OLYMPIC DAM PROJECT WATER SUPPLY - ENVIRONMENTAL CONSTRAINTS

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ABSTRACT

Mine and processing water supplies for the Olympic Dam Project are obtained from Borefield A, located on the south-west margin of the artesian portion of the Eromanga Basin, 100km north of the mine site. The borefield comprises nine production bores, tapping the Jurassic Algebuckina Sandstone at depths of 100-200m. Abstraction has resulted in depressurisation of the aquifer with cessation or decline of nearby spring flow. The effects have been judged to be environmentally significant due to fauna and flora supported by the springs and their importance in local aboriginal culture.

Expansion of the Olympic Dam Operations is dependent on increased water supplies. Borefield B has been located in a deeper, more productive part of the basin, 90km from Borefield A. The new borefield will result in reduced impacts in sensitive areas near the Basin margin.

INTRODUCTION

WMC Resources Ltd's Olympic Dam mine is situated 550km north of Adelaide. The Operation currently processes 2.4Mt/a of ore for the recovery of 70 000t copper, 1 400t uranium oxide, 24 000oz. of gold and 50 000oz. of silver. Groundwater for plant and domestic use is currently drawn at an average rate of 17ML/d. Mill and underground operations are currently undergoing an expansion to a capacity which will require up to 42ML/d by 2011.

Borefield A is located in a small southern embayment of the Eromanga Basin - its closest point to the mine site (Figure 1). The Eromanga Basin is roughly synonymous with the broader hydrogeological entity, the Great Artesian Basin, within the study area. The southern margin is a major groundwater discharge area for the Great Artesian Basin. Discharge from the Jurassic Algebuckina Sandstone aquifer occurs under natural artesian pressure by spring flow, associated with faults or outcrops and by diffuse leakage through relatively thin and often structurally disturbed, confining shales. Discharge from pastoral bores has also been focused on the marginal areas, since the aquifer is shallower, cheaper to develop, and pastoral activities are more intensive.

Abstraction from Borefield A is regulated by drawdown limits at the boundary of an area defined in "Special Water Licence 1" (Armstrong and Rowan, 1986). As these limits are approached, there is concern over the ecological effects of declining flow from spring complexes in the vicinity of the Borefield.

Potential expansion at Olympic Dam Operations would increase the water requirement to a maximum of 42ML/d by the year 2011. Criteria for the expanded supply system were to allow reduced abstraction at Borefield A and to minimise impacts on natural spring discharge and pastoral bores. The adopted site for Borefield B is 90km further into the Basin, comprising 3 production bores and 12 observation bores at distances of up to 45km from the borefield. The latter will be used to assess compliance with a prescribed maximum drawdown at the boundaries of an area specified under Special Water Licence 2.

Hydrogeology

Hydrogeologic background is covered in some detail in Audibert (1976), Seidel (1978) and Habermehl (1980). The main aquifer is a leaky confined aquifer with pressure levels maintained by rainfall recharge in up-lying areas of aquifer outcrop (Northern Territory and Queensland). The southern margin of the Basin is a major area of natural discharge. Natural discharge is via springs and diffuse vertical leakage through confining layers, especially where they thin near the basin margin.

Spring flows occur where the aquifer outcrops at the down-gradient end of the flow system, or where major structures have provided flow paths to the surface. Many of the springs in the study area occur near outcrop, with small fault displacements raising the aquifer and allowing a preferred path to a topographically depressed area.

Development of the Basin by drilling of water bores since 1880, has resulted in bore flow becoming the major component of groundwater discharge. Pressure and natural discharge is thought to have stabilised at lower levels with greater recharge and throughflow matching discharge from bores (Habermehl, 1980).

Borefield A

Borefield A is located in a NNE trending half-graben. The Proterozoic bedrock surface in the area is well described by a series of seismic refraction traverses (AGC, September 1987) showing a palaeotopographic depression which bifurcates to the south, corresponding closely to existing creek locations. Drillhole data shows the Algebuckina Sandstone aquifer pinches out to the west against a steeply rising bedrock surface. The aquifer is truncated to the east against a basement horst including the Hermit Hill Proterozoic inlier. Faulting along the Norwest fault zone has subdivided the area into two parallel (half) grabens: the Wellfield and Northeast Sub-Basins (Figure 2).

The structural setting imposes hydraulic barrier boundaries on three sides of the Borefield.

Numerical simulations for prediction of the aquifer response, presented in the original EIS, indicated that 9ML/d production could be sustained by steady-state inflow to the graben from the north (Kinhill-Stearns Rodger, 1982). Significant reductions in spring and bore flow rate were predicted to be localised, which has proven correct despite the fact that production has exceeded simulated rates.

Of particular recent concern has been declining flow rates from springs at Bopeechee. This is due to hydraulic communication between the Wellfield and Northeast Sub-Basins across and around the Norwest Fault Zone. The main strategy for limiting abstraction impacts near Borefield A is the development of Borefield B. Based on the ten year record of monthly water production, aquifer pressure and spring flow data, a fairly rapid recovery of spring flow rate is expected upon reduction of the production rate from Borefield A. As an interim measure a system has been established whereby up to 0.5ML/d of water taken from Borefield A is pumped across the Norwest Fault Zone hydraulic barrier to bore GAB20 where it is reinjected into the aquifer, thereby maintaining aquifer pressure in the southern part of the Northeast Sub-Basin. By this means pressure levels in the area have been stabilised over a period of increasing average abstraction.

Borefield B

The general concept of a second borefield was considered in the original EIS presented in 1982. Planning for the construction of Borefield B commenced in 1992. Initial investigations, including 120km of reflection seismic and 8 drillholes were focused on an area 50km north east of Borefield A. The aquifer thickness in this area was found to be highly variable, with complete pinchout over structural highs (Figure 3). A numerical groundwater flow model used to simulate the effects of abstraction at the site, showed that drawdown would be localised by the structural constraints, and that long term impacts would be significant at the Basin margin.

Borefield B has been constructed a further 40km to the northeast of the original site. Pre-existing exploration seismic data was used for targeting. The borefield is located in a broad structural low across which the aquifer thickens to 120m. Geophysical data shows aquifer continuity and further, more gradual thickening to the north. To the south, drawdown is limited by partial hydraulic discontinuity across structural highs. The borefield comprises three bores to a total depth of 800m. The Algebuckina Sandstone comprising weakly or uncemented clean coarse sands. Testing results gave an average hydraulic conductivity for the section of 10m/day. The artesian flow rate from each of the bores was up to 20.0ML/d (230L/sec) at temperatures in excess of 60 C.

A network of observation bores encircles the borefield. Regular pressure measurements at these bores will be used to assess compliance with the allowable drawdown at the boundary of the Special Water Licence area. An extensive gravity survey was undertaken to allow interpolation of the structures impacting on the Mesozoic sediments between seismic lines and to aid in targeting of the observation bores.

Significance of the Springs

The southern basin margin is characterised by the dominance of discharge processes in the form of both vertical leakage (evaporative discharge) and spring development. Many of the springs have developed mounds of calcareous precipitates and fine grained sediment which has led to the popular description of all the Great Artesian Basin Springs as "Mound Springs". Flows from individual springs are generally small (a few litres/sec) and the springs may be thought of as localised centres of concentrated vertical leakage loss. The diffuse vertical leakage losses are estimated to be of the order of 5mm/annum (Woods 1990) which represents a discharge of 5 megalitres/km^2/annum where no springs are developed.

The springs are regarded as significant for the following reasons;

·Aboriginal Culture - the springs play an important role on Aboriginal Legend

·European Settlement History - the original North/South telegraph line and railway followed the line of springs around the edge of the Simpson Desert.

·Biological

·the springs are regarded to be "evolutionary islands" in a desert environment.

·unique species of hydrobiid snails and the rare plant *Eriocaulon Carsoni* occur in the immediate vicinity of some of the springs.

migratory and resident bird populations depend on the springs for water supply and habitat.

· tourism - the springs form an interesting contrast to the arid conditions in the surrounding desert and can be visited en route to see Lake Eyre.

Although the popular concept of the mound springs is a series of permanent watering points on the edge of a desert, the springs themselves are certainly not permanent in the geological time frame and can show significant flow variation between observations.

Some of the smaller springs even demonstrate diurnal variation and sensitivity to atmospheric pressure variations. Owing to the nature of the discharge points it is extremely difficult to measure flow rates with any confidence and many of the discharge points ebb and flow as sediment blocks the conduit and is later washed clear. A decline in flow from a particular vent may be replaced by an increase in flow from an adjacent vent or by increased diffuse seepage from the mound thus making meaningful monitoring of spring flows very difficult.

Groundwater Flow Model

As part of the environmental impact assessment, it was necessary to predict the drawdown effects of the proposed abstraction schedule and to demonstrate how this drawdown would effect existing discharge from bores and springs. For this purpose a numerical finite difference model of the hydrogeological system (ODEX1) was constructed using MODFLOW and incorporating the results of the Borefield B construction programme.

Hydrogeological layer positions determined by existing geological mapping, gravity profiles, drilling and seismic reflection surveys were discretised to produce a finite difference grid. Input data for the model, and initial conditions, were obtained from the following sources.

-Aquifer pressure gradient from shut in pressure at bores

-Aquifer parameters by flow tests

-Long term discharge rates from pastoral bores and the Cooper Basin Oil and Gas Fields

-Estimates of spring discharge rates

-Leakage through overlying shales determined by chemical profiles (Woods, 1990)

-Response of shallow observation bores at Borefield A which indicated that storage in the confining beds is an important source of water.

Parameters subject to the above constraints were adjusted such that the simulated pressure field matched observed and assumed pressures after allowing the model heads to respond to a simulated period of pastoral bore development followed by some recovery due to a bore rehabilitation program begun by the South Australian Department of Mines and Energy in the 1950's.

The conceptual basis for the MODFLOW model is illustrated in Figure 4 with the main aquifer represented by Layer 3 and the aquitard (confining beds in which storage is an active component) by Layer 2.

Because of the immense size of the aquifer system, drawdown over periods up to several decades is primarily controlled by the geometry, permeability and storage characteristics of the aquifer and confining beds, which are fairly well constrained. For longer simulations, model boundary conditions which determine the groundwater throughflow rate become important.

Simulation of the operation of Borefields A and B at a combined rate of up to 42ML/d for 20 years (to year 2016), showed relatively minor impacts on spring discharge at the Basin margin. The operation of some nearby pastoral bores, which at existing artesian pressures drive hydroelectric turbines and /or extensive pipelines or bore drains, will be affected by the drawdown by varying degrees depending on their proximity to the borefield. Under the provisions of the Special Water Licence existing users will have their facilities maintained to the extent that they are effected by the development.

Predicted and Observed Impacts on Springs

Drawdown estimated by the model for year 2016 is shown in Figure 5. The drawdown at the basin margins is small since the margin represents the lowest elevations on the potentiometric surface (discharge area) and the aquitard, which is very leaky in the marginal areas, behaves as a buffer by balancing falling potentiometric levels with reductions in vertical leakage losses therefore lateral flow into the area of the springs is changed very little over the time span of the model runs.

Figure 6 shows the model heads at three spring sites for the period 1983 to 2016 together with observed spring flows from 1983 to 1996. As expected there is some correlation between model predicted head and observed spring flow but the behaviour of Emerald Spring is very erratic showing a jump in peak instantaneous discharge from 1.4l/s in February 1989 to 5l/s in July 1989 against a background of generally declining head. By December 1989 the flow had fallen to 2.4l/s and the trend of declining spring flow was re-established. The area is subject to frequent minor earthquake activity and it is thought that a new conduit with low frictional resistance may have opened up as a result of seismic disturbance leading to a short term increase in discharge which declined as the conduit became blocked with sediment.

In the absence of any other method of estimation, the future discharge from springs can only be predicted in terms of a change in flow rate which is assumed to be similar to the modelled change in head at the spring site. For many of the better defined springs this was achieved by setting model cells containing springs as RIVER cells with the ground elevation of the spring entered as both the river bed and river stage and a conductance obtained by back calculation from the observed spring flow. Provided that the head calculated by the model does not fall below ground level for the RIVER cell, a discharge will be reported in the model output file which is assumed to be the model discharge rate for the spring. In a model of such a large area the dimensions of the smallest individual cells are hundreds of meters therefore the discharge from the RIVER cells which simulate springs represents at best a rough approximation of the absolute values of spring flow. Change in model discharge from these cells expressed as a percentage of 1983 flow does however simulate the changes to be expected as the result of the stresses applied to the model. Where RIVER cells were not applied, the change in model head with respect to model ground level was regarded to be a good indicator of probable changes in spring flow.

It should be clear from the above description that spring flow is assumed to have a linear relationship with head above ground level. There may, however be some threshold value of head at any given spring site, below which flow ceases to behave in a linear fashion, but there is no evidence currently available on which to base any theoretical deviation from the linear assumption.

For the three springs shown in Figure 6 the following results were obtained:-

Emerald Spring (calculated from head change) 16% reduction in flow.
West Finniss Spring (RIVER Cell flow change) 38% ....
Hermit Hill Springs (RIVER Cell flow change) <2% ....

One spring, Bopeechee Spring, located very close to Borefield A, suffered a significant decline in flow between 1983 and 1994 with a borefield discharge rate of around 12 megalitres/day and when it became necessary to increase the discharge rate to 15-17 megalitres/day it was decided to attempt to modify the flow from Bopeechee Spring by increasing the local aquifer heads using a nearby observation well GAB20, as an injection well.

Maintenance of Spring Flow by Artificial Recharge.

In order to demonstrate that spring flow could be managed by locally increasing the head in the aquifer in the form of artificial recharge (injection) and to partially offset the impact of increasing discharge from Borefield A, observation bore GAB20, which is located in the Northern Sub-Basin, was equipped as an injection well with a capacity of up to 500Kl/day. Water from Borefield A was piped to the injection well site. Preliminary numerical model and analytical work suggested that, over the distance of 4 200m between GAB20 and Bopeechee Spring, an injection rate of 200Kl/day would result in a pressure rise of 40KPa at the spring and that injected water would take at least 200 years to travel from the injection site to the spring. Injection commenced in November 1995 and as Figure 7 shows, the decline in spring flow was arrested despite the increase in discharge rate from Borefield A.

CONCLUSIONS

Concerns over the impacts of Borefield A on nearby spring complexes, and a large expansion of the Olympic Dam Operations water supply requirement, will be satisfactorily addressed by the Borefield B development.

Careful siting of the new Borefield along with a comprehensive monitoring and reporting programme, and regulation of its operation by prescribed maximum impacts will ensure satisfactory long term performance of the water supply system and minimise impacts on the sensitive springs.

It has also been demonstrated that declining spring flow rates can be modified by the injection of groundwater with similar chemistry into the aquifer at remote sites.

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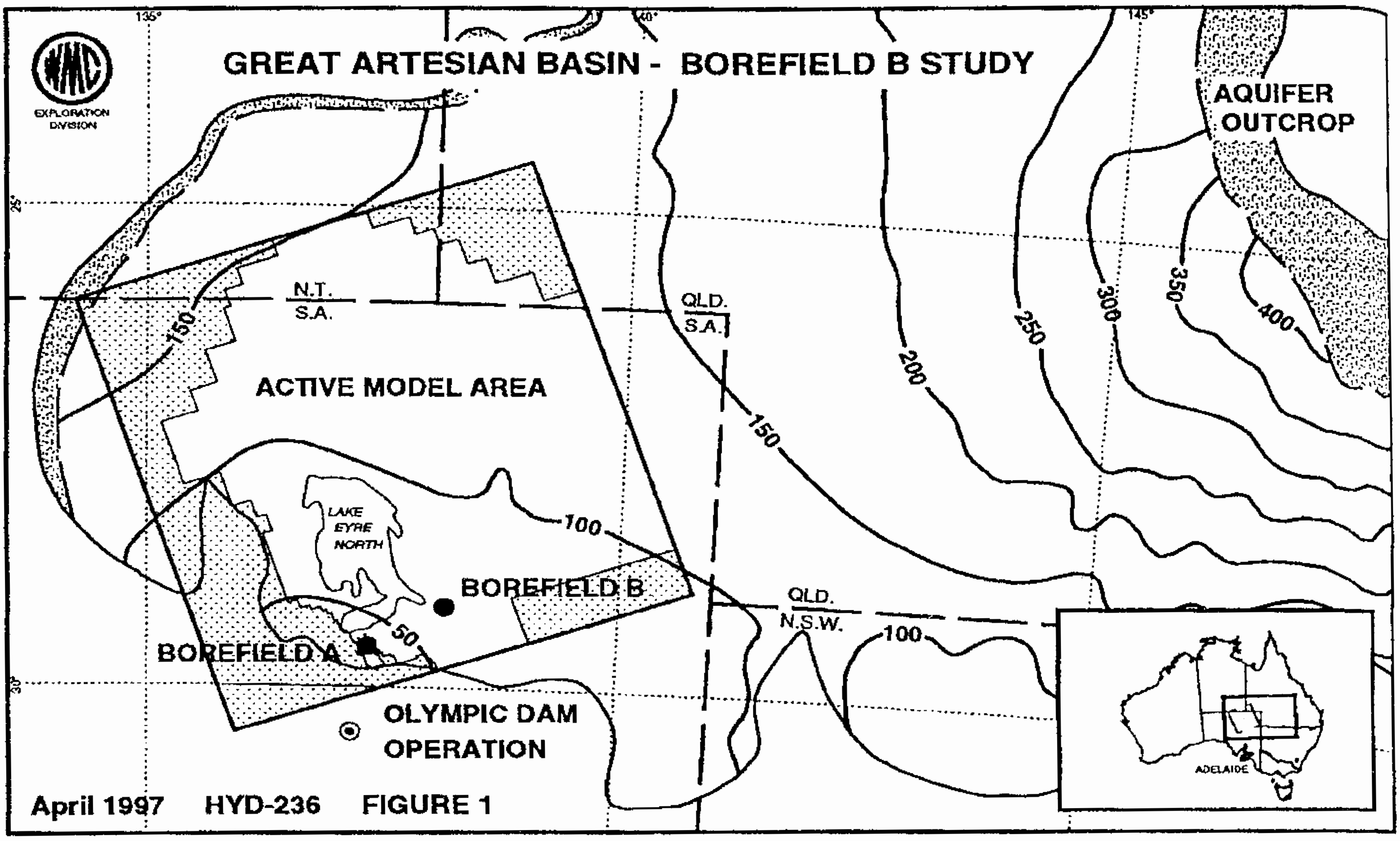
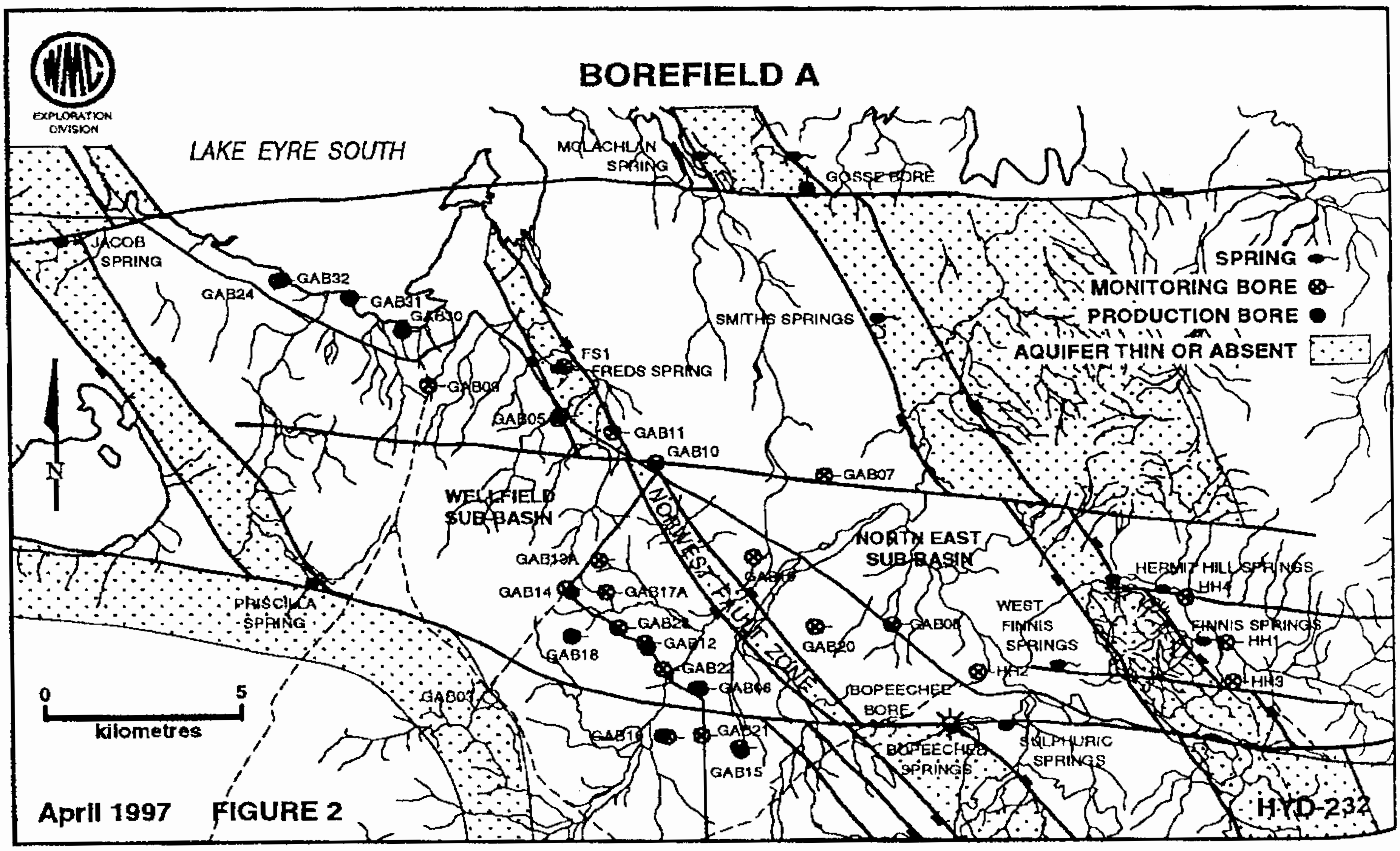
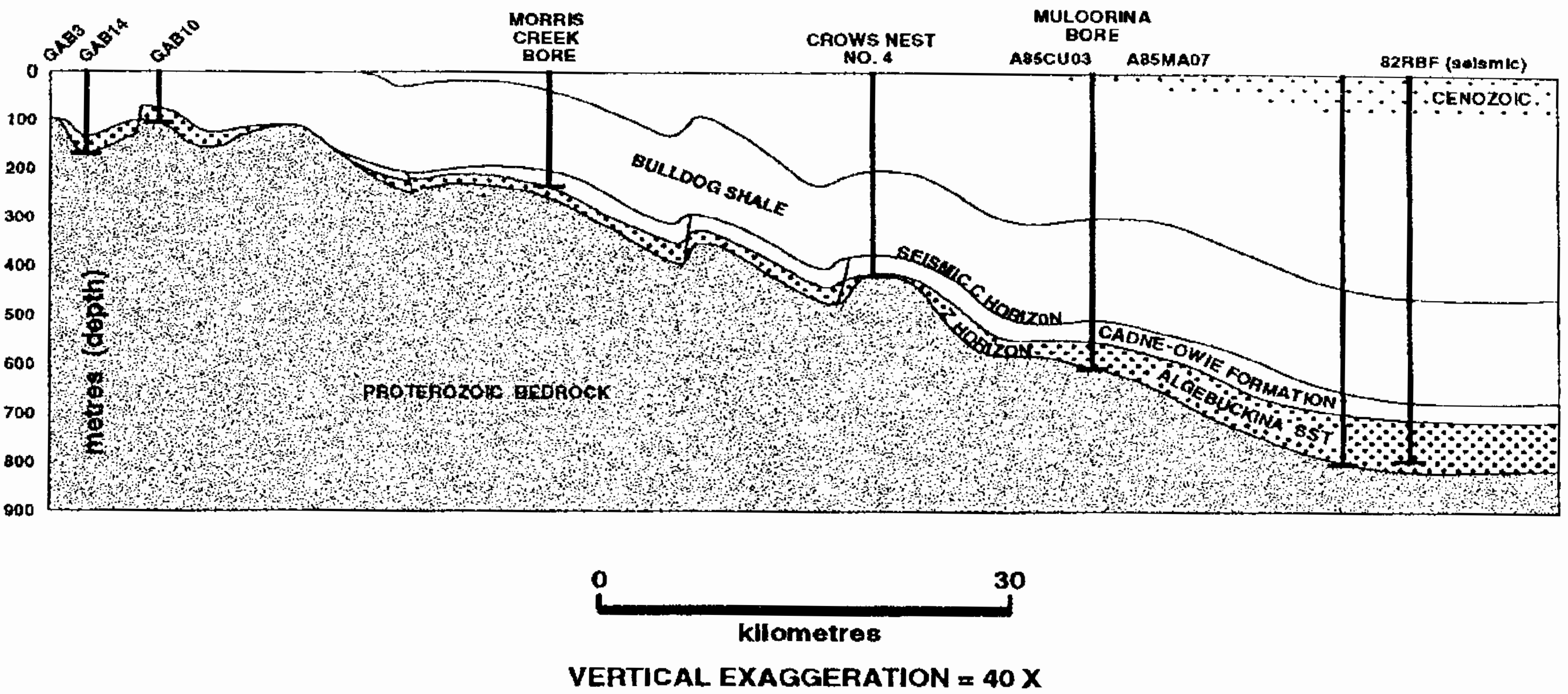


April 1997 HYD-236 FIGURE 1



April 1997 FIGURE 2 HYD-232

BOREFIELD A - BOREFIELD B
GEOLOGICAL CROSS SECTION



April 1997 **FIGURE 3** HYD-234

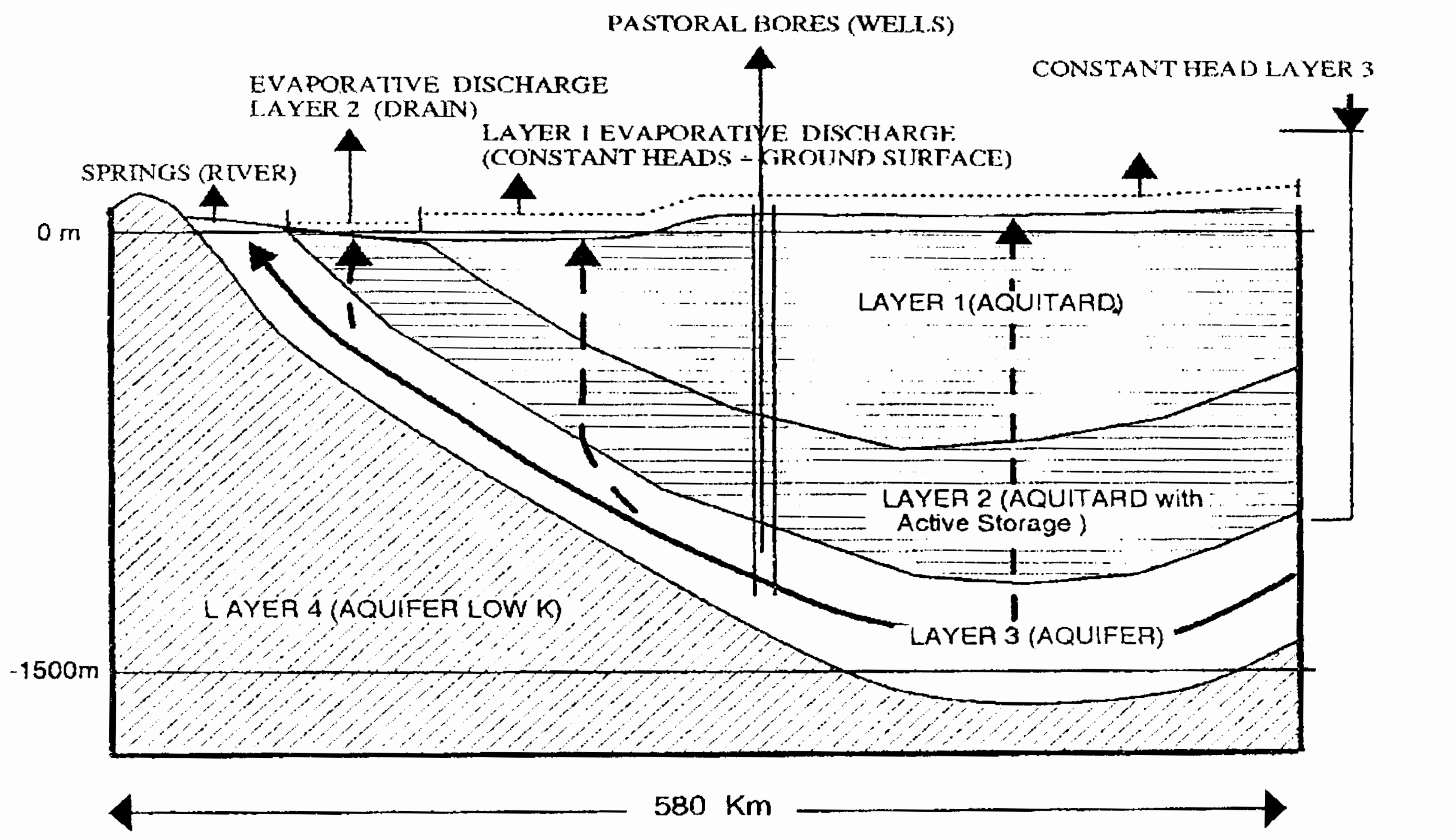
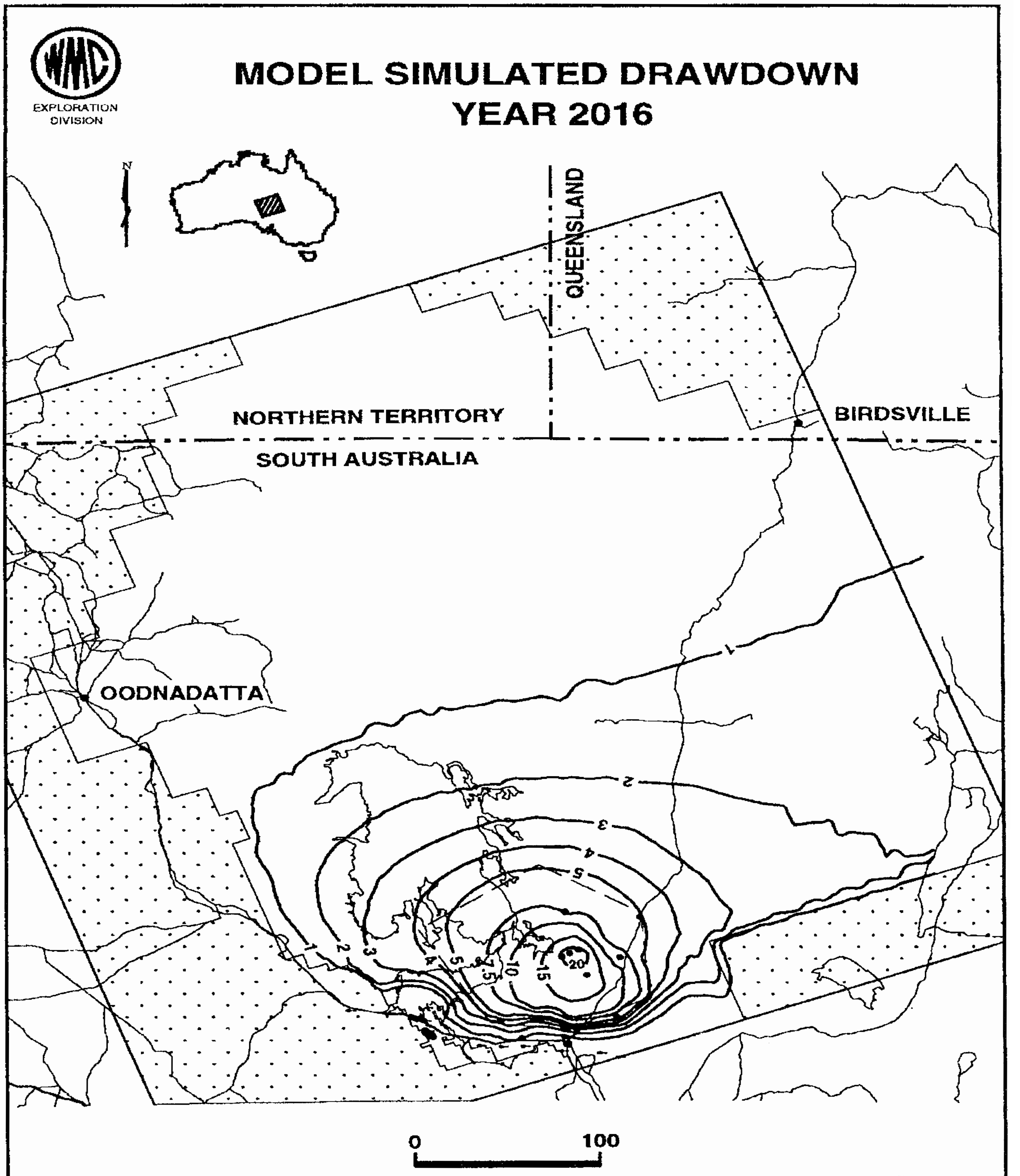


FIGURE 4 **ODEX1 CONCEPTUAL MODEL**



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ODEX 1 MODEL HEADS AND OBSERVED FLOW AT SPRING CELLS

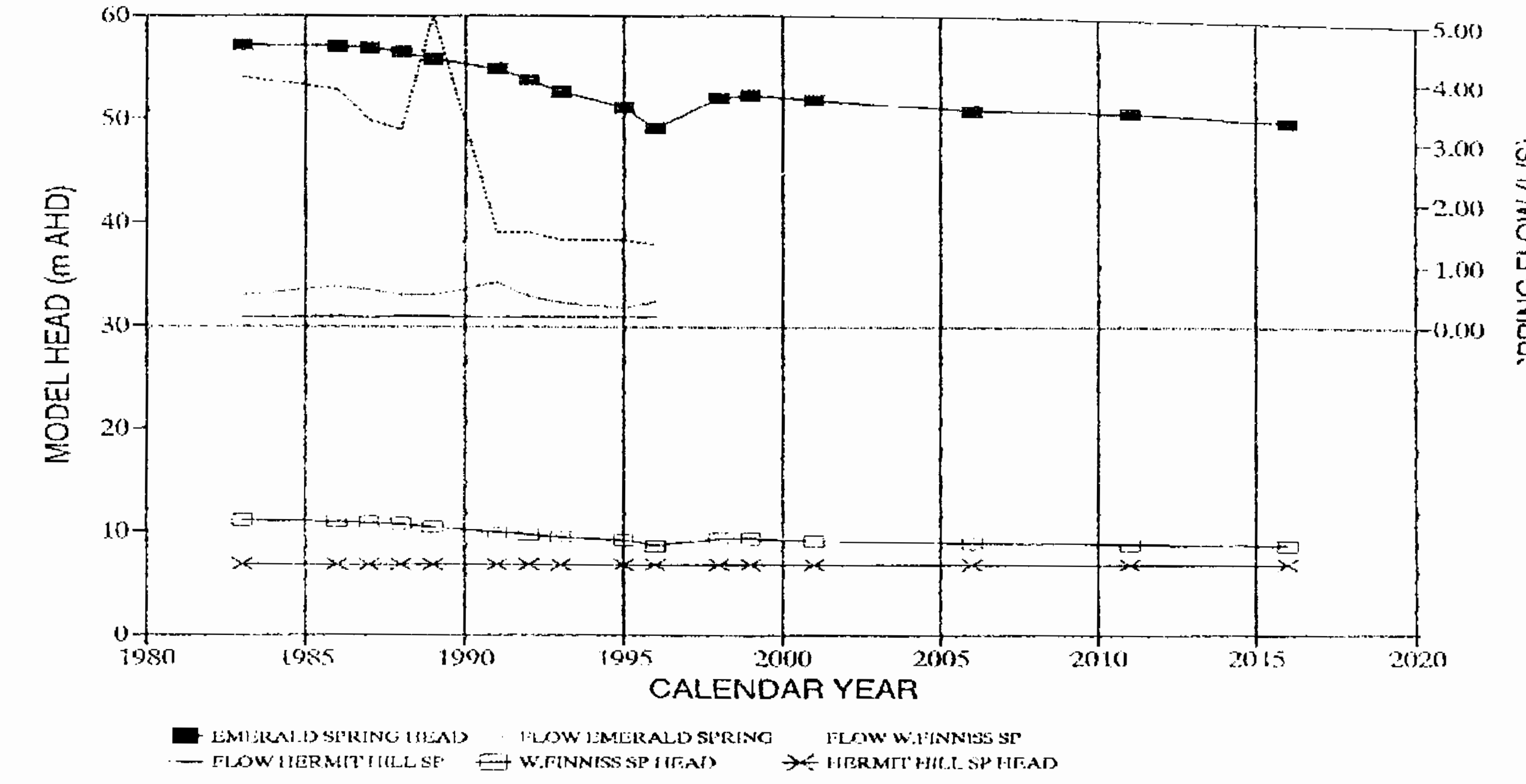

FIGURE 6

BOPEECHEE SPRING FLOW RATE SHOWING IMPACT OF INJECTION AT GAB20

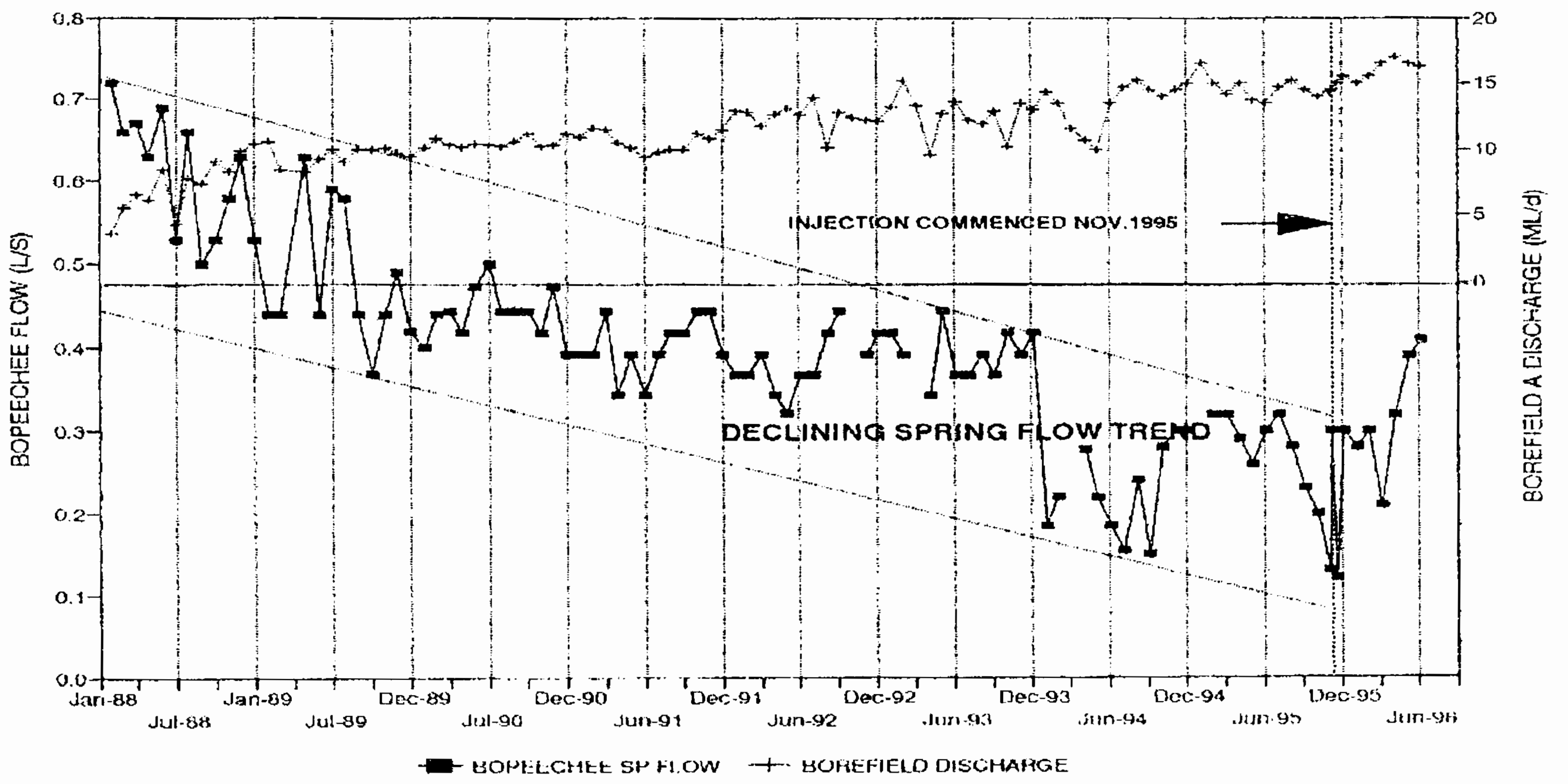

FIGURE 7