Drainage Master Planning for Land Drainage Flood Control in the Northern New Territories of Hong Kong

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Since the establishment of the Drainage Services Department in 1989, strategic studies have been carried out to develop a comprehensive land drainage and flood control strategy to prevent flooding and provide necessary drainage infrastructure for future needs. After formulation of the land drainage and flood control strategy, seven Drainage Master Plan studies have been and are being carried out on different drainage basins to resolve the drainage issues according to their drainage characteristics and development pressures. This paper discusses the Drainage Master Plan Study in the Northern New Territories (NNT DMP Study) as a case study to illustrate the considerations taken in formulating the strategy to handle one of the most flood prone areas in Hong Kong.

The NNT is susceptible to serious and frequent floodings due to its low-lying topography and inadequacies in the drainage system. Yet, the area is subject to high development pressure due to enormous population growth and urban expansion. In order to alleviate flooding and to support sustainable growth of the area, the NNT DMP Study has carried out comprehensive hydrological and hydraulic modelling based on a review of development trends in the area. With the support of the modelling results, various structural and management measures have been devised to resolve the drainage problems. Particular attention is drawn to the residual flooding problems and the recommended solutions.

Keywords: *Drainage Master Plan, Flooding, Prevention, DIA, AIMS*

INTRODUCTION

Due to its geographic location, Hong Kong experiences heavy, yet uneven distribution of rainfall every year. The rainfall in Hong Kong averages 2200 mm annually, and more than 80% of this falls during the period May to September. Intensities can be high, with 50 mm per hour and 200 mm in 24 hours being not uncommon. Flooding in low-lying areas, in particular the Northern New Territories, is therefore frequent. Flooding can cause huge disruption to transport, communications, daily life and commercial activities, inflict fatalities and damage properties and the economy.

The impact of flooding becomes more prominent as the Northern New Territories has experienced particularly rapid economic and housing developments over the last decade. Development has mushroomed along major transport network all over the Northern New Territories. The increase in population and housing demand has called for the provision of facilities and infrastructure to accommodate the people and to sustain the economic and population growth.

In the past, the provision of drainage infrastructure has been fragmented and was provided basically to meet the need of individual new towns or parcels of land development. This approach has drawbacks of being unable to formulate a comprehensive and long-term solution to the drainage problems.

Since the establishment of the Drainage Services Department (DSD) in 1989, the need to put drainage and flood control on a rational and planned basis was recognized. Over the years, DSD has commissioned consultants to develop a comprehensive flood prevention strategy for the whole territory. The ultimate goal of the flood prevention strategy is to improve the quality of life by alleviating the impact of flooding and reducing the corresponding damage. The impact of flooding on existing developed areas can be reduced through mitigation measures, while the flood risk in developing areas can be contained by effective planning and provision of adequate drainage infrastructure.

The Territorial Land Drainage and Flood Control Strategy Study - Phase I (TEL I) [1] paved the way and established an overall flood prevention strategy in 1990. The strategy can be grouped into five main categories:

- New flood prevention standards
- Long term structural measures
- Short term improvement measures
- Land use management and legislative measures
- Planned preventive approach to maintenance

Following TEL I, DSD commissioned consultants to carried out a Phase II study (TEL II) [2] to give a more in-depth study on five flood prone areas in the Northern and Northwest New Territories. During its study period between 1990 and 1993, the TEL II study developed computer models and basin management plans for the Ganges, Indus, San Tin, Kam Tin and Tin Shui Wai basins. The TEL II study included future land use projections within each basin and recommended necessary primary drainage to be constructed to mitigate widespread flooding.

With formulation of the overall flood control strategy and the implementation of the recommended primary drainage networks in the Northern and Northwest New Territories, DSD has extended the scope of study. In 1996, DSD employed consultants to carry out seven Stormwater Drainage Master Plan Studies (DMP Studies) to review the performance and condition of the existing drainage systems for most flood prone areas over Hong Kong. The objective of the studies is to identify inadequacies in the drainage system and recommend improvement measures. Another important role is to develop a computerised system to enhance the efficiency of drainage asset management by means of a territory-wide digital database of the drainage network.

Presented in this paper are the authors' experience and involvement in the development of the DMP Study on one of the most flood prone areas in Hong Kong, namely the Drainage Master Plan Study in the Northern New Territories.

FLOODING IN THE NNT

In the NNT, the San Tin, Indus and Ganges drainage basins make up an area of approximately 115 km^2 and are subsidiary basins of the Shenzhen drainage basin that covers an area of about 350 km^2. The low-lying areas in the NNT are susceptible to serious and frequent flooding. As most of the area in the NNT is a natural flood plain, flooding is a major issue and jeopardizes some of the development potential. Typical areas subject to flooding include the San Tin floodplain located to the north of Castle Peak Road, the River Beas and River Indus floodplains bisected by the KCRC railway line at Sheung Shui, and the Ganges floodplain near Kan Tau Wai. Figure 1 shows a typical scene of flooding in NNT.

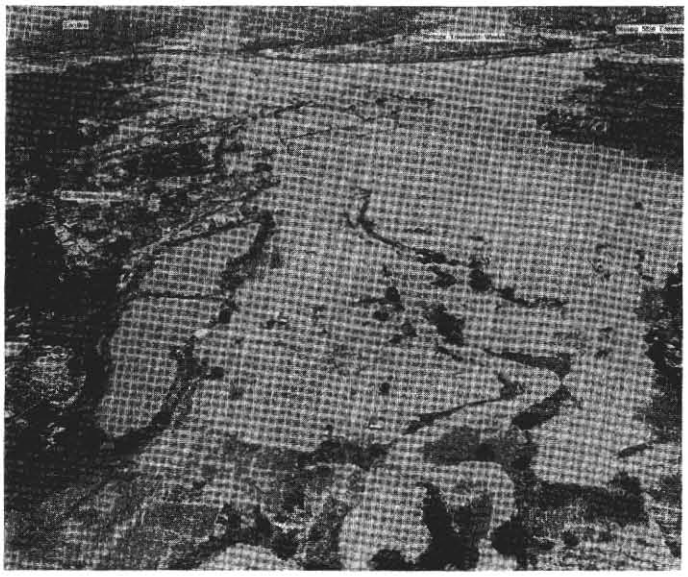

Figure 1 – Flooding in the Indus Basin of the Northern New Territories

The main cause of flooding is generally heavy rainfall coupled with high tide. The serious and frequent flooding problems in the NNT are further aggravated by the following factors:

- Flat and low lying topography
- Local constrictions due to inadequacies in the drainage system
- Increase in surface runoff and loss in flood storage due to land use changes from cultivated or fallow use to industrial, commercial or residential developments
- Reduction in conveyance capacities due to increased siltation originated from erosion of upland regions, or inadequate control during construction

Despite the flooding problem, the pressure of development need remains high. Several Strategic Growth Areas (SGAs) have been identified in the Planning and Development Studies on North East New Territories (NENT) and North West New Territories (NWNT) currently undertaken by the Planning Department and the Territories Development Department to accommodate future population growth and housing demand. Apart from these SGAs, there are numerous applications for changes of land use. Fragmented and individual developments are also taking place in the NNT.

THE NNT DMP STUDY

Major River Training Works

To alleviate the flooding problems and provide drainage infrastructure for future development, the Government is implementing a series of major river training works in NNT, following the recommendations in the TEL I and TEL II studies. The estimated cost of these major river training works amounts to about 2.5 billion dollars. After their completion, the extent of regional flooding under design and actual conditions will be greatly reduced.

However, the flooding and drainage problems cannot be totally eliminated and further works have to be carried out for the secondary and local drainage networks to alleviate local flooding and cater for new developments. In addition, measures have to be devised to solve the drainage problems in some low lying areas which cannot be drained by gravity into the primary drainage channels.

Flood Prevention and Drainage Provision in NNT DMP Study

The primary objective of the NNT DMP Study is to identify and rectify the inadequacies in the secondary and local drainage systems to ensure that the stormwater runoff can be effectively collected and conveyed into the primary channels.

A thorough discussion on flood loss prevention and management is given in the Manual and Guidelines for Comprehensive Flood Loss Prevention and Management (Ref. 3). Based on the guidelines given in the manual, the DMP is developed according to the following distinct but interconnected steps:

- Identification of Needs
- Assessment of Needs and Formulation of DMP Options
- Identification of Constraints
- Evaluation of DMP Options
- Formulation of DMP Recommendations

Identification of Needs

In order to identify the areas where drainage improvement is required and to evaluate the adequacy of the drainage system under existing and future conditions, both the existing and planned land use scenarios are considered in details during the analysis and planning of the drainage facilities for the NNT.

The planned land use scenario includes the planned developments under the relevant Outline Zoning Plans (OZPs) and the proposed Type A Strategic Growth Areas (SGAs) recommended under the NENT and NWNT Planning and Development Studies. The planned land use is assumed to be fully implemented by 2011. A hypothetical test condition on ultimate land use, which assumes that full development has taken place in all developable areas on the downhill side of the break of slope of the NNT study catchment, is also included.

Major flooding areas corresponding to the 1 in 50 year flood are identified through the assessment and drainage improvement measures are recommended in the NNT DMP Study. The 1 in 50 year flood is used because it is the flood protection standard adopted by the DSD for main rural catchment drainage channels.

Assessment of Problems and Formulation of DMP Options

Mathematical floodplain and river hydraulic models using a computer software MIKE 11 are developed as part of the DMP Study to analyze the flooding behaviour in the NNT. The models have been calibrated and verified using real data and are used for developing the DMP.

The purpose of computer simulation (or design flood analysis) is to identify deficiencies in the drainage system and to rectify them in a systematic approach. The design flood analysis was carried out for both existing and planned development conditions. The existing condition represents the expected state of the catchment and drainage network at the beginning of the 1999 wet season. The planned condition includes all committed catchment developments and drainage works. In modelling the future conditions, the Strategic Growth Areas (SGAs) in NENT and NWNT have been taken into account.

The design flood analysis was carried out for a full range of frequency events using a synthetic rainfall profile as recommended in the DSD Stormwater Drainage Manual. The performance of the drainage system has been assessed for a number of return periods: 2, 5, 10, 20, 50, 100 and 200 years. For each return period, different combinations of rainfall and tide have been simulated in accordance with the joint probability analysis recommended in the DSD Stormwater Drainage Manual.

Information provided by the design flood analysis is used in assessing the catchment responses to storms and determining where to direct the resources. Flooding problems requiring immediate attention are mitigated by first-aid measures while the long-term improvements will be provided through project items under the DMP. After identifying the needs, drainage improvement works are recommended to ensure that the proposed systems will achieve the required flood protection standard.

Identification of Constraints

The constraints associated with each improvement option are then identified and assessed. In formulating the DMP recommendations, due regard is paid to the various constraints and opportunities in order to ensure the proposed improvement works are feasible and cost-effective. Such constraints and opportunities include land availability, geotechnical considerations, traffic implications, environmental considerations, and interfacing roads, drainage or sewerage projects.

In general, land ownership and its availability is the most critical constraint. Resumption of private land is always a lengthy and time-consuming process. Any proposed land resumption will inevitably create great concerns from the owners and local representatives. With greater development potentials in the NNT, land values increases and this makes land resumption more difficult. In many cases, compensation will be made to the affected land owners; but problems are often more complicated and cannot be solved by simple monetary means. In rural areas, there are other constraints such as graves, urns and "fung shui" areas. The proposed drainage works should, wherever possible, avoid encroaching upon these areas.

Environmental impacts are also of major concerns. On the one hand, flood mitigation works would alleviate some adverse environmental impacts due to flooding, such as erosion of channels and damage to agricultural land. On the other hand, there could be certain adverse impacts due to drainage improvement works, especially during the construction period. For example, works within the Wetland Conservation Area of Mai Po, environmental requirements are particularly stringent. Detailed environmental studies and impact assessments are required to assess the feasibility of the project and to evaluate appropriate mitigation measures.

Evaluation of DMP Options

The option evaluation covers a variety of topics including system hydraulic performance, land requirements, environmental reviews, traffic reviews, geotechnical considerations, operational and maintenance requirements as well as cost considerations. Investigations are undertaken to find out the most practical and cost-effective method to meet the Government's flood protection standard.

Some general but essential selection criteria are included in the selection process. These criteria include:

- Technical difficulties
- Major risks
- Robustness / Reliability
- Maintenance
- Implementation / Programming
- Capital cost and operation and maintenance costs

The flood control alternatives are evaluated according to these criteria, with due consideration given to some intangible elements, such as risk to life and inconvenience to the public due to flooding.

Formulation of DMP Recommendations

A key objective for stormwater management and flood control is to afford a reasonable level of protection against flooding. In other words, the potential risk of loss of life and property damage must be reduced to an acceptable level. A complete stormwater management policy should encompass both structural and non-structural measures such that a balanced approach from aspects of demographic, social, economic, planning, development, environmental impacts, as well as the hydrological and hydraulic phenomena will be undertaken.

As the NNT is under a fast pace of development, one of the main emphases of the DMP is to focus on the provision of adequate stormwater drainage systems to cope with the demand and prevent flooding. The ongoing major river training works in the primary drainage system is the first step toward this aim. The next step is the provision of branch systems to collect and convey runoff generated from the development areas for safe discharge into the receiving waters through the primary drainage system. The major requirements for the future development in the NNT will therefore focus more on the structural measures. The provision of drainage networks will substantially remove the threat of flooding and enable development in most areas in the NNT.

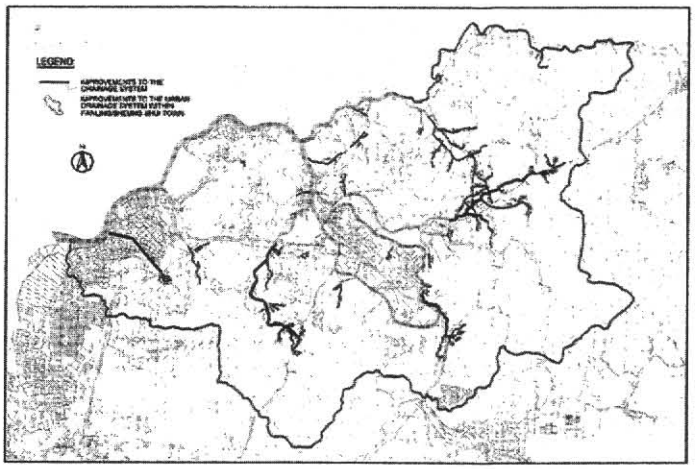

Figure 2 – Recommended Drainage Improvement Works for NNT

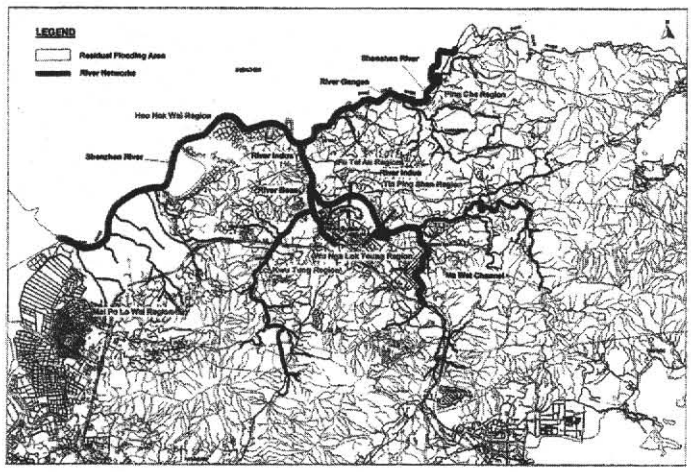

Figure 3 – Residual Flooding Areas in the NNT

The recommended structural measures can be divided into upgrading of rural channels and replacement of urban drains as shown in Figure 2. They are packaged for implementation in different time frames in order to effectively allocate resources and public funds, and to meet the time required for land resumption and to cope with the constraints identified in various impact assessments.

RESIDUAL FLOODING AND LAND MANAGEMENT

Despite the comprehensive structural improvement measures proposed, some low-lying areas in the NNT will be subject to flooding even after completion of the major river training works. This is due to the fact that some low-lying areas have ground levels lower than the water level within the future main drainage channels. As such, stormwater cannot drain into the main drainage channels by gravity during high floods. This problem is referred to as "residual flooding", but the flooding situation will be to a much reduced extent in comparison with the present situation where the main drainage works have not been in place.

Most areas affected by residual flooding are floodplains of existing rivers and the low-lying areas adjacent to the future main drainage channels. They are mainly agricultural lands with limited inhabitants. However the extent of area subject to residual flooding is not small in the NNT, and is shown in Figure 3. The severity of the problem varies from one location to another. A number of alternative approaches have been considered to alleviate the problem depending on its severity and specific constraints.

In the NNT DMP Study, apart from structural measures, the following management (non-structural) options are considered to alleviate the residual flooding problem: (a) Sustainable land use planning; (b) Earth filling through coordinated land management; (c) Re-housing; (d) Flood shelter; and (e) Flood relief measures.

Sustainable Land Use Planning

Flooding is a major concern only if people and properties are affected. It is apparent that land use is a key element in the evaluation of the impact of flooding. In densely residential areas, flooding cannot be tolerated, as risk to life and economic losses are high. However, if flooding occurs on marshes, abandoned agricultural land, the situation can be more tolerable, even flooding occurs frequently.

Flooding on actively used agricultural areas, including fishponds, is a case worth considering. The flood protection level for this kind of land use is 2 to 5 years. If residual flooding takes place on agricultural lands in less severe events, say less than 2 year flood events, some flood protection measures will be required. Otherwise, the area is considered as sustainable for agricultural use and adequate protection level has been provided.

In some cases, there are isolated houses or huts scattered around the agricultural lands. Residual flooding may affect these houses. As such, the number of houses needs to be checked in order to evaluate the impact of residual flooding.

In case development is necessary and flooding cannot be tolerated in the area, several alternative management solutions discussed in the following paragraphs may also be adopted simultaneously.

Earth Filling through Coordinated Land Management

One possible way to solve the residual flooding problem is to raise the ground to a level above the river channel bank. With this higher formation level, stormwater can drain into the river channel by gravity through drainage channels, or underground pipelines if provided. This approach can solve the problem effectively without any special maintenance requirements.

The reform of land should, however, be carried out in a coordinated manner. Isolated earth filling may aggravate the flooding situation in the adjacent areas. Indeed, the reform of land is not solely an engineering issue and has to be implemented in conjunction with other programmes such as land and housing developments. The problem is more related to land management and town planning, and is not confined to drainage engineering.

An effective way is to reform the land through large-scale development projects. For some new town development projects, the whole area is resumed and reformed above the design flood level. In so doing, the residual flooding problem will be properly addressed.

Large-scale developments within the NNT area are being identified in the Planning and Development Studies on the NENT and NWNT. Typical examples are the Kwu Tung North SGA and the Fanling North SGA. Residual flooding problems in these areas would be reduced significantly if the development areas can be formed above design flood levels.

Re-housing

For some isolated houses located in high flood risk areas, such as the San Tin floodplain, re-housing may be a viable solution. This would minimize the possibility of repeated emergency evacuations of the villagers by helicopters or boats.

However, re-housing would involve lengthy administrative procedures. Also, the local residents may not accept relocation to a place where they cannot earn a living as used to be. Re-housing may create social impacts and consultation with the concerned people must be carried out prior to formulation of a re-housing scheme.

Flood Shelter

Flood shelters are operated when severe flooding occurs. They serve to protect the lives of those people affected by flooding. However, their properties are inevitably subject to the risk of flood damage.

To minimize the flood risk to people and properties, the key is to operate an effective evacuation program, which relies on an accurate and timely flood warning system. The degree of benefit achieved will depend upon the warning time provided to the occupants in the residual flooding areas and the ability of these occupants to respond.

Flood Relief

The main aim of flood relief is to provide immediate assistance to overcome personal hardship and distress, including essential repairs to houses and the repair or replacement of essential items of furniture and personal properties.

Flood relief can be considered as zero premium insurance and does little to reduce the impact of future flood losses.

DRAINAGE IMPACT ASSESSMENT AND ASSET INVENTORY MANAGEMENT SYSTEM

Drainage Impact Assessment (DIA)

It must be borne in mind that even after the completion of all drainage improvement works, including the secondary and local drainage system proposed under the NNT DMP Study, there would be a need for some assessments on drainage impacts resulting from changes in catchment characteristics, such as individual house developments, new crossings on existing channels, filling on local drainage, small scale changes in land use and interfering with existing streams, etc.

The change in catchment characteristics in NNT will generally have the effects of: (a) increasing stormwater runoff; (b) advancing the time to peak runoff; (c) reducing active floodplain storage; (d) constraining floodplain flow; (e) re-directing natural drainage during construction; and (f) contributing to soil erosion (and thus downstream siltation).

Careful thoughts have been given to how the effects of these development changes can be mitigated. In most cases to date, proper attention has been drawn to the protection of the proposed developments and their impacts on other parts of the drainage basins through a drainage impact assessment (DIA) process discussed in TEL II Study in 1993.

The DIA is a sound and established administrative and management procedure for reviewing and controlling the impacts of developments and public works projects on the drainage system and flooding susceptibility. The DIA procedures are covered in DSD Advice Note No. 1 and DSD Technical Circular 18/95 for private developments and public projects respectively.

It is recongised in the NNT DMP Study that the control of runoff from development depends on the state of the drainage improvement works, as well as the pace of development in the study area. When all the drainage improvement works are in place, the constraints by drainage on development will be reduced. Based on hydrological and hydraulic modelling of the drainage basins, interim guidelines would be developed for DSD to evaluate drainage submissions.

Asset Inventory Management System (AIMS)

To evaluate a DIA submission, a full drainage system inventory of the Study area is required. Details of existing and planned land use, and hydrological and hydraulic data are essential. The NNT DMP Study has developed a drainage asset inventory management system (AIMS) which provides a framework of the hydraulic behaviour of the drainage basins and establishes a baseline against which the impacts of development on the hydraulic behaviour of the basin can be assessed.

With the Oracle database at its core and MapInfo as its user interface, the AIMS provides an excellent tool for management drainage assets. The system is user-friendly with intuitive working interface to ensure that the users can master the system with minimum amount of training.

The AIMS is able to import existing electronic data files for manhole and pipe data into the database. It provides appropriate screen forms for the input of relevant data for all new data of all assets. The AIMS also provides functions for the users to navigate over base map.

The AIMS is able to process query to select sets of asset data under user-defined criteria. The AIMS provides functions to manipulate and to identify, locate, categorise the selected sets of asset. It is able to display the selected assets or the manipulation results on screen or as hardcopy of summary tables or drainage maps. Further, the AIMS provides functions to export the selected asset data in electronic files for use in MicroStation, and also as input data files for hydraulic modelling software, such as MIKE11 and HydroWorks models.

CONCLUSIONS

The land drainage and flood control issues in the Northern New Territories have been dealt with by a comprehensive and effective manner under the NNT DMP Study. The main focus is to prevent flooding by providing adequate drainage infrastructure and effective management tools to keep track of the dynamic change of developments and drainage improvements in the NNT drainage basins.

The DMP strategy has been based on the state-of-the-art computational hydrological and hydraulic models. The existing deficiency and future requirement of the drainage systems have been evaluated and improvement measures have been proposed to pave the way for meeting future demand and preventing flooding. The major requirements for the future development in the NNT call for focus more on the structural measures. The provision of drainage network will substantially remove the threat of flooding to most areas in the NNT and enable development in the area.

Residual flooding poses a particular technical and management challenge in the NNT and forms a major component of the DMP strategy. Various options and measures have been proposed and discussed. They can be applied to the concerned areas to meet their specific constraints and opportunities. It must be recognised that residual flooding problem is not solely an engineering issue and requires concerted efforts from planning and land development management.

Apart from the proposed secondary and local drainage improvement works which amount to an estimated cost of 2 billion dollars, a drainage asset inventory management system (AIMS) has been developed for planning and managing the drainage system

under the current and future control of DSD. The AIMS can be used as an analytical tool to identify, locate, categorise and present drainage assets to facilitate checking of DIA submissions. It can also be used as a management tool for future planning of drainage improvement works.

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REFERENCES

[1] Mott-MacDonald (1990), "Territorial Land Drainage and Flood Control Strategy Study Phase I", *Report to Drainage Services Department*, Hong Kong Government.

[2] Binnie Maunsell Consultants (1993), "Territorial Land Drainage and Flood Control Strategy Study Phase II", *Report to Drainage Services Department*, Hong Kong Government.

[3] Economic and Social Commission for Asia and the Pacific (1991), "*Manual and Guidelines for Comprehensive Flood Loss Prevention and Management*", United Nations Development Programme.

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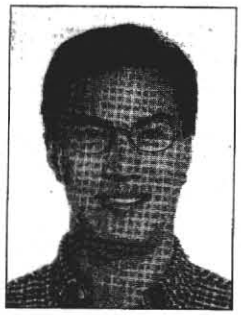

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