"), or from changes in land uses and recharge rates in the areas of deep aquifer infiltration. No readily apparent decrease in annual rainfall appear in available records. The infiltration areas are not defined, although increased growing of rice should increase the flooding of lands and the rates of infiltration in many areas. Groundwater production has been significant over at least the last ten years and this factor should be most related to declines in water levels.

Regional water levels can be seen in Table D-1.4. and vary from 3.0 - 5.0 m below ground surface in Belawan to 6.0 to 13.0 m below ground in Medan. Elevation of the ground level in Medan varys a great deal, although the wells generally lie between 20 and 35 m elevation. In Belawan, all wells lie within 1.0 to 2.0 m above sea level. Water levels vary from 20 to 25 m elevation in Medan to about 1.0 to 3.0 m below sea level in Belawan. The maximum distance between known wells is about 20 to 25 km. Therefore the slope of the hydraulic grade line on the intermediate and deep aquifers is about 1.0 m/1,000 m toward Belawan (south to north). Groundwater flows towards Belawan and appears to follow the general slope of the ground surface.

TABLE D-1.4

WATER LEVELS, DRAWDOWNS, AND SPECIFIC CAPACITIES FOR WELLS IN MEDAN AND BELAWAN WATER LEVELS

Well No. or Site	Static	Pumping	Drawdown (m)	Production (m 3/d)	Specific Capacity (m 3.d/m)
Belawan					
3(PAM)	-3.9 to	-	-	-	-
	-4.6	-	-	-	-
5(PAM)	-4.2 to	-	-	-	-
	-5.1	-	-	-	-
6(PAM)	-4.6	-7.5	3.0	360	120
7(PAM)	-4.5	-6.9	2.4	340	142
9(PAM)	-3.0	-6.5	3.6	720	200
11(PAM)	-3.4	-11.0	7.6	1,200	158
12(PAM-ES)	-2.9	-8.9	6.0	840	140
12(PAM-POB	-2.8	-4.5	1.7	432	254
14(POB)	-2.8	-4.5	1.7	360	212
16(POB-ES)	-5.0	-18.0	13	1,300	100
16(POB)	-4.0	-7.0	3.0	1,300	433
17(POB)	-4.0	-11.5	7.5	1,300	173
19(POB-ES)	-3.5	-11.8	8.3	1,440	173
19(POB)	-0.8	-18	17.2	1,870	109
20(POB-ES)	-3.8	-7.2	3.4	2.690	791
20(POB)	+0.3	-5.0	5.3	1,870	353
Medan					
Rispa 1 (No. 78)	-12.8	-	-	-	-
Rispa 2-ES (No. 78A)	- 5.6	-10.1	4.5	240	53
Danau Toba (No. 63)	-10	-42	32	768	24
	- 8.3	-38.0	29.2	720	25
Indra Deli 3-ES (No. 60)	-11	-16	5	480	96
Polonia Hotel	-10	-50	40	1,440	36
Darma Deli Hotel	-12	-20	8	820	102
Intan Nat'l	-12	-22	10	600	60
Iron INI-ES	-12	-28	16	600	38
Ico Mabar	-10	-	-	-	-
Herna Hospital	- 8	-28	20	960	48
Asrama Police Barrack	- 6	-12	6	600	100

Specific capacity (m^3 produced d/m drawdown) of wells provides a measure of the well efficiency and the aquifer productive capacity. Available records and a series of water level measurements were made for more than 10 wells in Belawan and Medan (Table D-1.4.). Some wells had earlier recorded water levels and comparisons could be made. Generally production has declined in most wells, and where water levels are known less water is now produced per metre of drawdown. Declines in capacity have occured at the same time as regional static water levels have declined, and discrimination of effects of poor well construction from aquifer production cannot be made with the available data.

Comparisons of the Belawan and Medan wells and drawdown (Table D-1.4.) quickly show differences of specific capacity in the two areas. Wells in Belawan had specific capacities from 100 to 790 m^3.d/m drawdown with common values between 100 and 200 m^3.d/m. In Medan, specific capacities vary from 24 to 102 m^3.d/m. Such differences suggest that either the aquifers in Medan had smaller storage, porosity, or permeability or the wells in Medan are not built as well as those in Belawan. Visual inspection of the facilities and reports of the drilling machines used on the wells and well construction would support the latter reason for poor specific capacity in the Medan wells.

In both Medan and Belawan, proper construction and operation have produced up to 100 m^3.d/m drawdown. If this capacity can be applied to new prospective wells, a well which produced a 1000 m 3.d would have a drawdown of only 10 m. Static water levels in Medan were 5 to 12 m below ground surface, and new production pumps would need to be set at greater depths than 25 m below surface and require a pumping head of 60 to 80 m. Pumps of 15 to 20 HP could provide this volume with this head.

D-1.6.2. Storage Capacity

Storage capacity is the volume of water which can be held in the aquifers beneath Medan; it equals the porosity (percent of open space) time the volume of the aquifer. The water level on the aquifer does not directly reflect the storage capacity, although the pressure may have expanded the aquifers' capacities. The effective storage capacity relates to the amount of water which can be withdrawn from the aquifers over a very large area and which will cause the water levels to decline by a unit value. Specific yield relates to the total amount of water which can be drained from a unit volume of aquifer; specific retention equals the amount of water remaining in the aquifer after draining the specific yield (specific yield + specific retention equal total volume of water held in the aquifer). Reported porosities of aquifers in Belawan and east Medan vary from 20 to 30 percent, and a specific yield of 10 percent would be a conservative estimate for the aquifer.

Storage capacity for the Medan aquifers is equal to the groundwater development area of Medan, times the effective aquifer thickness, times the specific yield:

East Medan

6,000 m (E-W) x 15,000 m (N-S) x 70 m (thickness) x 0.10
= 630,000,000 m^3
= 7.0 m^3/m^2 land area or 70,000 m^3/ha

West Medan

8,000 m (E-W) x 10,000 m (n-S) x 70 m (thickness) x 0.10
= 560,000,000 m^3

Belawan Corridor

3,000 m (E-W) x 15,000 m (N-S) x 70 m (thickness) x 0.10
= 315,000,000 m^3

Total of 1,505 M m^3

This volume is about 21.5 M m^3 per metre of aquifer but is not directly related to drawdown of water levels in the well casing. This volume equals a conservative estimate of the specific yield.

Water levels in wells penetrating a pressurized aquifer reflect the total water column in the aquifer and its horizontal extensions. If water movement occurs in the aquifer, then pressure will diminish in the direction of flow; in the Medan study area, water levels fall towards Belawan and are below sea level in Belawan. In a static aquifer, water levels should be identical in all wells penetrating the same aquifer.

When withdrawals exceed the inflow to the total aquifer, the pressure levels will fall and eventually reach the depth at the top of the aquifer, in Medan it is assume to be at about 70 to 90 m below ground surface. If pumping continues, the water level will fall and water will drain from the aquifer - this represent the specific yield and water remaining in the aquifer is specific retention. Decline of the pressure level in well does equal a fall in the water level in peripheral extensions of the aquifer.

D-1.6.3. Subsurface Flow

Groundwater travels through the intermediate and deep aquifers from its recharge areas, probably to the south, to its discharge or outflow areas beneath the Straits of Malaka. Neither recharge or outflow areas are known, although the flow from south to north can be estimated. The outflow represents that volume which is discharged without beneficial human uses. In order to compute the outflow, the values for the wetted cross-sectional area of the aquifer, the slope of the hydraulic gradient of the aquifer and the preliminary of aquifer had to be determined.

The outflow section was considered to be 3 km in width, which is the width of the coastal zone formed by the Belawan and Deli rivers. The effective aquifer thickness was measured in several wells as at least 70 m (about 70 percent of a total 100 m). Slope of the hydraulic gradient between Medan and Belawan was estimated to be 0.001 which is based upon well water levels. The transmissivity of the aquifer was computed from pumping test performed for the Port of Belawan during a previous study. Their value for T which is utilized herein is 565 m^3.d/m.

Based on this value for T, the permeability of the aquifer was computed by the following formula:

$$P = \frac{T}{m}$$

where P = permeability

T = transmissivity

m = aquifer thickness

$$P = \frac{565\ m^3.d/m}{70\ m} = 8.07\ m^2.d/m$$

Using Darcy's equation for underflow:

$$Q = PIA$$

where Q = subsurface outflor

P = coefficient of permeability

I = slope of the hydraulic gradient

A = wetted cross sectional area

$$Q = 8.07\ m/d \times .001 \times 3000\ m \times 70\ m$$
$$= 1695\ m^3/d$$
$$= .02\ m^3/s$$
$$= 20\ l/s$$

D-1.6.4. Safe Yield

The storage capacity beneath Medan is estimated at about 1,500 M m^3 or 22 M m^3/metre of aquifer thickness. Assuming no natural recharge enters the aquifer beneath Medan, one metre of aquifer thickness could supply about five years of production at 12,000 m^3/d (all existing wells). At somewhat lower averaged rates over the last 30 years (9,000 m^3/d), the decline in water levels should have been between 4.0 and 5.0 m, and more than that seen in Belawan about 3 m in 30 years. Such relationship suggest that either:

1. Recharge has an inflow of about 1.1 M m^3/yr (3,000 m^3/d) and has balanced some withdrawals

2. The aquifer is more widespread than presumed with an even larger volume per metre thickness of aquifer, but smaller recharge.

3. The aquifer is less widespread but with a much higher recharge.

4. The lowered water levels in deep wells only reflects local

concentrated pumping, and

5. Some combination of all the above (1) to (4).

These divergent alternatives clearly demonstrate the need for substantial increases in the amount of geohydrological data before any reasonable estimate of groundwater resources can be made. Such data should describe:

1. Form and continuity of the aquifers
2. Location of recharge and outflow
3. Total withdrawals from groundwater
4. Pressure gradients on the deep aquifers
5. Local and regional drawdown, and
6. Porosity and transmissivity.

As an indication of the potential yield for the aquifer, the estimated available storage capacity of 1,500 M m^3 and 22 M m^3/m aquifer thickness could be withdrawn over a period of 30 years at the rate of 50 M m^3/yr. This equals a daily production of about 140,000 m^3/d. Such production withdrawal would lower the water level in the aquifer by about 2.3 m/yr without and recharge.

All major aquifer under Medan are being recharged, but the rates of regional recharge and movement to replenish specific areas may be slower than the rate of with drawals from the aquifers. As indicated above the rate of outflow in Belawan in equal to about 1,700 m^3/d with a withdrawal of about 9,000-12,000 m^3/d. This presume a regional hydraulic gradient of about 0.1 percent (0.001), with increased withdrawals in Medan, the gradients towards central Medan should increase and inflow towards the production wells should increase the replenishment of the producing portion of the aquifer. The inflow will increase towards the permeability of the aquifer sediment. After the rate of inflow reaches the permeability value, no increase will occur and additional withdrawal will lower the groundwater volume held in storage - i.e. mining the groundwater.

The hydraulic gradients on aquifers under Belawan is inclined towards the Straits of Malaka, and deep groundwater flows towards the Straits. If pumping in Medan depresses the regional groundwater pressure levels, the existing flow towards the Straits may be reversed and groundwater

will begin to flow southward towards the Medan wells. Sea water may then infiltrate the aquifer under the Straits, and move towards and eventually pass the wells at Belawan. Sea water has not been observed in any Belawan wells which has been properly drilled, 10 of 20 wells.

D-1.7. GROUNDWATER QUALITY

The quality of groundwater in the Medan study area is best known from the Belawan wells operated by PAM Tirtanadi. Other records are also available for some wells operated by the Port of Belawan. Single records of initial water quality for private wells have been gathered for only eight wells. Drilling contractors report a general improvement of water quality with greater depth down to about 200 or 240 m below the surface. Wells deeper than this may enter the Tertiary bedrock and may encounter some natural gas and oil. Only one well (Port Well No. 15) has been abandoned due to poor water quality; salt water contamination was attributed to improper sealing of the casing and leakage of contamined shallow groundwater. Some preliminary analyses for iron (HACH Kit) have indicated valves of 0.5 to 2.5 mg/l.

Since most wells have long gravel packs (perhaps 100 m) which drain several aquifers, poor quality in the upper aquifers and better quality only in the deeper aquifers cannot be verified or refuted. The shallow groundwater table above 10-15 m below the surface can be assumed to contamined by bacteria, ammonia, hydrogen sulphide, and other chemicals. Presumed iron contamination of the aquifers between 80 and 150 m below surface may indicate leakage of contaminated shallow groundwaters into the deeper aquifers. River and the Sibolangit spring waters contain concentration ranges for iron of 0.3-2.8 mg/l and for chlorides of 0.7-17 mg/l. These are similar to those found in the groundwater.

Since the rivers and the groundwaters in the mountains to the south do contain significant levels of iron and chlorides, the groundwater below Medan and Belawan would be expected to contain similar levels of these elements, and the occurence of better quality water at greater depths could be explained by infiltration

of the better qulaity water from some source other than that of the local rivers of the related aquifers supporting the Sibolangit springs.

Although the temperature of water is not of great significance for the overall quality of water supplies, a trend of higher temperatures in the groundwater was found from Medan to Belawan. Water temperatures in Medan were about 27-29°C, 30°C in Titipapan and Labuhan, and from 31-33°C in Belawan. The temperature of groundwater from 100 m or more below the surface would be normally expected to reach at least 3-5°C warmer than the mean annual surface temperature; for Medan, temperatures of surface water samples ranged from 25° to 28° with a mean annual temperature of about 26°C. Thus the deep groundwater temperatures appear to be slightly cooler than would be expected based upon the surface temperatures and the geothermal temperature gradient of about 1°C per 30 m depth. Temperatures of the spirng waters of Sibolangit vary from 23° to 25°C, and water from the same aquifer could contribute such cool water to the Medan and Belawan aquifers with some increase in water temperature as the water flows northwards. More detailed studied of the water temperature profiles within the water wells (when being drilled, or if developed without gravel packs) could provide indications of leakage of shallow waters into the deeper aquifers or the mixing of waters in the deep aquifer.

In general the water quality of many wells appears to be equal to the water quality of some samples of the rivers of the springs. Although iron is reported at undesirable levels in the groundwater, no restriction is placed against the use of surface or spring waters with similar levels. Surface and well water in other cities and part of Sumatra have similar water quality.