5. Schedule of limits to instantaneous take of groundwater

5A Schedule of equations to determine stream depletion effects of the take of groundwater

Requirement to determine stream depletion on surface water
The Bekesi and Hodges[1] equations are used to determine whether a proposed groundwater take may have an effect on nearby surface water that is greater than 5 litres per second.

The Bekesi and Hodges equations are preferred to other equations reported in the literature as they are less demanding of hydrogeological data, and allow a reasonable relationship to be calculated empirically, which can be transposed to determine the threshold distance between the point of groundwater take and the surface water body. These equations consider pumping occurs over 30 days, and assumes a 90 percentile confidence. Which equation is used depends on the proposed maximum rate of take (Q in litres per second):

Where 5 l/s $\leq$ Q $\leq$ 25 l/s	$r = 65 \times Q$
Where Q > 25 l/s	$r = 1138 \times \log Q$

r = distance between abstraction structure and surface water body (metres)

If r is greater than the actual distance from the point of groundwater take to the surface water body, then the stream depletion effect is considered to be greater than 5 litres per second. However, there may be exceptions to the empirical relationship (see below).

Calculation of stream depletion effect and allocation to surface water
The Jenkins[2] equations are used to calculate the stream depletion effects (or Q_s) which will be considered against the available allocation of the relevant surface water body.

$$\mathbf{Q_s = Q_w erfc(U)}$$

$$\mathbf{U = -(r^2S/4Tt)}$$

Where:

Q_s	is the rate of stream depletion (cubic length per time)
Q_w	is the pumping rate of the well (cubic length per time)
r	is the perpendicular distance from the point of groundwater take to the surface water body (length)
S	is the storativity (or specific yield) of the aquifer (dimensionless)
T	is the transmissivity of the aquifer (square length per time)
t	is time
'erfc(U)'	refers to the Complementary Error Function of U

Where subsurface intake structures have a bore head in a different location from the position of the intake screen, the closest part of the intake screen or gallery should be used for the purpose of measuring the distance to the surface water body in terms of Policy 6.4.1A(c) and the equations set out above.

Situations where stream depletion effect is unlikely

There are a number of situations where the stream depletion effect of groundwater is not likely to be valid; these include hydrological factors related to the depth of the bore screen. In addition, the Bekesi and Hodges, or Jenkins equations have situations where they are less valid or have violated their basic assumptions. The situations referred to above are summarised as follows:

Where the adjacent surface water body;

(a) Has an impermeable bed; or

(b) Is ephemeral, or dry for extended periods, containing or conveying water only in episodes of high runoff; or

(c) Is separated from the underlying water table by an unsaturated zone, decoupling the interaction into a one-way loss of surface water from the surface water body.

Where the groundwater system;

(a) Has very low permeability (e.g. schist fractured rock aquifers. Although the low permeability will calculate a very low stream depletion effect in the Jenkins equation, this is not considered in the empirical Bekesi and Hodges equations); or

(b) Has very steep gradients or perched water tables adjacent to surface water body boundaries; or

(c) Does not influence surface water due to the depth of the bore or well screen.

These situations are often not immediately discernable and may require a higher level of assessment to distinguish the nature of connection between groundwater and surface water. Where an applicant seeks that Policy 6.4.1A should not apply, and that the take should be considered as a full groundwater take under the provisions of 12.2, then the applicant may apply to take groundwater as a discretionary activity under Rule 12.2.4.1.

Use of analytical equations other than the Jenkins Equation:

The use of analytical equations will be accepted over the equations given above, when an applicant can clearly demonstrate:

1) That the analytical equation is derived from, or is otherwise comparable to, the Jenkins Equation; and

2) That this equation is in common use for the purpose, and shares a degree of acceptance in such use amongst groundwater professionals.

Use of numerical groundwater flow models:
The use of numerical groundwater flow models will be accepted over the equations given above, when an applicant can clearly demonstrate:

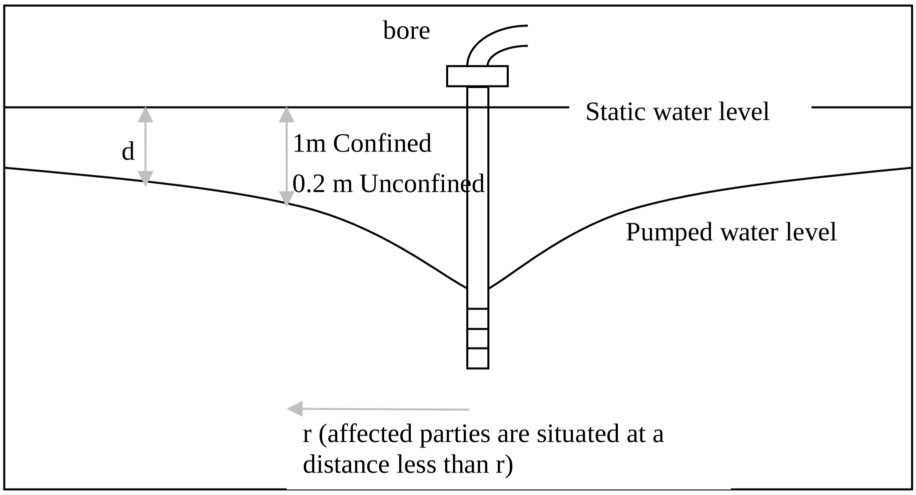
1) That the numerical method is validated or potentially validated at a generic level against either the Theis Equation or the Jenkins Equation; and
2) That the model is in common use for the purpose, and shares a degree of acceptance in such use among groundwater professionals.

[1] Bekesi, G; and Hodges, S. 2006: The protection of groundwater dependent ecosystems in Otago, New Zealand. Hydrogeology Journal. Vol. 14, No 8, December 2006, pp 1696–1701.

[2] Jenkins, C T, 1977: Computation of rate and volume of stream depletion by wells. In "Techniques of Water Resource Investigations of the United States Geological Survey". Chapter D1, Book 4, 3rd Edition. USGS, Department of Interior, Washington DC.

5B Schedule of method for identifying groundwater takes potentially affected by bore interference

This schedule is the method for identifying parties likely to be affected by bore interference when a new application to take groundwater is received. The significance of any interference may result in limits being placed through conditions on permits to take groundwater, depending on distance from another bore, and may limit the instantaneous take of groundwater from any one bore in order to maintain existing access to water.



The radius will be determined using a significant interference of d ≥ 1 m for confined aquifers or d ≥ 0.2 m for unconfined aquifers, and the 'Theis' equation:

$$\mathbf{d = QW(u)/4\pi T \text{ where } u=r^2S/4Tt}$$

Also where:

d is the interference

Q	is the pumping rate from the bore
W(u)	is the "well equation", approximated by a Taylor series: $-0.5772 - \ln(u) + u - u2/2 \cdot 2! + u3/3 \cdot 3! - \ldots$
r	is the distance from the pumping bore
S	is specific yield/storativity of the unconfined/confined aquifer
t	is the time or duration of pumping
T	is the transmissivity of the aquifer

For clarification, the variables required for the 'Theis' equation will be quantified as follows:

Q	from the consent application: maximum daily volume
r	from maps, aerial photos, or preferably GPS coordinates
T and S	from pumping tests or conservative estimates
t (in days)	from consent application: maximum annual volume divided by the maximum daily volume

If a variable cannot be estimated from the consent application or the applicant did not supply the information, the Council will estimate it on an environmentally conservative basis.