# CHAPTER 4

## Urbanization and Flash Floods.

### 4.1: Urbanization factors and processes.

In this section the urbanization factors and processes are discussed based on:

a- Past, current and future landuse.

b- Population growth, housing, industrialization and government policies.

#### 4.1.1: Past, current and future landuse.

The landuse pattern follows closely the urban process. Currently, urban and associated areas occupy about 5.07 sq.km. or 8% of the sub-basins' total land area. The other 82% are mainly oil palm estates. Although, this percentage of urban and associated areas appeared to be insignificant, the rates of landuse change from agricultural to urban land usage (urbanization rate) with the underlying factors must be considered.

Since 1966, there had been an addition of 4.23 sq.km. of urban and associated area; a 500% increase. The rates are on the increase. From 1989 to 1995, the rate was 0.17 sq. km./ year, giving a total addition of 1.02 sq. km. From 1995 to 1998 February, the rate was 0.34 sq.km./year or doubled the former, giving an addition of 1.02 sq.km.

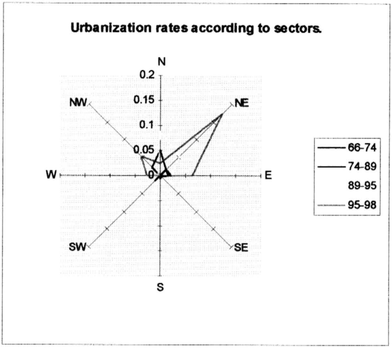
Comparing these rates with previous decades the urban process was more rapid since 1989 (Table 4.1).

Table 4.1
Urban land areas, changes and urbanization rates (1966 - February 1998).

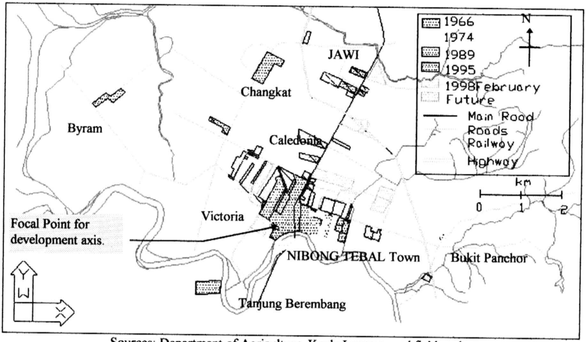
| Urban land area (sq.km) | Sectors according to geographical directions. | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Year | N | NE | E | SE | S | SW | W | NW | Total |
| 1966 | 0.24 | 0.3 | 0.1 | 0.03 | 0.004 | 0.02 | 0.02 | 0.13 | 0.844 |
| 1974 | 0.24 | 0.42 | 0.27 | 0.04 | 0.05 | 0.02 | 0.02 | 0.21 | 1.27 |
| 1989 | 1 | 0.67 | 0.5 | 0.04 | 0.05 | 0.22 | 0.02 | 0.53 | 3.03 |
| 1995 | 1.53 | 1 | 0.63 | 0.04 | 0.05 | 0.22 | 0.02 | 0.56 | 4.05 |
| 1998 | 1.6 | 1.52 | 0.82 | 0.04 | 0.05 | 0.22 | 0.1 | 0.72 | 5.07 |
| Change (sq.km) | | | | | | | | | |
| Period. | N | NE | E | SE | S | SW | W | NW | Total |
| 66-74 | 0 | 0.12 | 0.17 | 0.01 | 0.046 | 0 | 0 | 0.08 | 0.426 |
| 74-89 | 0.76 | 0.25 | 0.23 | 0 | 0 | 0.2 | 0 | 0.32 | 1.76 |
| 89-95 | 0.53 | 0.33 | 0.13 | 0 | 0 | 0 | 0 | 0.03 | 1.02 |
| 95-98 | 0.07 | 0.52 | 0.19 | 0 | 0 | 0 | 0.08 | 0.16 | 1.02 |
| Urbanization Rate- average (sq.km./year) | | | | | | | | | |
| Period. | N | NE | E | SE | S | SW | W | NW | Total |
| 66-74 | 0 | 0.015 | 0.023 | 0.0012 | 0.0057 | 0 | 0 | 0.01 | 0.055 |
| 74-89 | 0.051 | 0.017 | 0.015 | 0 | 0 | 0.013 | 0 | 0.021 | 0.117 |
| 89-95 | 0.088 | 0.055 | 0.022 | 0 | 0 | 0 | 0 | 0.005 | 0.17 |
| 95-98 | 0.023 | 0.173 | 0.063 | 0 | 0 | 0 | 0.026 | 0.053 | 0.34 |

The North, North Eastern and Eastern sectors are more urbanized, constituting about 78% of the current total urban area (Chart 4.1 and Map 4.1). The North Eastern sector currently had the highest rate of change; 0.173 sq. km/year. Other sectors ranged from 0 to 0.63 sq.km./year. The South Eastern, South and South Western sectors remained unchanged since 1974. The South and South Western sectors remained unchanged because available space for expansion is limited by the river. Areas South of Krian River were not taken into analysis because it is beyond the study area. In the case of South Western sector, the current condition is expected to change in future because this sector has been designated for urban usage by Seberang Prai Municipal Council (MPSP).

Chart 4.1



Map 4.1
Expansion of urban areas: 1966 - 1998 February.




Sources: Department of Agriculture, Kuala Lumpur; and fieldwork.
Note: Future landuse is shown on Map 4.2

4.1.2: Current landuse according to drainage units.

The current land uses for each drainage units are listed in the Table 4.2.

Table 4.2
Drainage units and landuse as at 1998 February.

| Drainage units | | landuse in % | | |
|---|---|---|---|---|
| units | area | urban | agriculture | forest |
| A1 | 2.994 | 0.03507 | 0.96493 | 0 |
| A2 | 0.166 | 0 | 0 | 1 |
| | | **0.03** | **0.92** | **0.05** |
| | | | | |
| B11 | 0.22 | 0.51818 | 0.48182 | 0 |
| B12 | 0.105 | 0.33333 | 0.66667 | 0 |
| B13 | 2.83 | 0.06431 | 0.93569 | 0 |
| B14 | 1.502 | 0 | 1 | 0 |
| B15 | 1.805 | 0 | 1 | 0 |
| B2 | 0.174 | 0.5977 | 0.4023 | 0 |
| B31 | 0.153 | 0 | 1 | 0 |
| B32 | 0.08 | 0 | 1 | 0 |
| B41 | 0.276 | 0.08152 | 0.91848 | 0 |
| B42 | 0.075 | 0.27733 | 0.72267 | 0 |
| B5 | 0.43 | 0.36977 | 0.63023 | 0 |
| B6 | 0.412 | 0.58131 | 0.41869 | 0 |
| | | **0.11** | **0.89** | **0** |
| | | | | |
| CA1 | 1.048 | 0.04246 | 0.95754 | 0 |
| CA2 | 0.27 | 0.25926 | 0.74074 | 0 |
| CA31 | 2.731 | 0.01245 | 0.98755 | 0 |
| CA32 | 0.054 | 0 | 1 | 0 |
| CA33 | 0.72 | 0.00833 | 0.99167 | 0 |
| CA34 | 0.136 | 0 | 1 | 0 |
| CA41 | 0.811 | 0.17238 | 0.82762 | 0 |
| CA42 | 0.076 | 0 | 1 | 0 |
| CA51 | 0.74 | 0.49649 | 0.50351 | 0 |
| CA52 | 0.101 | 0.68317 | 0.31683 | 0 |
| CA6 | 0.417 | 0.7458 | 0.2542 | 0 |
| | | **0.15** | **0.85** | **0** |
| | | | | |
| CB1 | 0.107 | **1** | **0** | **0** |
| | | | | |
| CB2 | 0.052 | **1** | **0** | **0** |
| | | | | |
| CC1 | 0.343 | 0.50816 | 0.49184 | 0 |
| CC2 | 0.305 | 0.67213 | 0.32787 | 0 |

| | | | | |
|---|---|---|---|---|
| CC3 | 0.045 | 1 | 0 | 0 |
| CC4 | 0.3 | 0.84667 | 0.15333 | 0 |
| CC5 | 0.085 | 1 | 0 | 0 |
| CC6 | 0.281 | 0.8363 | 0.1637 | 0 |
| CC7a | 0.153 | 1 | 0 | 0 |
| CC7b | 0.1 | 0 | 1 | 0 |
| CC8 | 0.01 | 1 | 0 | 0 |
| | | **0.75** | **0.35** | **0** |
| | | | | |
| CD1 | 1.342 | 0.07004 | 0.80402 | 0.12593 |
| CD2 | 0.24 | 0.68333 | 0.275 | 0.04167 |
| CD3 | 1.817 | 0.12933 | 0.78976 | 0.0809 |
| CD4 | 3.004 | 0.00166 | 0.88182 | 0.11651 |
| | | **0.08** | **0.82** | **0.1** |
| | | | | |
| E1 | 0.247 | **0.16721** | **0.83279** | **0** |
| E2 | 0.535 | **0.2785** | **0.7215** | **0** |
| E3 | 0.7 | **0.11714** | **0.88286** | **0** |
| E4 | 0.916 | **0** | **1** | **0** |

Note: Bold figures are percentage for network total.

Drainage units CC1-CC8, CB2 and CB1 are the most urbanized units, about 75%. They consist mainly of closely built residential and commercial buildings. The rest are agriculture areas, ranging from 85% to 100% of their respective land area.

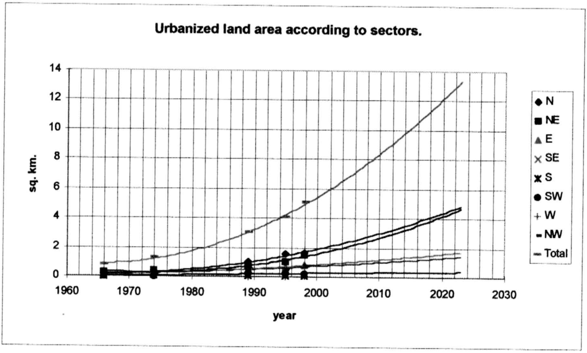
4.1.3: <u>Future landuse.</u>

The spatial and temporal trends of urbanization enable projection of future landuse to be made. The rates shown in Table 4.1 are average rates based on their interval years. However, for purpose of projection, a continuous and consistent rate is used, so that a trendline can be produced. The trendlines for each sector are shown in the Chart 4.2.

The total urbanized areas by the year 2008 are projected to be 7.8 sq.km., and increased to 13.1 sq.km or 22 % of the total sub-basin area by 2023. This is an expansion of 62 %. The Northern and North Eastern sectors are projected to occupy about 64% of the year 2008's total and 55 % of the year 2023's total urban area. These sectors are projected to be more urbanized than the rest. The urban areas on the Eastern and North Western sectors are projected to occupy about 26% in 2008 and 27% in 2023. These sectors would experience moderate urbanization. As for the other sectors, their expansion of urban landuse would be minor.

In conclusion, Nibong Tebal town could be expected to expand towards the North and North East region. This trend is consistent with the Penang State Land Development Master Plan.

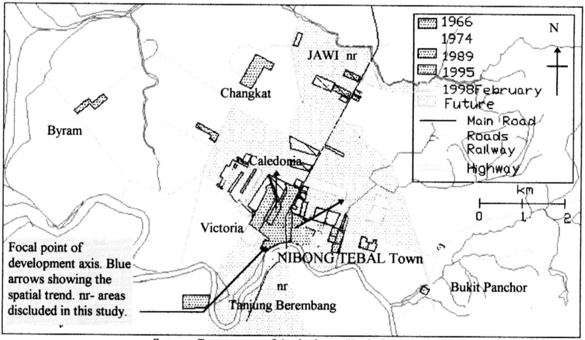
Chart 4.2



For the purpose of studying potential flash floods, the future urban areas are assumed to be equal to the total urban areas designated by the Seberang Prai Municipal Council. The future urban areas are shown on Map 4.2.

Fully urbanized, the total land area size covered 28.5 sq.km. (excluding Jawi and Southern bank of Krian River) or 47% of the sub basin's total land area under study. If the current trends persist, this could be reached within 50 years from 1998.

Map 4.2
Future urban landuse as designated by MPSP.




Source: Department of Agriculture, Kuala Lumpur.

Urbanization is concentrated on the North and North Eastern sectors of the town (refer to Map 4.2). The thrusts are marked by the blue arrows.

The South Western sectors are designated for extensive development under MPSP's plan. Therefore, the current trend for this sector may change drastically in the near future.

The rest will possibly remain agricultural as designated. However, there are provisions for changing the current landuse designation within MPSP's policy. Therefore, this is not absolute.

Table 4.3
Future designated landuse according to drainage units.

| Drainage units | | landuse in % | | |
|---|---|---|---|---|
| units | area (sq. km) | urban | agriculture | forest |
| A1 | 2.994 | 0.32331 | 0.67669 | 0 |
| A2 | 0.166 | 0 | 0 | 1 |
| | | **0.30633** | **0.64114** | **0.05253** |
| B11 | 0.22 | 1 | 0 | 0 |
| B12 | 0.105 | 1 | 0 | 0 |
| B13 | 2.83 | 0.27208 | 0.72792 | 0 |
| B14 | 1.502 | 0 | 1 | 0 |
| B15 | 1.805 | 0 | 1 | 0 |
| B2 | 0.174 | 1 | 0 | 0 |
| B31 | 0.153 | 1 | 0 | 0 |
| B32 | 0.08 | 1 | 0 | 0 |
| B41 | 0.276 | 1 | 0 | 0 |
| B42 | 0.075 | 1 | 0 | 0 |
| B5 | 0.43 | 1 | 0 | 0 |
| B6 | 0.412 | 1 | 0 | 0 |
| | | **0.33428** | **0.66572** | **0** |
| CA1 | 1.048 | 0.06966 | 0.93034 | 0 |
| CA2 | 0.27 | 0.03704 | 0.96296 | 0 |
| CA31 | 2.731 | 0.44855 | 0.55145 | 0 |
| CA32 | 0.054 | 0 | 1 | 0 |
| CA33 | 0.72 | 0.24861 | 0.75139 | 0 |
| CA34 | 0.136 | 1 | 0 | 0 |
| CA41 | 0.811 | 1 | 0 | 0 |
| CA42 | 0.076 | 1 | 0 | 0 |
| CA51 | 0.74 | 1 | 0 | 0 |
| CA52 | 0.101 | 1 | 0 | 0 |
| CA6 | 0.417 | 1 | 0 | 0 |
| | | **0.53041** | **0.46959** | **0** |
| CB1 | 0.107 | **1** | **0** | **0** |

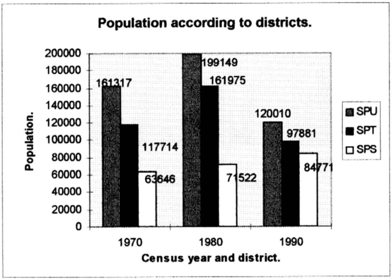
| | | | | |
|---|---|---|---|---|
| CB2 | 0.052 | **1** | **0** | **0** |
| | | | | |
| CC1 | 0.343 | 1 | 0 | 0 |
| CC2 | 0.305 | 1 | 0 | 0 |
| CC3 | 0.045 | 1 | 0 | 0 |
| CC4 | 0.3 | 1 | 0 | 0 |
| CC5 | 0.085 | 1 | 0 | 0 |
| CC6 | 0.281 | 1 | 0 | 0 |
| CC7a | 0.153 | 1 | 0 | 0 |
| CC7b | 0.1 | 1 | 0 | 0 |
| CC8 | 0.01 | 1 | 0 | 0 |
| | | **1** | **0** | **0** |
| CD1 | 1.342 | 1 | 0 | 0 |
| CD2 | 0.24 | 1 | 0 | 0 |
| CD3 | 1.817 | 0.12933 | 0.78976 | 0.0809 |
| CD4 | 3.004 | 0.00166 | 0.88182 | 0.11651 |
| | | **0.28455** | **0.63783** | **0.07762** |
| E1 | 0.247 | **1** | **0** | **0** |
| E2 | 0.535 | **1** | **0** | **0** |
| E3 | 0.7 | **1** | **0** | **0** |
| E4 | 0.916 | **1** | **0** | **0** |

The break down of future land uses according to drainage units are given in Table 4.3. Most of these units will be 30 to 60 % urbanized. Drainage units CC1-CC8 that cover the full extent of Nibong Tebal town will be 100% urbanized. Existing pockets of medium density villages would possibly be redeveloped into closely built up residential area. Drainage units B11, B12, B2, B 31/32, CC1, E3, E4 and part of A2 are designated to be fully industrialized zone. The rest of the urban areas would be residential and commercial zones.

4.1.4: Population growth and housing.

Population growth by district is shown in Chart 4.3.

Chart 4.3

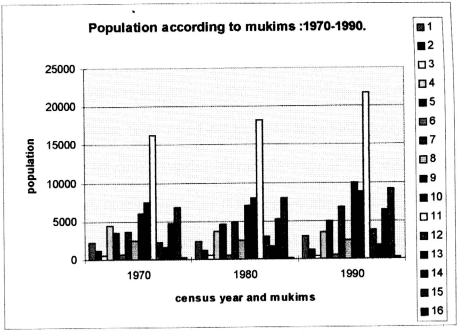



Source: Department of Statistics, Kuala Lumpur.

Note: SPU- Seberang Prai Utara (Northern District of Seberang Prai); SPT - Seberang Prai Tengah (Central District of Seberang Prai); SPS - Seberang Prai Selatan (Southern District of Seberang Prai) where the study area is located.

The Southern District or SPS (study location) is experiencing a gradual increase in population. From the 1970 to 1990 census, 14% increase in total population was recorded. The Northern and Central District (SPU and SPT), had negative growth between 1980 to 1990. This could be due to emigration during the mid 80's economic slump. In 1990, SPS population are 28% of the total population of Seberang Prai. Current data is not available because the next census will be in the year 2000.

Chart 4.4




Source: Department of Statistics, Kuala Lumpur.
Note: Mukims within SPS only.

Table 4.4
Mukim population of 1970-1990, 1995 estimates and projections.

| mukim | 1970 | 1980 | 1990 | rates* | 1995 | 2000 | 2010 | 2015 |
|---|---|---|---|---|---|---|---|---|
| 1 | 2172 | 2354 | 3027 | 0.0166 | 3196 | 3473 | 4100 | 4455 |
| 2 | 1128 | 1156 | 1230 | 0.0043 | 1248 | 1275 | 1331 | 1360 |
| 3 | 459 | 504 | 451 | -0.0009 | 464 | 462 | 458 | 456 |
| 4 | 4440 | 3686 | 3533 | -0.0114 | 3260 | 3079 | 2747 | 2595 |
| 5 | 3496 | 4623 | 4953 | 0.0174 | 5594 | 6102 | 7262 | 7922 |
| 6 | 621 | 547 | 479 | -0.013 | 449 | 421 | 369 | 346 |
| 7 | 3705 | 4816 | 6816 | 0.0305 | 7830 | 9120 | 12372 | 14411 |
| 8 | 2491 | 2450 | 2526 | 0.0007 | 2515 | 2524 | 2541 | 2550 |
| 9 | 6001 | 7014 | 10001 | 0.0255 | 10982 | 12476 | 16099 | 18289 |
| 10 | 7444 | 8022 | 8718 | 0.0079 | 9056 | 9421 | 10196 | 10607 |
| 11 | 16211 | 18229 | 21695 | 0.0146 | 23131 | 24883 | 28795 | 30976 |
| 12 | 2272 | 2946 | 3779 | 0.0254 | 4295 | 4876 | 6287 | 7138 |
| 13 | 1539 | 1738 | 1798 | 0.0078 | 1897 | 1973 | 2133 | 2218 |
| 14 | 4672 | 5295 | 6367 | 0.0155 | 6815 | 7364 | 8599 | 9292 |
| 15 | 6742 | 7949 | 9113 | 0.0151 | 9880 | 10655 | 12392 | 13363 |
| 16 | 253 | 193 | 285 | 0.006 | 263 | 271 | 288 | 297 |
| sum | 63646 | 71522 | 84771 | 0.0143 | 90195 | 96880 | 111775 | 120056 |

Note: * exponential rates. Base year for estimates and projections is 1990.

The population according to mukim for SPS is shown in Table 4.4. The total population for 1995 are estimated to be 90,195, and are projected to reach 120,056 by the year 2015. Mukim 15, 14, 11, 10, 9 and 7 have higher populations. These mukims cover several towns in SPS, namely Simpang Ampat, Sungai Bakap, Jawi and Nibong Tebal. Jawi, Changkat and Nibong Tebal -West are located within mukim 11 and Nibong Tebal -East within mukim 7. Mukims 11 and 7 account for 34% of SPS' estimated population for 1995. Together both mukims have the highest population. Mukim 7 had the highest growth rate. Mukim 11 with the growth rate of 0.0146 (exponential) is considered to be comparatively moderate. Their total populations are projected to reach 45,387 by the year 2015, a 23 % growth from 1990's total and 38% of the projected SPS' total.

From 1970 to 1990, the number of houses had increased from 11,251 to 19,550 for SPS. Based on 1990 census, each house had an average of 4.3 occupants. If there are no changes to the average, the number of houses for SPS area could reach 27,920 units by the year 2015. For mukims 11 and 7, the number of houses could reach 10,609 units.

The implication is clear, higher population means more land areas are needed for housing, commerce and industry.

4.1.5: Industrialization and government policies.

The urbanization phenomenon at Nibong Tebal is not unique when the transformation of Penang's economy is considered.

The details of Penang's economic structure are shown in Table 4.5. The contribution of the manufacturing sector to the state's GDP rose from 12.7% in 1970 to 46% in 1990 and projected to reach 50% by the year 2000. This is among the highest in Malaysia. Agriculture's shares of the GDP decrease significantly, from 19.5% in 1970 to a mere 3.3% in 1990. It is likely to drop below 2 % by the year 2000. Tertiary sectors did not change significantly. It is clear secondary sector will continue to be a major contributor to the state's economy.

Table 4.5
Penang's economic structure 1970-2000.

| Sectors | 1970 | 1980 | 1990 | 2000 |
|---|---|---|---|---|
| Agriculture, livestock, forestry and fishery. | 19.5* | 6.5 | 3.3 | 1.8 |
| Mining and quarrying. | 0.2 | 0.5 | 0.5 | 0.2 |
| Manufacturing. | 12.7 | 41.0 | 46.0 | 50.1 |
| Construction. | 5.8 | 4.2 | 2.9 | 2.2 |
| Electricity, gas and water. | 3.1 | 2.0 | 2.0 | 2.0 |
| Transport, storage and communications. | 7.5 | 9.2 | 11.2 | 11.8 |
| Wholesale and retail trade, hotels and restaurants. | 26.7 | 16.6 | 12.6 | 13.0 |
| Finance, insurance, real estate and business services. | 9.7 | 7.9 | 9.3 | 9.5 |
| Government services. | 4.3 | 9.4 | 9.7 | 7.2 |
| Other services. | 10.5 | 2.7 | 2.5 | 2.3 |

Source: Penang State Government.
Note: * all figures are in percentage.

The impact of industrialization on landuse is obvious. More agriculture land would be converted for residential, commercial and industrial usage.

Penang's economic policy is basically industrial development on a sustainable scale without leaving out other sectors. In pursuing industrial development, more land areas are required. However, land is limited and there are physical, legal and social constraints to development. Hence, optimization of landuse is a key challenge for policy makers and regional planners. Land use policies in Penang are faced with two broad challenges, namely:

1- The optimizations of land use to ensure sustainable growth.

2- The reversal of environmental degradation so as to improve quality of life.

Consequently, land use restructuring and designation became essential. Out of the total land area (105,800) hectares: 16.5% are projected to be built up areas; 2.5 % for public recreation space; rural residential and mixed horticulture 12.0% ; agriculture 60% and natural vegetation 9.0% by the year 2000.

Urbanization in previously agricultural regions like the Southern District are consequences of development strategies that stem out of the economic policy mentioned above. Relevant Penang's agriculture and rural development strategies are:

1- Modernising agriculture.

2- Embarking on a rural industrialization program which includes:

- Locating new industries in rural growth centres.
- Setting up agro-based industries.
- Promoting and assisting small and medium as well as cottage industries.

3- Developing new growth centres. Permatang Tok Mahat, Nibong Tebal and all the way to Simpang Ampat and Batu Kawan are designated to be major growth centres. These new growth centres will be complete with industrial, residential and commercial zones. The transformation had already begun.

Relevant land use and urban redevelopment strategies are:

1- Harmonizing land uses to ensure sustainable development.

2- Planning of spatial land use in an integrated manner involving 'ecological units', namely the coastal zones and river basins.

3- Diverting development pressures to new growth centres (mentioned above). Urban development will be dispersed to new growth centres to spread out development and alleviate socio-economic, spatial and environmental problems as well as rural-urban disparities. A functional hierarchy of towns for the state which will be based on the 'greater' or 'corridor' concept will be adopted.

Another policy that shaped the rural landscape is embedded in the demographic and human resource development strategies. One of the long term demographic plan is to have 60% of Penang population on Seberang Prai.

Under the Town and Country Planning Act (1976), Structure and Local Plans are prepared by Local Authority (MPSP- Department of Town Planning and Adornment). Local plans are details at district level that must conform to the Structure Plan. Part IV of the Act on Planning Control requires developers to obtain "Planning Permission" before commencing, undertaking or carrying out any development. This is an instrument of development control adopted by the government. As a result, development is to be carry out on designated areas only. However, there are legal instruments to convert land area designated for agriculture use to urban land use. In such cases, the approval State Authority under the National Land Code is required.

In short, rural areas like SPS under the state policy will inevitably experience land use conversion from agricultural to industrial and residential land usage .

4.2: Flood events.

Flood events in the study area are:

1990, 20-22 September: Severe flooding occurred in all districts except the Northern District. However, Nibong Tebal was slightly effected.

1991, 2-6 June: Penang was hit by the worst flood in 33 years as a result of heavy rainfall (30-33 years return period). Nibong Tebal was affected (refer Map 4.3).

Recorded flood depths ranged from 0.2m to 0.6m. Recorded rainfalls were 150mm at Bukit Panchor and 179 mm at Sungai Bakap. Total flooded area was 2.3 sq. km. Flood lasted for 24 to 48 hours. Heavy rain caused river bunds to overflow. Details on flooded areas are stated below.

- 3-6 June: Kg. Paya Kemian and Kampung Surau were flooded. Flood depths ranged from 0.1m to0.35m; covering a total area of 0.8 sq.km. for 24 hours.
- 3-4 June: Nibong Tebal town, Victoria and Kepala Batas were flooded. Flood depths ranged from 0.1 to 0.5 m; covering a total area of 1 sq.km. for 24 hours.
- 3-4 June: Tiram River and Byram were flooded. Flood depths ranged from 0.3m to 0.6 m, covering a total area of 0.5sq.km. for 48 hours.

1992: No flood was reported for SPS. Only one severe case in SPT. Elsewhere, only minor incidences.

1993, November: Parts of SPS, SPT, SPU and Penang Island were flooded. Details on flooded areas (for Nibong Tebal only) are stated below.

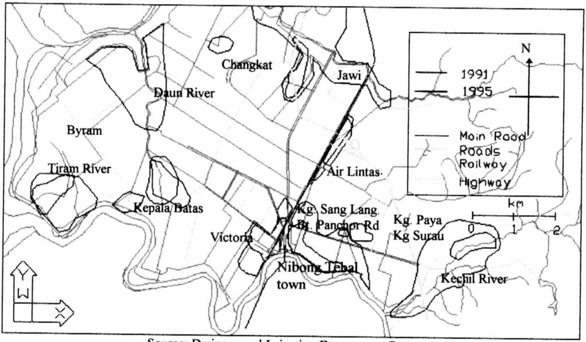
- 1 November: Methodist Secondary School, Tong Hai village and Taman Sri Nibong in Nibong Tebal were flooded. Average flood depth was 0.5m. Total flooded area was 0.6 sq. km.
- 10-13 November: Byram Road was flooded. A total area of 3.5 sq.km. was flooded to the depths of 0.3m to 0.6m.

18 September, 1995: Penang state was hit by a very severe flood. Nibong Tebal was severely affected (refer to Map 4.3). Recorded flood depths ranged from 0.5m to 1 m. Recorded daily rainfalls were 190 mm at Sungai Bakap and 110mm Bukit Panchor (return period of 1 in 100 years). Total flooded area was 4.5 sq.km. Flood lasted for 12 to 48 hours. The cause of flooding was due to heavy rain. Details on flooded areas are as below.

- 18 September: Bukit Panchor Road, Taman Bersatu and Sang Lang village were flooded. Flood depths ranged from 0.2 to 0.5m; covering a total area of 0.15 sq.km. for 12 hours.
- 18 September: Nibong Tebal town , Victoria and Telok Ipil were flooded. Flood depths ranged from 0.2 to 0.5 m; covering a total area of 0.92 sq.km. for 12 hours.
- 18-19 September: Tiram River and Byram were flooded. Flood depths ranged from 0.2m to 0.3m; covering a total area 2.8 sq.km. for 48 hours.
- 18-20 September: Daun and Mati River were flooded. Flood depths ranged from 0.2m to 0.5m; covering a total area of 3.1 sq.km. for 48 hours.
- 18-19 September: Air Lintas was flooded. Flood depths ranged from 0.2m to 0.6m; covering a total area of 0.5 sq.km. for 48 hours.
- 18-19 September: Kechil River was flooded. Flood depths ranged from 0.2m to 1.0m; covering a total area of 2.6 sq.km. for 48 hours.

1996, 21 October: Parts of SPS were flooded including Nibong Tebal. Flooded areas in Nibong Tebal were Methodist Secondary School, Pinang village and Tong Hai village. Recorded flood depths ranged from 0.15m to 0.25 m. Total flooded area was 0.02 sq.km. Flood lasted for 12 hours. Flooding was caused by heavy rainfall coinciding with high tide.

Map 4.3
Flood boundaries for 1991 and 1995 (major floods).



Source: Drainage and Irrigation Department, Penang.

The available flood reports concentrated more on major flood events. Flash floods occurred more frequently in Nibong Tebal than what were being reported. Past events were briefly documented. Efforts had been made by the researcher to gather more details concerning past and present flash flood events. The compiled details are shown in Table 4.6.

Table 4.6
Flash flood events in Nibong Tebal Town*, 1996 to 1998 May.

| Date. | Depth (m). | Extent (sq.km.). | Duration (hr) | Daily Rainfall (mm). | Rainfall Intensity (mm/hr). | Tidal condition (m LSD)** |
|---|---|---|---|---|---|---|
| 22-23/4/96 | *** | | | 49.7 | | +0.22 - +0.8 |
| 16-17/9 | | | | 17.5 | | -0.84 - +1.00 |
| 8-9/10/96 | | | | 60.4 | | +0.8 - +0.31 |
| 21/10 | 0.15-0.25 | 0.02 | 12 | 35.06 | | +0.17 - +0.5 |
| 11/10 | | | | 15.0 | | +0.7 - +0.3 |
| 16/10 | | | | 19.3 | | +1.00 - +0.5 |
| | | | | | | |
| 15/4/97 | | | | 59.6 | | +0.3 - +0.5 |
| 22/8 | | | | 76.9 | | +1.2 - +0.29 |
| 25/8 | | | | 9.7 | | +0.1 - +0.5 |
| 6/9 | | | | 41.7 | | +1.2 - +0.1 |
| 13-14/10 | | | | 50.2 | | +0.01 - +0.4 |
| 22-23/10 | 0.3-0.5 | 0.5 | | 29.3 | | +0.5 - +0.6 |
| 13/11 | 0.2-0.3 | 0.2 | | 31.5 | | +0.9 - +0.3 |
| 18/11 | 0.2-0.3 | 0.2 | | 8.3 | | +0.5 - +0.3 |
| | | | | | | |
| 7/1/98 | 0.25-0.3 | 0.2 | 4 | 36 | 54 | -0.92 - +0.64 |
| 28/1 | 0.2-0.3 | 0.2 | 1.5 | 27 | 64.8 | -0.9 - -0.7 |
| 6/2 | 0.25-0.3 | 0.2 | 2 | 36 | 36 | -0.88 - +0.24 |
| 28/3 | 0.25-0.3 | 0.2 | 3 | 40 | 42 | -1.44 - +1.08 |
| 6/5 | 0.25-0.36 | 0.3 | 6 | 85 | 56.6 | +0.5 |
| 22/6 | | | | 11 | | +0.75 - -0.5 |
| 25/6 | 0.25-0.3 | 0.2 | | 69 | | +0.83 - -0.72 |
| 26/7 | 0.25-0.36 | 0.3 | 8 | 85 | | +1.25 - +0.93 |

Sources: Drainage and Irrigation Department, Penang, Bagan Serai and Ampang; Malaysian Meteorological Service, Petaling Jaya; Methodist Secondary School, Nibong Tebal; fieldwork.
Notes: ***-data not available.**-Mean Tide is at 0.479m LSD.*-This table is for the Nibong Tebal town and its peripheral areas only (specifically drainage units: CC1-CC8,CB1 and CB2).

This compilation of flash flood events is by no means complete. However, it is the best available. As shown above, flash floods were frequent. For the year 1996, there were six incidences; 1997, 8 incidences and up to the month of July this year, 8 cases. The frequency of flash floods had increased from 0.5/month (1996) to 1.14/month (July

1998). The increase in frequency coincided with the higher urbanization rate experienced since 1990. Thus, the urban process could have induce this increase in frequency of flash floods.

80% of the cases occurred during the inter monsoon season when this area experience higher rainfall. Hence, the number of cases for 1998 could be expected to increase during the coming September-October inter monsoon period.

The flood depths usually ranged from 0.2m to 0.3m; covering a total area of 0.2 sq.km. (town and peripheral area only). Flood duration varies according to a combined factor of tidal condition, rainfall duration and intensity. This combined factor will be discussed in the later section.

For flash flood events from January to May 1998, their rainfall durations were 40, 25, 60, 77 minutes respectively. Assuming their rainfall to be normally distributed, the time lag between maximum rainfall intensity and peak discharge are as following: 32.5, 17.5, 15, 10 minutes respectively. These readings were taken at first design point (DP1) of the CC1-CC8 drainage network located at the Methodist Secondary School culvert. The time lags are short. This is because the concentration time is short. The estimated concentration time at DP1 is within 26 to 22 minutes for rainfall intensities of 25mm/hr to 85 mm/hr (rainfall duration assumed to be 1 hour). A very short lag reflects the surface condition. Drainage units CC1-CC8, CB1 and CB2 are about 70-100% impervious, consisting of closely built buildings.

For vegetated areas with scant undergrowth, a major portion of the unintercepted rainfall formed the surface runoff because infiltration rate is low. Infiltration rates did not differ much under different degrees of saturation for rainfall intensities above 10 mm/hr. This implied that the surface runoff will be high even in season where there is a deficit in soil moisture content.

Most of the flood events occurred during heavy rainfall coinciding with high tide. All the drainage outlets for this area are located between -0.9 to -1.9 m LSD and are submerged during high tide. As a result, their discharge ability was greatly reduced and in some outlets impossible during those flood events. This condition was further aggravated by incapacitated drains. As a result, overflowed drains and backwater effect flooded the lower areas.

The flood prone areas are Tong Hai village, Pinang village, Sang Lang village, Methodist Secondary School and Taman Nibong Tebal. As discussed earlier (Chapter 3), these areas are depressions.

Although, there were no lost of lives or major flood damages, it disrupts daily commercial activities especially in Taman Nibong Tebal. The effects on school activities are the worst. In 1996 and 1997, on a number of occasions students had been dismissed early because class rooms wère flooded. In areas outside of Nibong Tebal town, work had to be stopped when plantations got flooded.

### 4.3: Current flood mitigation measures.

A brief description and evaluation of the current flood mitigation measures are:

1- Main drains and tidal gates - discharge capacity and efficiency.

2- Other mitigation measures.

#### 4.3.1: Main drains and tidal gates.

The present conditions of drains are shown in Table 4.7a. Evaluations are based on rainfall intensities of 1 in 1, 10 and 50 years return period. The first return period is considered to be the lowest evaluation level. Rainfall durations are assumed to be equivalent to the time of concentration and 1 hour.

For level one evaluation (rainfall intensity equals to 2.5cm/hr), most unit's peak discharges do not exceed their respective drain capacity. Exceedences occured at drainage unit CA1, CA2, CD1, CD3, CD4 and E4. Except for unit CA2, the others are serious, having their capacities exceeded by 0.3 to 5 times. Obviously, these conditions will be more serious at higher rainfall intensities.

Table 4.7a
Drain capacity- present.

| Drainage Units. | Drain capacity (cumecs) | Drainage Units' peak discharge when rainfall duration= Tc (cumecs) | | | | Drainage Units' peak discharge when rainfall duration= 1 hr. (cumecs) | | |
|---|---|---|---|---|---|---|---|---|
| | | Rainfall Intensities (cm/hr) Tr=1,10,50 | | | | Rainfall Intensities (cm/hr) Tr=1,10,50 | | |
| | Q=VA | 2.5 | 6 | 8.5 | | 2.5 | 6 | 8.5 |
| A1-A2 | 15.4582 | 1.08361 | 11.4524 | 19.132 | | 1.05444 | 11.2358 | 18.8242 |
| | | | | | | | | |
| B13* | 19.3161 | 4.60633 | 26.8821 | 43.5967 | | 4.41596 | 25.946 | 42.1779 |
| B2 | 6.4446 | 0.53961 | 1.43499 | 2.06866 | | 0.61363 | 1.67527 | 2.43721 |
| B31/32 | 6.11926 | 0.35978 | 1.19834 | 1.80708 | | 0.41524 | 1.42411 | 2.16998 |
| B41/42 | 6.88417 | 0.70551 | 2.04233 | 3.00932 | | 0.74469 | 2.20263 | 3.26924 |
| B5 | 6.4446 | 1.13368 | 3.03447 | 4.39528 | | 1.12843 | 3.06325 | 4.46498 |
| B6 | 10.5011 | 1.27815 | 3.39422 | 4.89089 | | 1.40559 | 3.83718 | 5.58308 |
| | | | | | | | | |
| CA1 | 0.15479 | 2.16477 | 4.09809 | 6.75758 | | 1.89447 | 3.58911 | 5.92011 |
| CA2 | 0.21798 | 0.29665 | 1.40374 | 2.19178 | | 0.29665 | 1.42023 | 2.22712 |
| CA31* | 36.3637 | 1.36039 | 14.4008 | 23.7349 | | 1.44866 | 15.7042 | 26.095 |
| CA41/42 | 12.3364 | 2.22265 | 6.11329 | 8.87479 | | 2.51173 | 7.15655 | 10.5347 |
| CA51/52 | 4.2187 | 2.41684 | 4.42294 | 7.97499 | | 2.33226 | 4.39862 | 7.97499 |
| CA6 | 7.59914 | 1.27826 | 3.51754 | 5.17399 | | 1.31354 | 3.73537 | 5.56133 |
| | | | | | | | | |
| CB1 | 2.07285 | 0.36588 | 1.01513 | 1.49713 | | 0.43359 | 1.24534 | 1.8609 |
| CB2 | 0.47583 | 0.21358 | 0.56361 | 0.80685 | | 0.24783 | 0.67739 | 0.98304 |
| | | | | | | | | |
| CC1 | 3.1656 | 1.07022 | 2.82641 | 4.06522 | | 1.23805 | 3.37888 | 4.91906 |
| CC2 | 2.59638 | 1.05531 | 2.78466 | 3.99699 | | 1.23278 | 3.36647 | 4.89499 |
| CC3 | 0.90701 | 0.16122 | 0.50223 | 0.71867 | | 0.18337 | 0.5916 | 0.85854 |
| CC4 | 4.18149 | 1.06056 | 2.81736 | 4.05166 | | 1.26341 | 3.45193 | 5.01371 |
| CC5 | 3.53401 | 0.33196 | 0.87865 | 1.26022 | | 0.39709 | 1.08537 | 1.5751 |
| CC6 | 2.25056 | 0.99284 | 2.63581 | 3.78986 | | 1.1855 | 3.23897 | 4.70468 |
| CC7a | 1.92379 | 0.61285 | 1.61884 | 2.3193 | | 0.72945 | 1.99384 | 2.89349 |
| CC7b | 3.45495 | 0.21418 | 0.5687 | 0.82555 | | 0.23306 | 0.63435 | 0.92874 |
| CC8 | 34.7799 | 0.04652 | 0.12425 | 0.17844 | | 0.04956 | 0.13547 | 0.1966 |
| | | | | | | | | |
| CD1 | 0.65296 | 2.70147 | 7.15846 | 10.3686 | | 2.50475 | 6.67789 | 9.69657 |
| CD2 | 0.85737 | 0.74992 | 1.9973 | 2.87825 | | 0.72633 | 1.95445 | 2.82721 |
| CD3 | 2.57399 | 3.81875 | 10.2126 | 14.8312 | | 3.34461 | 8.94953 | 13.001 |
| CD4 | 0.86773 | 5.55124 | 14.8105 | 21.5382 | | 4.84549 | 12.9287 | 18.8049 |
| | | | | | | | | |
| E1 | 2.55657 | 0.56943 | 1.53123 | 2.23384 | | 0.63869 | 1.7602 | 2.58968 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| E2 | 11.5738 | 1.3958 | 3.70468 | 5.35436 | | 1.48423 | 4.04662 | 5.90371 |
| E3 | 7.31994 | 1.53254 | 4.13052 | 6.03079 | | 1.46898 | 3.98738 | 5.83631 |
| E4 | 1.763 | 1.89589 | 5.06747 | 7.37486 | | 1.78671 | 4.80382 | 7.00543 |

Note for Table 4.7a and 4.7b: *Drainage units B13 includes B 11,12,14 and 15; CA31 includes CA 32,33,34. Figures in red indicate drain capacity being exceeded by peak discharge.

For level two evaluations (rainfall intensity of 6 cm/hr), 36 % of the drains had their capacities exceeded by 1 to 16 times. The worst case is at drainage unit CD1.

For level three evaluations (rainfall intensity of 8.5 cm/hr), most drains had their capacity exceeded. At 1 in 50 years return period level, their capacities were exceeded by 9 to 24 times. The worst cases are at drainage units CD1, CD4 and CA1.

As for drainage units B2, B31/32, B41/42, B5, B6, CA31, CA41/42, CA6, CB1, CC3, CC5, CC7b, CC8, E1 and E2, their capacities were not exceeded in an any case. Therefore, they are considered to be sufficient for the present condition and for the rest improvement are needed.

Table 4.7b shows the future conditions. No drainage improvement is assumed for future conditions. The evaluations showed that for level one evaluation (rainfall intensity equals to 2.5cm/hr), most unit's peak discharges do not exceed their drain capacity. Exceedance occurs at drainage units CA1, CA2 , CD1, CD3, CD4 and E4. Except for CA2, the others are serious, having their capacities exceeded by 1 to 5 times. Obviously, a more serious condition can be expected for higher rainfall intensities.

Table 4.7b
Drain capacity- future.

| Drainage Units. | Drain capacity (cumecs) | Drainage Units' peak discharge when rainfall duration= Tc (cumecs) | | | | Drainage Units' peak discharge when rainfall duration= 1 hr. (cumecs) | | |
|---|---|---|---|---|---|---|---|---|
| | | Rainfall Intensities (cm/hr) Tr=1,10,50 | | | | Rainfall Intensities (cm/hr) Tr=1,10,50 | | |
| | Q=VA | 2.5 | 6 | 8.5 | | 2.5 | 6 | 8.5 |
| A1-A2 | 15.4582 | 3.98785 | 16.6392 | 25.8061 | | 3.89148 | 16.3639 | 25.4472 |
| | | | | | | | | |
| B13* | 19.3161 | 6.92442 | 31.1542 | 49.1732 | | 6.64489 | 30.0955 | 47.6109 |
| B2 | 6.4446 | 0.62913 | 1.68479 | 2.42832 | | 0.73882 | 2.01944 | 2.93065 |
| B31/32 | 6.11926 | 0.85629 | 2.28587 | 3.29074 | | 1.02444 | 2.80014 | 4.06362 |
| B41/42 | 6.88417 | 1.24332 | 3.34441 | 4.82807 | | 1.34724 | 3.68245 | 5.34405 |
| B5 | 6.4446 | 1.50838 | 4.06668 | 5.87542 | | 1.5289 | 4.17899 | 6.06464 |
| B6 | 10.5011 | 1.50013 | 4.01167 | 5.77907 | | 1.70654 | 4.66454 | 6.76927 |
| | | | | | | | | |
| CA1 | 0.15479 | 2.23073 | 4.30752 | 7.02089 | | 1.95218 | 3.77253 | 6.15079 |
| CA2 | 0.21798 | 0.29667 | 1.40374 | 2.19178 | | 0.29618 | 1.42023 | 2.22712 |
| CA31* | 36.3637 | 6.15754 | 22.9265 | 34.8428 | | 6.62547 | 25.2157 | 38.6061 |
| CA41/42 | 12.3364 | 3.69331 | 9.7434 | 13.9447 | | 4.17299 | 11.4062 | 16.5528 |
| CA51/52 | 4.2187 | 3.01465 | 8.08772 | 11.6647 | | 2.99722 | 8.1924 | 11.889 |
| CA6 | 7.59914 | 1.57559 | 4.18684 | 6.01622 | | 1.68621 | 4.60896 | 6.68862 |
| | | | | | | | | |
| CB1 | 2.07285 | 0.43193 | 1.14029 | 1.63323 | | 0.51178 | 1.39887 | 2.03007 |
| CB2 | 0.47583 | 0.21362 | 0.56361 | 0.80685 | | 0.24783 | 0.67739 | 0.98304 |
| | | | | | | | | |
| CC1 | 3.1656 | 1.35007 | 3.57032 | 5.11893 | | 1.56153 | 4.26819 | 6.19409 |
| CC2 | 2.59638 | 1.22459 | 3.23383 | 4.63269 | | 1.4303 | 3.90948 | 5.67351 |
| CC3 | 0.90701 | 0.19032 | 0.50223 | 0.71867 | | 0.21644 | 0.5916 | 0.85854 |
| CC4 | 4.18149 | 1.13395 | 3.01308 | 4.3295 | | 1.35063 | 3.69173 | 5.35752 |
| CC5 | 3.53401 | 0.33201 | 0.87865 | 1.26022 | | 0.39709 | 1.08537 | 1.5751 |
| CC6 | 2.25056 | 1.06651 | 2.83222 | 4.06861 | | 1.27329 | 3.48033 | 5.05072 |
| CC7a | 1.92379 | 0.61295 | 1.61884 | 2.3193 | | 0.72945 | 1.99384 | 2.89349 |
| CC7b | 3.45495 | 0.35901 | 0.96283 | 1.3885 | | 0.40266 | 1.1006 | 1.5972 |
| CC8 | 34.7799 | 0.04652 | 0.12425 | 0.17844 | | 0.04956 | 0.13547 | 0.1966 |
| | | | | | | | | |
| CD1 | 0.65296 | 4.87916 | 13.0517 | 18.8039 | | 4.5588 | 12.2687 | 17.715 |
| CD2 | 0.85737 | 0.86316 | 2.31406 | 3.33664 | | 0.8467 | 2.28999 | 3.31204 |
| CD3 | 2.57399 | 3.79623 | 10.1647 | 14.7686 | | 3.32527 | 8.90965 | 12.9493 |
| CD4 | 0.86773 | 5.55182 | 14.8105 | 21.5382 | | 4.846 | 12.9287 | 18.8049 |
| | | | | | | | | |
| E1 | 2.55657 | 0.93541 | 2.48483 | 3.57005 | | 1.12388 | 3.07193 | 4.45805 |
| E2 | 11.5738 | 2.05786 | 5.45528 | 7.83065 | | 2.3837 | 6.51545 | 9.45535 |
| E3 | 7.31994 | 2.56055 | 6.8414 | 9.85216 | | 2.78366 | 7.60868 | 11.0419 |
| E4 | 1.763 | 3.33717 | 8.92332 | 12.8541 | | 3.53552 | 9.66375 | 14.0242 |

For level two evaluations (rainfall intensity of 6 cm/hr), 46 % of the drains had their capacities exceeded by 1 to 19 times. The worst case is at drainage unit CD1.

For level three evaluations (rainfall intensity of 8.5 cm/hr), most drains had their capacity exceeded. At 1 in 50 years return period level, their capacities are exceeded by 9 to 28 times. The worst cases are at drainage units CD1, CD4 and CA1.

As for drainage units B2, B31/32, B41/42, B5, B6, CA31, CA6, CC3, CC5, CC7b, CC8 and E2, their capacities were not exceeded in an any case.

These exceedence factors indicate the drain performance in handling peak discharges. Higher exceedence factor means poorer the performance. It also means higher overbank flow, causing more severe flooding.

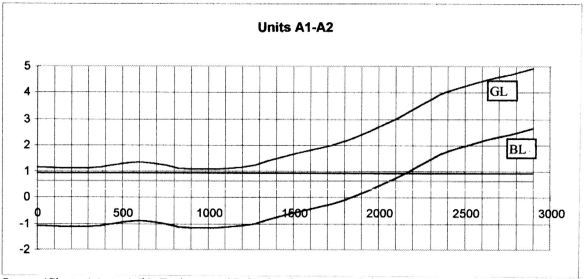
More drains will have their capacities exceeded under future condition. Therefore, drainage improvements are needed to manage higher discharges in the future.

The above analysis are only concern with each unit's peak discharges and not the accumulated peak discharges along their drainage networks. The above analysis is useful for renetworking the drainage units. Cases of exceedences resulting from accumulated peak flows or discharges will be discussed in Section 4.4.

Besides insufficient capacities, lack of standardization of drainage design and maintenance had made a number of drainage sections inefficient. Further discussions on drainage inefficientcy are being made below.

Units A1-A2 (Chart 4.5a): The trunk drain is incapacitated by dense vegetation. Its profiles are shown below. From section 0m to 2000m, the bed levels are below mean tide (0.479 m LSD). As a result, under normal tidal condition, this section is ineffective, having partial flow only.

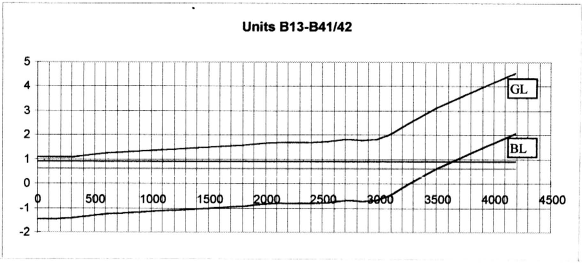
Chart 4.5a




Source (Charts 4.4a to 4.4h): Drainage and Irrigation Department, Seberang Jaya.
Note for Charts 4.4a to 4.4h : Y axis represent elevation in metres LSD. X axis reperesent horizontal distance in metres. The three horizontal linear lines represent flood depth of 1,2 and 3 feet above 0 LSD. GL-ground level, BL-bed level.

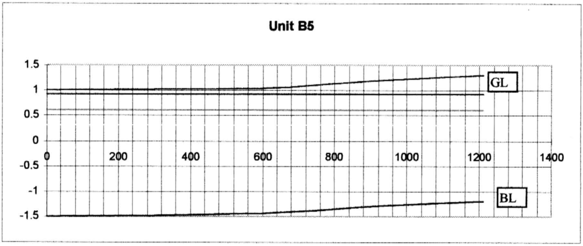
Units B13-B41/42 (Chart 4.5b): Moderately vegetated. For section 0m to 3500m, bed levels are below mean tide, making this section ineffective under normal tidal condition.

Chart 4.5b




Unit B5 (Chart 4.5c): Moderately vegetated. The whole section is effected by normal tide. In events of severe flood, the outlet section could be submerged. This section is connected to drainage unit B13.

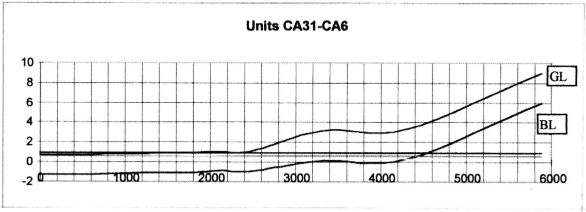
Chart 4.5c



Units CA31-CA6 (Air Lintas to Sang Lang village): The trunk drain is well maintained with minimal vegètation and almost uniform. The upper section of this drain have higher velocity as result of higher gradient (Chart 4.5d).

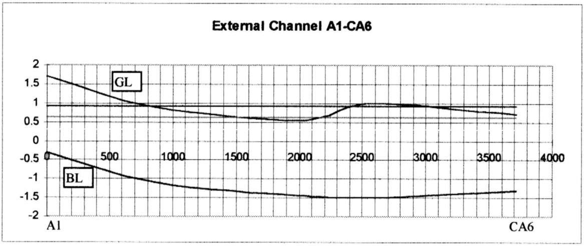
However, section 0m to 4400m is effected by normal tide, making discharge inefficient. In event of a severe flood, this outlet section and section 1100-2000m could be submerged.

Chart 4.5d



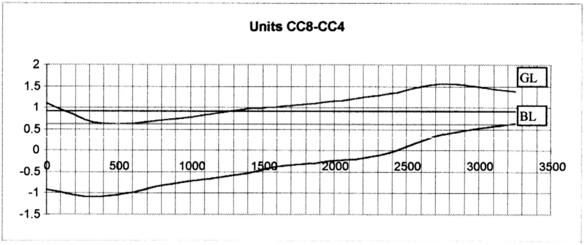

External channel from units A1 to CA6 (Chart 4.5e): Section 0m to 2000m is densely vegetated. Flow is very inefficient and, at certain parts almost stagnant. The whole section of this drain is affected by normal tide. In the event of a severe flood, section 1500m to 2300m (having surface elevation of 0.6m or 2 feet) and unit CA6's outlet could be submerged.

Chart 4.5e




Units CC8-CC4 (Chart 4.5f) and it's branches (Nibong Tebal Town- Former Police Station to Taman Berjaya): Generally, the drains are well maintained. Except for section 100m to 800m (earthen with moderate to dense vegetation), the rest are well-maintained concrete drain. However their design are not uniform. There are minor constrictions. Some sections are trapezoidal and others rectangular in shape. Variation of shape can effect the hydrodynamic pattern of flow, resulting in either decreasing or increasing flow velocity. Its drainage gradient is not uniform, resulting in the same effect as above.

Chart 4.5f



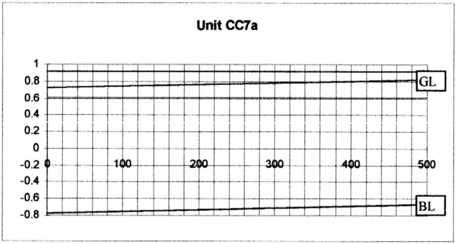

A careful analysis revealed that the channel gradient of section 100m to 500m from the outlet have an opposite orientation. This could decrease the flow velocity and retards discharge. As a result, it facilitates flooding.

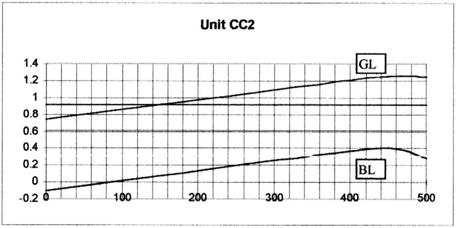
Almost all the sections of this drainage network are ineffective during normal tide. As a result, only partial flow can occur during normal tidal condition.

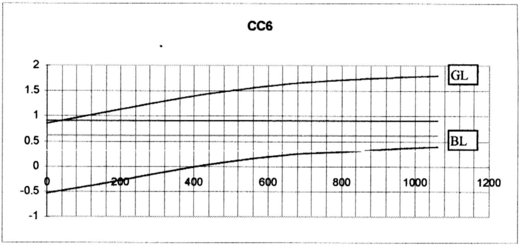
The unit CC7a (earthen) converged with the trunk drain (Chart 4.5f) at section 0 m (unit CC7a). Unit CC2 (concrete) is connected to the trunk drain at Tong Hai village culvert. Unit CC6 (concrete), is connected to the trunk drain at Taman Nibong Tebal-Sri Nibong culvert (Charts 4.5g). All of them are ineffective during normal tide.

Charts 4.5g

Units CC7a, CC2 and CC6





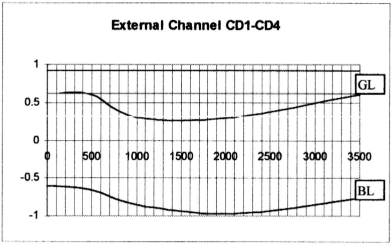

Units CD1-CD4 (Charts 4.5h): These units run parallel to each other into the external channel. The outlet is at drainage unit CD4 or section 2000m of the external channel. All are earthen drains except for the upper section of drainage units CD2 and CD3. The drains are uniform but incapacitated by dense vegetation.

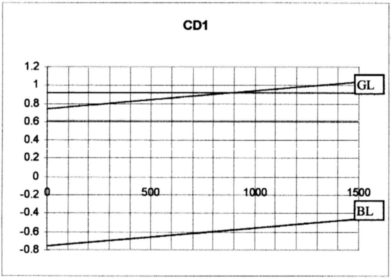
The ground level of section 500m to 3500m (external channel), is lower than 0.6m and section 1000-2200m lower than 0.3m. This section can be overflowed easily during high peak discharge.

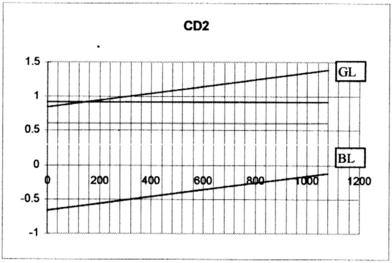
All of them are affected by normal tide. Under normal tidal condition, this section is ineffective, having partial flow only.

Chart 4.4h

External Channel CD1-CD4 and Units CD1, CD2, CD3 and CD4.

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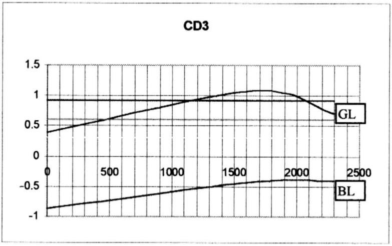
1
0.5
0
-0.5
-1
0
200
400
600
800
1000
1200
GL
BL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0
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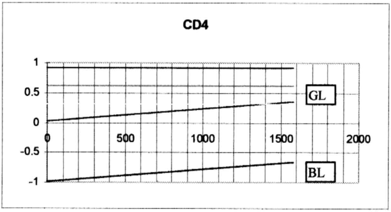
1500
2000
2500
GL
BL


CD4
1
0.5
0
-0.5
-1
0
500
1000
1500
2000
GL
BL

The present conditions of tidal gates are shown in Table 4.8. Under normal tidal height, Gate B2 and Gate Balai Lama (Nibong Tebal town) are unable to discharge. Both can only function during very low tide. However, for Balai Lama, a pumphouse with maximum capacity of 2 cumecs is under construction. Another pumphouse is planned for Gate B2. The performances of pumps were analyzed in Chapter 5. The rest are able to discharge under normal tidal height.

Table 4.8
Main tidal gates.

| ID | Location. | Design. | Status | Q (cumecs) |
|---|---|---|---|---|
| A | A1-A2 | Single 1.524m x 1.524m door, L=18m, u/s -1.0668m R.L. d/s -1.3716m R.L, S=0.0169, concrete,well rounded inlet. | F | 7.58 |
| B | B5 | Single 1.524m x 1.524m door, L=18m, u/s -0.85m R.L. d/s -1.158m R.L, S=0.017, concrete, well rounded inlet. | F | 9.77 |
| B2 | CA6 | Twin 1.8m d corrugated metal pipe, L=14m. u/s -1.22m R.L d/s -1.828m R.L, S=0.044 well rounded inlet. | F | 0 |
| Gate Balai Lama | CC8 | Twin 1.8m d corrugated metal pipe, L=4m. u/s -0.9m R.L d/s -1.5m R.L, S=0.15, sharp inlet.<br>under construction: 2 cumecs pumphouse. | F | 0 |
| C | CD4 | Twin 1.524m x 1.524m door, L=18m, u/s -0.975m R.L. d/s -1.28m R.L, S=0.017, concrete,well rounded inlet. | F | 13.74 |
| D1 | Mati River | Twin 1.524m x 1.524m door, L=18m, u/s -1.37m R.L. d/s -1.7m R.L, S=0.018, concrete,well rounded inlet. | F | 14.9 |
| E | Daun River | Twin 3.048m x 4.26m door, L=0.2m, u/s -2.13m R.L. d/s -2.44m R.L, concrete, well rounded inlet. | NF | 0 |

Source: Drainage and Irrigation Department, Seberang Jaya; fieldwork.
Note: F-functioning, NF-not functioning. Q: head water assumed to be equal to maximum drain depth at inlet and mean tide = 0.479m LSD.

Currently, Gate E is not functioning. Only one of its gates is useable. However, it is only useful for recharging purpose. This is because its outlet is heavily silted, about 1 metre deep. The estimated total silt to be remove in order to restore Gate E is 1,250 $m^3$ cube.

4.3.2: Other flood mitigation measures.

A new culvert was constructed in February 1998, to divert flow from drainage unit CC2 into E2. However, the inlet section is densely vegetated, making it useless. Drainage unit CC2's drain was originally constructed to discharge into E2, but currently it is flowing into unit CC3 as backwater.

The levees have been very effective in stopping tidal flooding. Without the levees, this region could be flooded frequently to the depth of 0.5m to 1m, covering 50% of the land area.