

## **LEGISLATIVE COUNCIL BRIEF**

### **UNUSUAL GROUND SETTLEMENT IN TSEUNG KWAN O**

#### **INTRODUCTION**

At the meeting of the Executive Council on 21 November 2000, the Council noted the investigation findings on the unusual ground settlement in Tseung Kwan O (TKO).

#### **BACKGROUND**

2. Unusual ground settlement in the TKO reclamation was first reported in early 1999. A detailed investigation of the causes of the unusual settlement and its effect on existing buildings and other facilities has now been completed.

3. The extent of area affected by the unusual settlement, comprising mainly Tiu Keng Leng, TKO town centre, TKO Area 86 and the TKO Industrial Estate (TKOIE), is shown in Figure 1 at Annex A. The locations of existing residential buildings (in three zones) at the affected town centre are shown in Figure 2 at Annex B.

#### **MAGNITUDE OF SETTLEMENT AND LATEST STATUS**

4. The magnitude of settlement varies in different areas. At Tiu Keng Leng and the part of town centre to the north of Tong Ming Street, the settlement was very small being in the range of only 70 to 80 mm measured since early 1999. Further south of the town centre between Tong Ming Street and Tong Tak Street, this settlement measured since early 1999 ranged from 150 to 270 mm. In other areas of TKO reclamation, including Area 86 and TKOIE, the settlement ranged from 50 to about 800 mm.

5. In almost all the areas, the highest rate of settlement (approximately 40 mm per month at the town centre and up to 160 mm per month for part of other areas) was recorded in the first six to nine months of 1999. Since then, the rate of settlement has decreased substantially. As at October 2000, the settlement in most parts of zones 1 and 2 of the town centre has virtually stopped. As regards zone 3 of the town centre, Area 86 and TKOIE, the settlement was about 0 to 30 mm per month. These settlements included the normal settlement of the reclamation itself and the rates measured indicated that they have already reduced substantially as compared with early 1999.

## **THE INVESTIGATION AND FINDINGS**

6. The investigation of the causes of the unusual settlement is undertaken by Territory Development Department (TDD) through the engagement of a consultant, Maunsell Consultants Asia Ltd. (MCAL), who is also the consultant responsible for the design and supervision of the construction of the original TKO reclamation. The focus of MCAL's investigation is on the settlement at the TKO town centre.

7. The investigation study has identified three probable causes of the unusual settlement, those being -

- (a) Greater than the predicted normal settlement of the reclamation;
- (b) Consolidation of the subsurface soil strata due to drawdown of groundwater; and
- (c) Effects of post-reclamation construction activities.

8. The study has, through detailed site investigation, laboratory tests, field instrumentation and a computer model simulating the ground water regime, arrived at the following conclusions in respect of the town centre area -

- (a) The reclamation itself generally performed as designed.

There is no sign that it has contributed to any unusual settlement.

- (b) The unusual settlement was mainly caused by a significant groundwater drawdown in the lower soil strata of the reclamation. The only credible cause of settlement was the inflow into the Strategic Sewage Disposal Scheme (SSDS) Stage I tunnel being constructed outside TKO reclamation (see alignment of SSDS Stage I tunnel shown on Figure 1 at Annex A).
- (c) Minor localised settlements were found in the reclamation fill materials at some locations near construction activities, such as construction of foundations and associated water pumping.
- (d) The design of the SSDS Stage I tunnel has included a permanent lining which will seal off entry of groundwater once completed. This permanent lining will be completed at the end of 2000. Once the permanent lining is completed, the groundwater level will gradually resume to normal.
- (e) Minor ground heave may occur as the groundwater starts to rise but the effect on buildings and other facilities will be insignificant. This process will take place over a period of 3 to 6 years. Thereafter, the settlement trend will revert to the normal settlement rate of a mature reclamation.

9. An executive summary of MCAL's investigation report is at Annex C. (A copy of the full investigation report (in English only) has been deposited in the Legislative Council Secretariat for the reference of Members.)

10. Outside the town centre, TKO Area 86 has been taken over by Mass Transit Railway Corporation Ltd. (MTRCL) for construction of its railway depot. MTRCL has been monitoring the settlement of that area.

The TKOIE is owned by the Hong Kong Industrial Estates Corporation (HKIEC) who is carrying out its own investigation of the cause of settlement of the TKOIE site.

### **INDEPENDENT REVIEW OF MCAL'S STUDY**

11. In view of MCAL's past involvement in the design and supervision of the construction of the TKO's reclamation, we have engaged Professor N. R. Morgenstern of the University of Alberta, Canada, an internationally renowned geotechnical engineering expert, to provide an independent view on the investigation study by MCAL. He holds the view that the approach, methodology and analysis employed in MCAL's study are objective and reasonable and he agrees with the conclusions drawn.

### **EFFECTS OF UNUSUAL SETTLEMENT ON SAFETY OF BUILDINGS AND OTHER FACILITIES**

12. In addition to the investigation of the settlement cause, TDD has together with other relevant departments have completed an assessment on the effect of unusual settlement on building safety.

13. In the assessment, detailed checks were carried out by Buildings Department (BD), Architectural Services Department and Housing Department on the effect of unusual settlement on the foundations of all existing buildings under their respective jurisdiction. The checking confirms that all those foundations still possess an adequate safety margin although factors of safety (FOS) have been slightly reduced by the down drag force on the piles caused by the settlement. All these buildings are structurally safe. It is also concluded that the FOS's are likely to increase as the groundwater starts to rise on completion of the SSDS permanent lining at the end of this year.

14. Residents in Beverly Garden (a Private Sector Participation Scheme development) and Tong Ming Court (Home Ownership Scheme development) situated in the town centre are concerned that the buildings of these two developments might be affected by the unusual ground settlement. In response to those concerns, site monitoring was

commissioned on the settlement of buildings. The monitoring confirms that despite settlement of the surrounding ground at ground level within the boundary of the estate, none of the buildings have shown any sign of movement.

15. There were reports of defects found in some residential flats of Beverly Garden. In response, BD had carried out visits to those flats. None of the defects inspected are settlement related. However, the developer of Beverly garden and Housing Department have advised that they would be prepared to undertake the repairs related to ground settlement first and sort out responsibility with Government separately if necessary.

16. A summary of the Building Safety Report is enclosed at Annex D. (A copy of the full Building Safety Report (in English only) has been deposited in the Legislative Council Secretariat for the reference of Members.)

17. Apart from building safety, unusual settlement would have an effect on roads, paving and underground facilities. Inspections by government maintenance departments and utility companies have identified some defects such as pavement cracks and dislocated pipes. None of the defects found is serious. Many of them are being rectified by the respective authorities in the course of normal maintenance.

18. Government maintenance departments as well as private utility companies will continue their proactive monitoring of all the affected facilities.

## **ENVIRONMENTAL IMPLICATIONS**

19. This matter has no environmental implications.

## **PUBLICITY OF THE INVESTIGATION FINDINGS**

20. A press conference will be arranged for the afternoon of 21 November 2000. The LegCo Panel on Housing and the Panel on Planning, Lands and Works will be briefed on the investigation findings.

TDD will also arrange briefings with the Sai Kung District Council and other interested bodies.

**SUBJECT OFFICER**

21. Any enquiries may be directed to Mr MAK Chai-kwong, Project Manager (New Territories East) of the Territory Development Department, at telephone number 2301 1380 or fax number 2739 0076.

**WORKS BUREAU**

**21 November 2000**

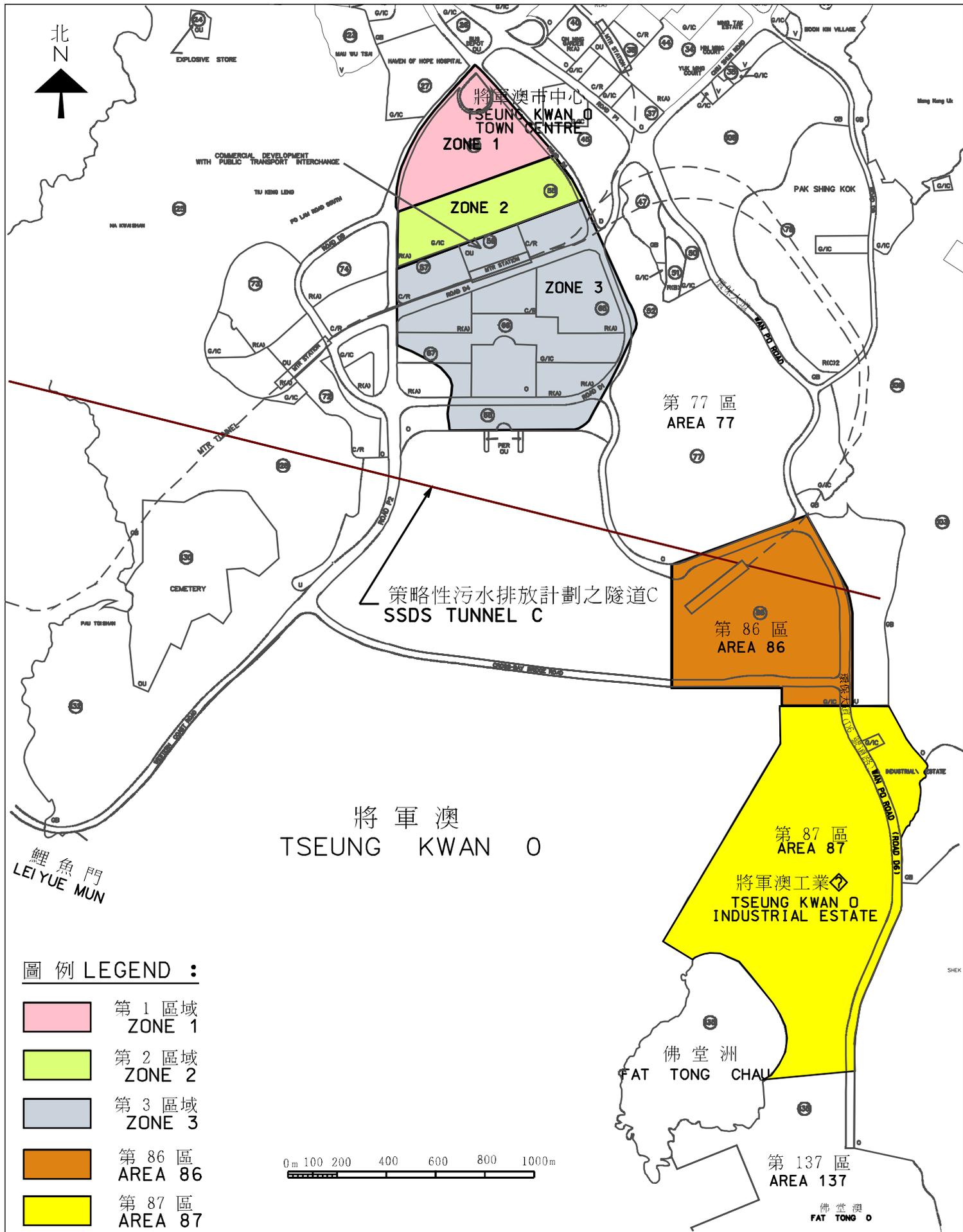
# **UNUSUAL GROUND SETTLEMENT IN TSEUNG KWAN O**

## **ANNEXES**

- Annex A - Figure 1
- Annex B - Figure 2
- Annex C - Executive Summary of Investigation Report
- Annex D - Summary of Building Safety Report

## **Annex A**

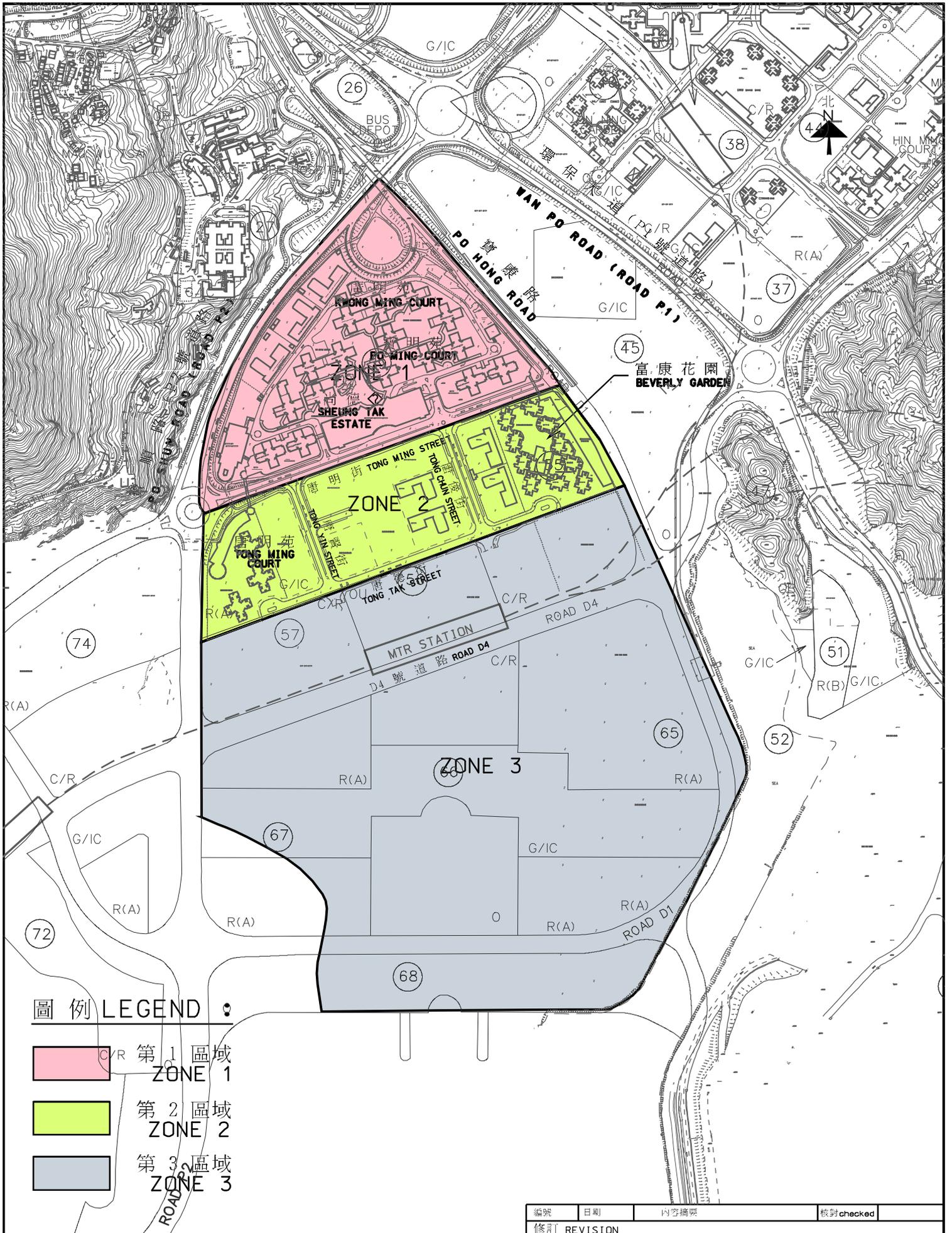
**Figure 1**



圖別名稱 drawing title 將軍澳受不正常沉降影響的地區 <b>AREAS AFFECTED BY UNUSUAL SETTLEMENT IN TSEUNG KWAN O</b>	繪圖 drawn <b>M K LEE</b>	簽署 initial	日期 date <b>15.11.2000</b>	比例 scale <b>1:20 000</b>	辦事處 office 新界東拓展處 NT EAST DEVELOPMENT OFFICE
	核對 checked	簽署 initial	日期 date	圖別編號 drawing no. <b>Fig 1</b>	<b>拓展署</b> TERRITORY DEVELOPMENT DEPARTMENT

## **Annex B**

### **Figure 2**



圖例 LEGEND

- C/R 第 1 區域  
ZONE 1
- 第 2 區域  
ZONE 2
- 第 3 區域  
ZONE 3

編號	日期	內容摘要	核對 checked
修訂 REVISION			

圖則名稱 drawing title

將軍澳市中心受不正常沉降影響的地區  
AREAS AFFECTED BY UNUSUAL SETTLEMENT  
IN TSEUNG KWAN O TOWN CENTRE

繪圖 drawn	簽署 initial	日期 date
S K WONG		15-11-2000
核對 checked	簽署 initial	日期 date
核准 approved	簽署 initial	日期 date

比例 scale	1 : 8 500
圖則編號 drawing no.	Fig 2

辦事處 office	新界東拓展處 NT EAST DEVELOPMENT OFFICE
拓展署 TERRITORY DEVELOPMENT DEPARTMENT	

## **EXECUTIVE SUMMARY OF INVESTIGATION REPORT**

The Town Centre area of Tseung Kwan O New Town is on land reclaimed from the original bay. Reclamation started in the 1980s and progressed in stages up to the present. Reclamation was carried out by filling over the layer of soft marine mud which formed the original sea bed. Only in the areas of the seawalls and the major box culverts was the mud removed; this being necessary to ensure the stability of the seawall and to minimise settlement of the culverts, which had to be built early. The retention of the marine mud meant that its consolidation would give rise to significant settlement. It was anticipated that the majority of the settlement would take place before development on the reclamation was complete.

2. The process of reclamation applies extra stress to the underlying layers of soil and settlement is an inevitable result. The material that is generally of most concern is the marine mud. In the case of Tseung Kwan O, two measures are adopted to accelerate the settlement. These are band drains and pre-loading. Band drains involve the insertion into the marine mud a pattern of permeable fabric columns that allow the water to find a shorter path out of the mud. By helping the water to escape the consolidation is speeded up. Pre-loading or surcharging involves overfilling to increase the stress in the material and thus put more pressure on the water to hasten its being squeezed out. The preloading mounds have been placed in areas where roads were to be built and have generally been left in place for about 15 months.

3. Reclamation proceeded as planned, with the settlement occurring much as expected until late 1998. Then in early 1999 an increase in the settlement was observed in the area of the Town Centre. This was not expected and caused concern.

4. The magnitude of the additional settlement was less than the settlement due to the marine mud consolidation, but it was occurring after the settlement due to the marine mud consolidation had stabilised. The sudden increase in settlement was unusual.

5. As the increase in settlement was unexpected it could not immediately be explained and investigations were put in hand to identify the cause. Once a cause could be confirmed it was necessary to investigate the impact on both the existing and future developments. This report sets out the details of these investigations, and identifies the most credible cause for the unusual settlement. The report discusses the impact of the unusual settlement and predicts the future behaviour of the reclamation.

6. The investigations involved the drilling of boreholes to measure the state of the various soil layers. These quickly indicated that the water pressures in the layers below the marine mud were much lower than would normally be expected. This drawdown of the water would lead to settlement of the lower strata and it was therefore, a likely cause of the unusual settlement. The investigations were also able to confirm that the reclamation had been built as specified and that the marine mud had consolidated and settled as expected. As settlement can also arise as a result of other construction activities, these were also reviewed. Although they did cause some settlement this was quite localised and of relatively smaller magnitude, hence the other construction activities could not be the cause of the larger more general unusual settlement that was taking place.

7. The water drawdown was unexpected and a reason for it was sought. The amount of drawdown was increasing to the south where the SSDS Stage I tunnel was being excavated. This is sited about one kilometre south of the Town Centre under the TKO bay and is in bedrock over eighty five metres below the reclamation level. It had been assumed that it was too remote from the reclamation to have affected it, however, following the observation of the unusual settlement, this was re-examined. It had been reported that there was significant water inflow into the tunnel and hence, it was possible that it was causing the observed drawdown. In order to test this hypothesis, a geological study of the area was carried out. This review indicated that the rock through which the tunnel was built was intersected by a system of fractures, which in some areas were likely to be quite severe. This could mean that the rock was effectively permeable. The presence of the very thick and highly impermeable marine mud layer prevented replenishment of the drained rock by seawater. Computer models were developed with probable mass rock permeabilities, based on measurements carried out in rock, and the inflow into the tunnel

calculated. These state of the art computer models demonstrated that the water inflow into the tunnel could cause the observed water drawdown. Hence, in the absence of any other cause, it was possible to conclude that the inflow into the tunnel was the only credible cause of the drawdown and hence, the cause of the unusual settlement.

8. As noted in paragraph 1, consolidation of the marine mud gives rise to substantial settlement. That settlement is normal and expected. The rate of such settlement slows with time and by late 1998 was already quite small in the Town Centre. The increase in rate of settlement was therefore quite noticeable even though, generally still of relatively small magnitude compared with the preceding normal settlement of several metres.

9. We tested soil samples from many locations in the Town Centre and used the test results to calculate the theoretical total settlement since early 1999. The calculated theoretical settlements were of similar magnitude to the measured settlements. We then used the same test results to calculate the portion of settlement that may be caused by the drawdown of groundwater and were able to estimate the proportion of the total settlement due to drawdown since early 1999. In some places construction activities have contributed a small amount of local settlement.

10. The study and the ongoing monitoring have shown that the settlement due to the drawdown has already reduced. In most parts of the Town Centre area, settlement has virtually stopped and groundwater has started recovering. The total settlement recorded in the Town Centre area since early 1999 was 70 to 80 mm (north of Tong Ming Street) and 150 to 270 mm (between Tong Tak Street and Tong Ming Street). In both zones the current rate of settlement is generally less than 3mm/month and at many locations we have recorded no settlement in the past month. South of Tong Tak Street the maximum total settlement as measured along the seawall since May 1999 was 200 to 280 mm. The maximum settlement along the seawall is now 8mm/month but is generally 3 to 6 mm/month.

11. It is expected that lining of the tunnel will be completed in end 2000 and that the inflow into the tunnel will be stopped. Sophisticated computer modelling of the groundwater build-up indicates that the drawdown could recover quite quickly within the bedrock, although full recovery in the rock will

take some time. As the groundwater recovers there will be some swelling of the underlying layers and this will combine with the remaining settlement. The net result is that settlement would continue to reduce and predictions are there would only be minor future ground movement.

12. The final objective of the study was to describe the impact of the settlements on the existing and future development. The first and potentially most significant effect is the consolidation of the lower soil strata as a result of the drawdown. This is of importance, as this will give rise to some additional negative skin friction loading on any piles that pass through these strata. This effect was evaluated by the concerned departments who conclude that, all these foundations possess adequate safety margin, though there was slight reduction in the factor of safety of the piles, and the buildings are safe. Indeed with the additional data on the soil parameters the safety could be stated with a high degree of confidence.

13. In general, the only other effect is an increase in the ground settlement taking place after completion of some developments. This has the effect of creating differences in level between the buildings' ground floor and the surrounding ground. These settlements may cause the settlement allowances already built into the utility connections to be exceeded and works may be required to be carried out to avoid cables or pipes from fracturing/damage. However, these are relatively minor problems that can be overcome through maintenance programmes and the management bodies have been carrying out regular monitoring and inspection.

## **SUMMARY OF BUILDING SAFETY REPORT**

### **1. INTRODUCTION**

- 1.1 This report summarises the assessment results conducted by the Housing Department (HD), Architectural Services Department (ArchSD) and Buildings Department (BD) on the structural integrity of all existing buildings within the areas in Tseung Kwan O (TKO) affected by the unusual ground settlement.

### **2. THE AFFECTED AREAS**

- 2.1 The areas affected by the unusual ground settlement include Tiu Keng Leng, the TKO Town Centre (TKOTC), Area 86 and TKO Industrial Estate (TKOIE). The TKOTC can be sub-divided into three Zones (Zone 1 to Zone 3) from North to South. The assessments cover mainly those buildings in TKOTC Zones 1 and 2, and in the TKOIE. For those buildings in Tiu Keng Leng, TKOTC Zone 3 and Area 86, which are still under construction, they are not included in the present assessment. There are only minor ground water drawdown and ground settlement in Tiu Keng Leng and the effects on the buildings are minimal.

#### Tseung Kwan O Town Centre Zone 1

- 2.2 The existing buildings in this area are all constructed by the Housing Authority. They include -
- (a) Sheung Tak Estate (Public Rental Flats) with a housing block for senior citizen and a commercial complex;
  - (b) Kwong Ming Court (Home Ownership Scheme);
  - (c) Po Ming Court (Home Ownership Scheme);

- (d) Two primary schools and one secondary school; and

#### Tseung Kwan O Town Centre Zone 2

2.3 Zone 2 is well developed and the developments have already been occupied. They are -

- (a) Beverly Garden (Private Sector Participation Scheme);
- (b) Four primary schools and three secondary schools; and
- (c) Tong Ming Court (Home Ownership Scheme).

#### Tseung Kwan O Industrial Estate

2.4 There are twelve buildings within this area. According to the Hong Kong Industrial Estates Corporation's investigation report, Varitronix Ltd., Yan Hing Engineering Works Ltd., HAECO and Wong's Circuit (PTH) Ltd. are outside the influence zone of the ground water drawdown. No structural assessment has been carried out for these buildings. Also for HK Telecommunication Ltd., no assessment has been made as it is only a small kiosk.

### **3. TYPES OF FOUNDATION**

3.1 In general, the foundations for the high-rise housing blocks are large diameter bored piles socketed in bedrock. For the low-rise buildings, spread footing or steel H-piles are used.

### **4. RESULTS OF THE ASSESSMENT**

4.1 The results of the assessments on the effect of the unusual settlement show that all existing buildings are safe. HD, ArchSD and BD have completed checks on the effect of unusual settlement on the foundations of those existing buildings under their respective jurisdiction. The

checking confirms that the factors of safety (FOS) for the building foundations, though slightly reduced by the down drag force on the piles caused by the unusual ground settlement, are still possessing an adequate safety margin. The FOS's are likely to increase as the groundwater level rises up.

## **5. SITE INSPECTIONS**

- 5.1 In addition to carrying out detailed calculations to confirm the safety of the buildings, HD, ArchSD and BD have conducted several site inspections of the buildings in the affected areas. The inspections have verified that there are no signs of structural defects on any of the existing buildings in the affected area.

## **6. OTHER DEFECTS IN BUILDINGS**

- 6.1 There were reports of defects at the domestic units and the kindergarten made by the occupants in Beverly Garden. In response, BD carried out five site visits between November 1999 and October 2000. A total of 23 domestic units and the kindergarten block were inspected. None of the defects inspected are settlement related. The probable causes of such defects are shrinkage, temperature stress, workmanship and construction methods.

## **7. TIU KENG LENG, TKOTC ZONE 3, AREA 77, AREA 86 AND THE TKO INDUSTRIAL ESTATE**

- 7.1 There are eight developments in various parts of the affected areas or their vicinity which are still under construction. The responsible authorities/Registered Structural Engineers of these developments are aware that the ground water drawdown in Tseung Kwan O might have an effect on their developments. They have to make provisions in the foundation designs and will need to demonstrate that their buildings will meet the requirements of the relevant authorities upon completion and before occupation permits are issued.

## **8. CONCLUSION**

- 8.1 Based on the assessments of the piled foundations of the existing buildings in the affected areas, together with site inspections, the concerned departments have confirmed that all these buildings are safe.