Sustainable Groundwater Management
Lessons from Practice

Case Profile Collection Number 20

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Controlling Groundwater Abstraction and Related Environmental Degradation in Metropolitan Bangkok – Thailand

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This case history is presented as an important example of progressive, adaptive, and eventually successful, control of groundwater abstraction using a regulatory approach and economic tools – when faced with (serious and irreversible) associated environmental degradation. This was made possible through the presence of an appropriately-empowered and well-organized regulatory agency (DGR of which the first author is Director General and which GW-MATE has previously advised) and an excellent long-standing groundwater and land monitoring network. The authors thank Oranuj Lorpensri & Surapol Dhammasarn (both DGR-Bureau Chiefs) for their detailed account of some aspects of the extended history and practical operation of the regulatory process.

GENERAL SITUATION OF GREATER BANGKOK

Hydrogeological Setting

- Greater Bangkok has developed to occupy much of the Lower Chao Phrayh Basin, which is underlain by a thick accumulation (reaching 500m depth) of inter bedded recent alluvial and marine sediments (of Pliocene-Pleistocene-Holocene geological age) (Figure 1). The sequence is known to contain 8 semi-confined 'aquifer horizons' separated by relatively thin aquitards overlain by the Holocene Bangkok Clay – which confines the aquifer system in much of the urban area but thins out northwards towards the Middle Chao Phrayh Basin (Figure 1) (an important recharge area of the aquifer system).

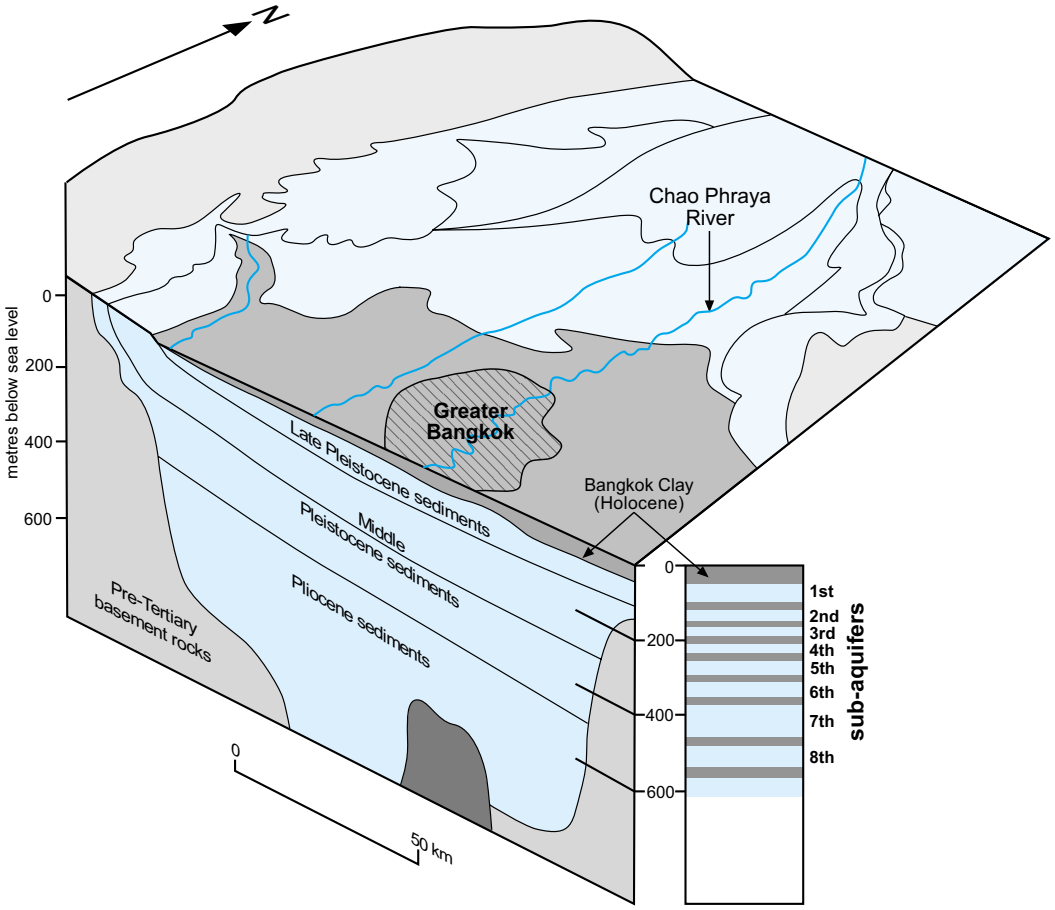
Groundwater Resource Development 1950-80

- Widespread exploitation of groundwater for urban water-supply commenced in the 1950s, originally mainly by the Metropolitan Waterworks Authority (MWA) and reached a level of about 500 Ml/d by 1980 with private industrial abstraction also becoming increasingly significant.

- The 'primary targets' for water well construction were the 2nd, 3rd and 4th sub-aquifers (the Phra-Pradaeng, Nakhon Luang and Nonthaburi Formations respectively) in the depth range 100-250m bgl

(Figure 1), with the latter most of these in particular yielding over 50 l/s to adequately-designed water wells. This groundwater resource exploitation caused a lowering of the groundwater levels in these sub-aquifers over much of Greater Bangkok – with piezometric surfaces quite widely reaching to greater than 40m below MSL by 1985 (Figure 2).

Figure 1: Hydrogeological block diagram to show the structure of the Middle & Lower Chao Phraya alluvial aquifer system in relation to Greater Bangkok

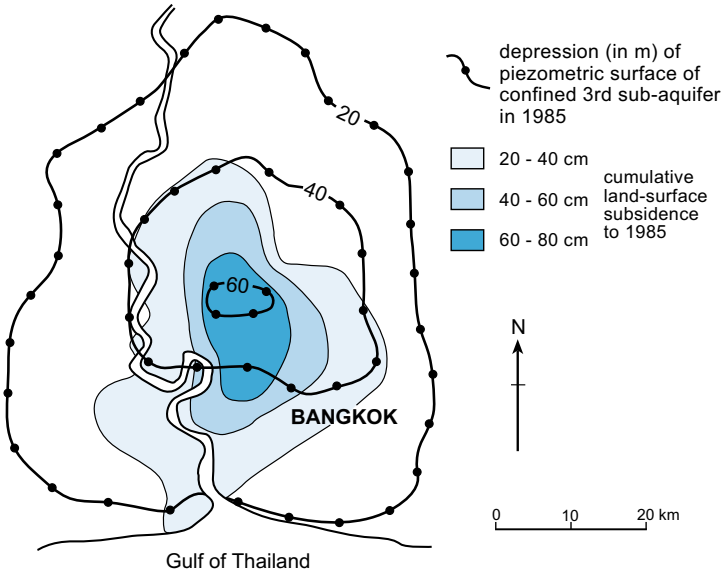


Susceptibility to Environmental Degradation

- By 1980 there was evidence of significant land subsidence in the centre of the metropolitan area as a result of aquitard compaction related to the lowering of piezometric surfaces and associated drainage of these previously uncompacted sediments (Figure 2). Given the nature of the terrain this land subsidence was not only accompanied by significant damage to the urban infrastructure but also by increased flooding risk during tidal surges.

- In addition the depression of piezometric surfaces to below mean sea-level also raised concerns about aquifer sea-water intrusion – with indications of rising salinity in the 2nd Sub-Aquifer (in which Cl concentrations increased to above 1,500 mg/l in the centre of the city).

Figure 2: Distribution of land subsidence related to groundwater abstraction in Greater Bangkok in 1985



HISTORY OF GROUNDWATER MANAGEMENT INITIATIVES

1985-95 Reducing MWA Abstraction but Private Use Escalates

- The initial approach to reducing groundwater abstraction was to require the MWA progressively to close its water wells, in favour of development of surface water sources with import to the city. However, although MWA abstraction was eliminated by the late 1990s, the increased domestic, commercial and industrial tariffs for mains water-supply (imported from more distant sources requiring treatment) triggered a massive increase in the drilling of private water wells, whose total abstraction reached over 2,000 Ml/d by the late 1990s (Figure 3) – with a further 400 Ml/d abstraction by 3 Provincial Waterworks Authorities (PWAs) with supply responsibilities in the outer-lying parts of Greater Bangkok.

- The 'explosion' of private water well drilling was to meet two rather different types of demand :
  - domestic water-supply for urbanizations, large apartment blocks and some commercial users, who typically constructed 100mm diameter wells to around 150m depth (in the 2nd/3rd Sub-Aquifers) yielding normally up to 1 Ml/d at costs in the range T bht 180-230 k (US$ 5-7 k)
  - industrial and other commercial users, who in many cases employ larger boreholes (200-300 mm-diameter) targeting deeper sub-aquifers – a 500m borehole would cost in the order of T bht 5000 k (US $ 145 k) and provide yields of up to 10 Ml/d.

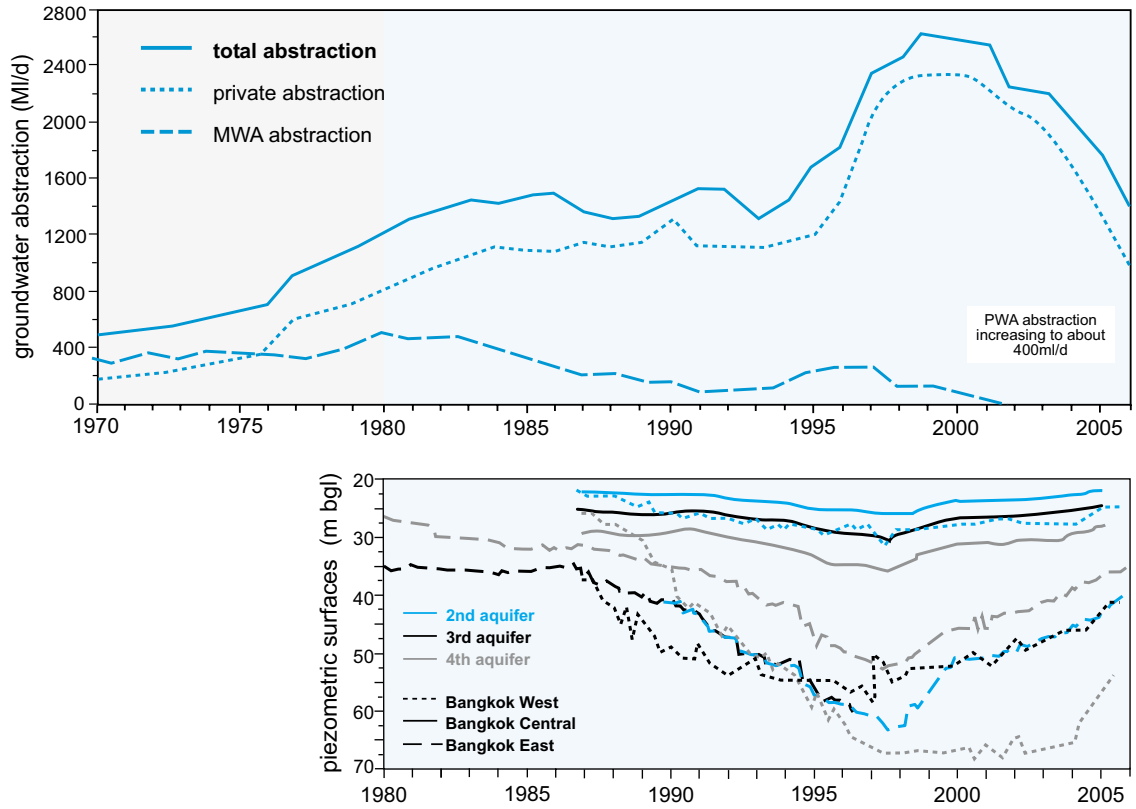
- The (then) DMR-GWD had been given powers to take stock of groundwater use through the Groundwater Act of 1977. But in 1983 the DMR-GWD recommended to the Thai Cabinet that

stronger measures were needed to constrain and reduce groundwater abstraction in Greater Bangkok, given the widespread evidence of serious land subsidence and associated problems. These measures included :

- definition of 'critical areas' where water well drilling would be banned
- powers to seal water wells in areas with mains water-supply coverage
- licensing and charging for groundwater abstraction according to metered (or estimated) abstraction rates.

However, it took some years for the required measures to be fully defined, legally approved, and for their implementation to commence. At first (in 1985) charges were fixed at a level which was 'essentially nominal' (Tbht 1.0 (US$ 0.03) /m^3) and provided no incentive to reduce abstraction – but their existence did serve to normalize groundwater use administration and develop a sound information base.

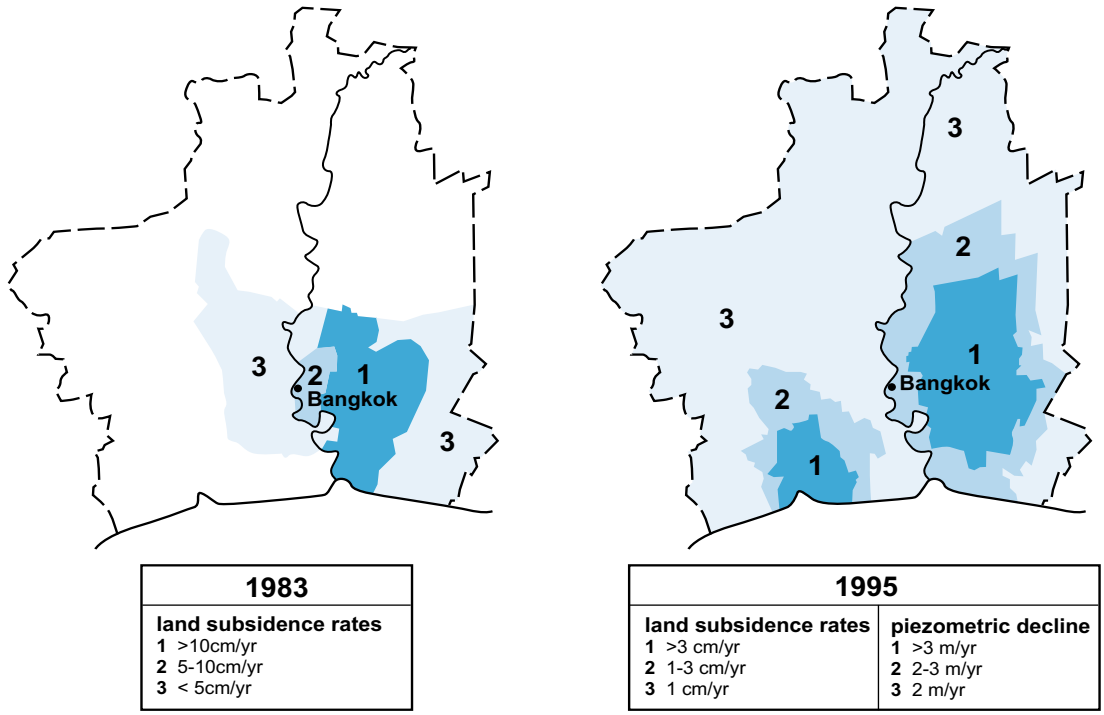
Figure 3 : Historical evolution of groundwater abstraction and piezometric surfaces in the Greater Bangkok aquifer system



1995-2005 – More Effective Measures to Control Private Groundwater Use

- Recent years have seen more concerted action to constrain groundwater abstraction within environmentally-tolerable limits, guided primarily by the temporal and spatial trends in the rate of land subsidence, and the measures have included :
  - revised definition of 'critical areas' recognizing the appearance of some 'new centres' of incipient land subsidence in the southwestern and eastern suburbs, and the significance of groundwater abstraction through the metropolitan area (Figure 4)
  - the progressive raising of groundwater resource charges which were restructured into two separate components :
    - a groundwater use fee (from which domestic use in areas without mains water-supply is exempt) which was increased from Tbht 3.5 (US$ 0.09)/m^3 in 1994 to Tbht 8.5 (US$ 0.21)/m^3 by 2003
    - a groundwater conservation fee (from which there are no exemptions but which is applied only within the newly defined critical areas) introduced from 2004 at rates from Tbht 1.0 (US$ 0.03)/m^3 to Tbht 8.5 (US$ 0.21)/m^3 with the implication that in the most critical areas industrial and commercial groundwater users could be paying a total of Tbht 17.0 (US$ 0.42)/m^3 for ground water abstraction.
  - more aggressive application of sanctions and water well sealing
  - public awareness campaigns on the need to arrest the trend in land-surface subsidence.

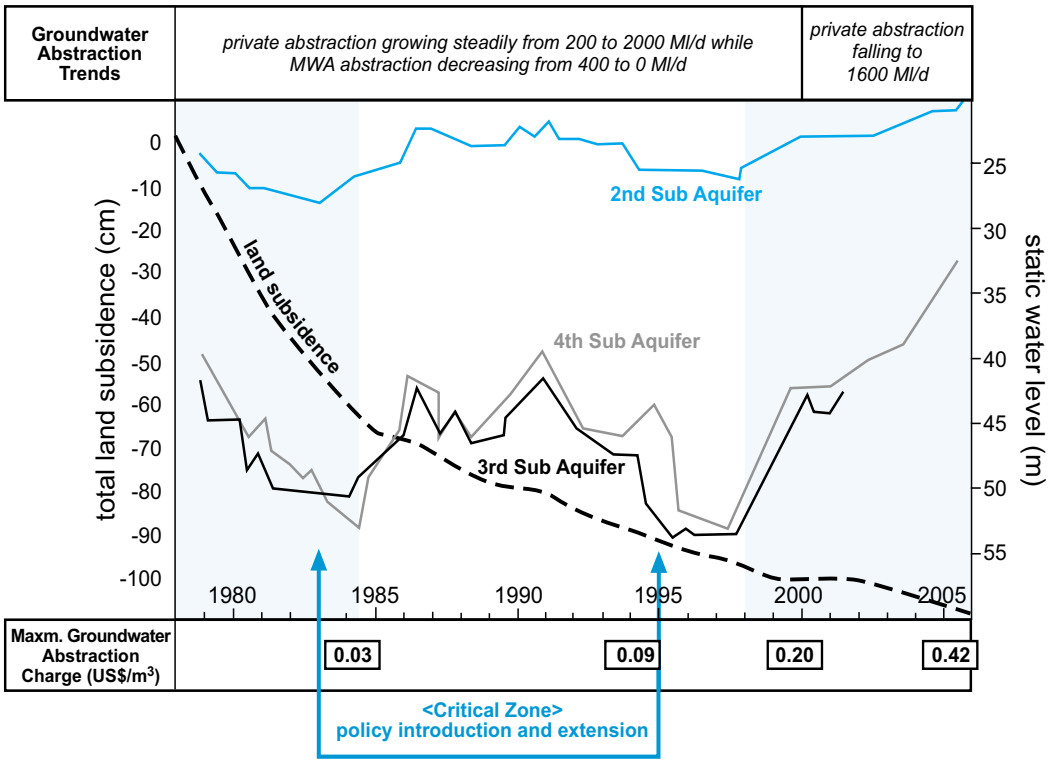
Figure 4 : Revised definition of 'critical areas' as regards land-surface subsidence control in Greater Bangkok



- The positive outcome of this policy, both as regards controlling groundwater abstraction and reducing land subsidence, is shown in Figure 5 – which shows the long-term trends for a key monitoring station in the city centre area.

- Today there are just over 4000 licensed water wells in Greater Bangkok operated by around 3000 owners, abstracting about 1,600 Ml/d (580 Mm^3/a) which represents approaching 15% of the total water-supply. Since licenses are required for all wells of more than 15m depth, this includes all of those tapping the main freshwater sub-aquifers – although it is accepted that there are probably an additional 10% above this figure (including some illegal wells and those at government installations which are exempt). Some 58% of the current licensed abstraction is by industrial users (individual plants and enterprise estates, with the textile and food sectors predominant), but many of the largest industrial water-users have moved out of Greater Bangkok to escape the increasing water charges.

Figure 5 : Timing of groundwater management interventions in relation to groundwater abstraction, piezometric surfaces and total land-surface subsidence in Bangkok city centre



- The other two important 'abstraction groups' are domestic use in private urbanizations/large apartment blocks (36%) and some PWA public water-supply sources (6%). The former is now only licensed in those areas outside of current mains water-supply coverage (the MWA offers service in 80% of its area of potential operation but for the PWAs this figure is not much more than 20%). There has been conflict in some districts (eg. Pathumtham Province) when the mains water-supply was substantially extended but with high charges (T bht 21/m^3 / US$ 0.60/m^3) and water well users made a political protest about

having to move onto mains supply. This was resolved by allowing water well users :

- to continue using their wells conjunctively for the period up to their next license renewal (up to 10 years)
- to retain their wells as a back-up supply for 15 years, provided they were adequately metered and open to inspection.

- To perform the task of groundwater resources administration the (now) DGR has some 25 headquarters staff (supplemented by short-term contract personnel as necessary for special tasks) and has seconded 3 persons to each of the 7 provincial government offices making-up the metropolitan area, who are responsible for routine local license administration and site inspection.

- The DGR is also currently in the process of letting a large groundwater resource administration audit contract to a reputable local university to evaluate the performance of the licensing and charging system, to identify any potential 'loopholes' in the current groundwater law, and to come-up with published recommendations on future management.

CONCLUDING REMARKS

- The Greater Bangkok area has two characteristics which have made the task of controlling urban private groundwater abstraction both more pressing and somewhat easier :
  - the threat of environmental degradation in general, and land-surface subsidence in an already flood-prone area in particular, which has served as a political focus for groundwater resource management efforts
  - the presence of the Holocene Bangkok Clay overlying in the aquifer system throughout the urban conurbation, which has restricted wholesale access to groundwater and reduced the number of water wells being drilled and number of users that have to be managed.

- Nevertheless, the 'Greater Bangkok experience' is very important, and has demonstrated the following principal achievements in groundwater resource management policy and practical administration :
  - the ability to reverse trends in groundwater resource decline and environmental degradation through consistent and persistent application of regulatory measures (licensing and charging)
  - the successful targeting of groundwater management measures in objectively-defined priority areas rather than having to apply them universally (which would have high administrative overhead and economic penalty)
  - the capacity of a central groundwater 'apex' agency working in a decentralised fashion in unison with provincial government offices to manage a diffuse resource like groundwater
  - the management value of long-term investments in groundwater-related environmental monitoring
  - the capability of reaching a relatively high level (above 80%) of groundwater resource fee collection
  - the recycling of part of the groundwater resource charges collected (the conservation fee) into a 'groundwater fund' from which to finance related monitoring and research activities.

- The principal aspect which has not yet been addressed is groundwater pollution control in the more vulnerable aquifer system recharge areas located towards and beyond the northern limit of Greater Bangkok. While the DGR has the responsibility and capability to provide a framework for protection in terms of defining areas of higher vulnerability which fall within the probable capture zones of the main areas of potable water-supply abstraction, they have as yet little influence over land-use planning procedures, industrial chemical handling and effluent discharge to the ground and also agricultural land-use practices. Moreover, the current legal provisions interpret even serious soil/groundwater pollution as referable only to 'civil law action' (attracting small fines) and not to 'criminal law' (where the potential penalties are very much higher).

Publication Arrangements

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