Results of an Investigation into the Impact of Irrigation Wells on Groundwater Availability in the Baltic Area

G.H. Somers & J.P. Mutch
P.E.I. Dept. of Fisheries & Environment

Prince Edward Island
CANADA

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Background:

Over the past several years there has been increased interest in agricultural irrigation. This increased demand for water, often in relatively small watersheds, raised new challenges for resource managers, and in the spring of 1995 the Department of Environmental Resources (now Department of Technology and Environment) released an "Irrigation Policy" defining how available water resources would be allocated between various users. Because of the relative abundance of groundwater on P.E.I., the policy encouraged the extraction of groundwater for irrigation, especially where surface water resources are limited, or heavily utilized.

Under this policy, groundwater extraction for irrigation purposes is handled in the same manner as for other high capacity wells, with proponents being required to obtain Groundwater Exploration Permits and Groundwater Allocations. This process includes the evaluation of possible impacts of each proposal on other groundwater users and the environment, and is based primarily on pump testing data required as a condition of the permit. In spite of the safeguards in place through this process, concerns over the impact of high capacity wells persisted. In 1997 and 1998 the Department engaged in additional monitoring activities in the Baltic area to further address this issue and to validate the underlying assumptions that have influenced policy in this area. This report describes the nature of this work and the results from the 1997 and 1998 field seasons.

Study Scope and Methodology:

The Baltic region was chosen for study primarily because of the relatively high density of irrigation wells in the area, and because of its relatively small, and thus manageable, watershed size. The study area comprises the Baltic River and Shipyard River watersheds, with a combined area of approximately 33 square kilometers (km^2). Within this area, there are seven irrigation sites relying on groundwater sources (high capacity irrigation wells) with well yields ranging from 150 to 300 imperial gallons per minute (igpm). The study area and the location of irrigation wells are shown on Figure 1.

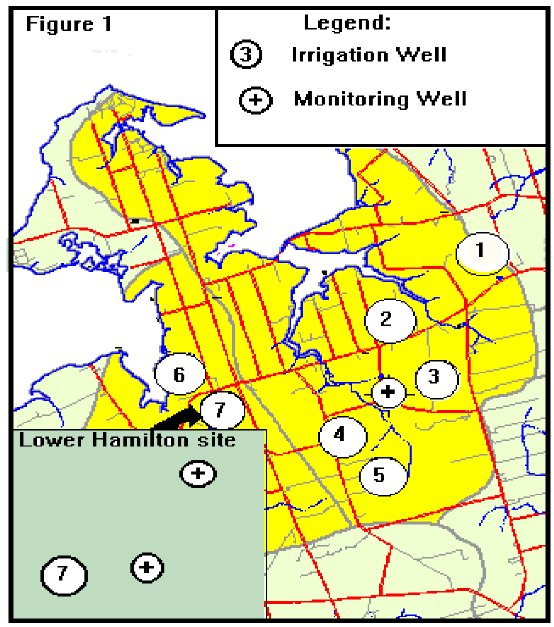

Figure 1. Location of irrigation and observation wells in the Baltic Area

The assessment in this report follows two lines of reasoning. The first approach focuses on changes to the water table as a result of pumping, both in the immediate vicinity of irrigation wells and throughout the watershed as a whole. This approach also allows for a comparison of the level of impact predicted during the environmental assessment of the proposal with the actual impact under operational conditions.

The second approach involves an examination of the effect of pumping in the context of an overall "water budget" for the watershed area. It compares actual groundwater withdrawals with the amount allowed under the permits issued, and with the overall availability of groundwater in the study area.

To conduct these analyses several types of information were required including the location and pumping capacity of irrigation wells in the study area, observation wells at which to observe movement of the water table, and records for the actual periods of pumping at each site. These data combined with regional information on the general climatic and hydrogeological characteristics of P.E.I. are sufficient to conduct a useful assessment of the impact of groundwater extraction activities. Information on the location and capacity of irrigation wells was available directly from Department files, as was relevant general climatic and hydrogeological information. To assess the effect of pumping on local water table elevations, two monitoring wells were equipped with continuous water level recorders at distances of approximately 30 metres and 300 metres from a typical irrigation well in Lower Hamilton (Site 7).

In addition, an observation well was constructed in the central portion of the study area in 1997 to measure overall trends of the water table during the irrigation season, and thus provide an indication of the net impact of all irrigation activity in the study area.

Data from a long term groundwater monitoring well in Summerside was used for comparison purposes. Records of pumping schedules for five of the seven irrigation sites were obtained from the irrigators in order to assess the actual level of pumping activity during the 1997 irrigation season. In addition, irrigation records from the site (Site 7) in Lower Hamilton were obtained for the 1998 field season.

Impact of Pumping on Water Table Elevations:

When a high capacity well is pumped, the most immediate and obvious result is a lowering of the water table in the vicinity of the well. In general, this lowering of the water table increases with time and with pumping rates, and diminishes with distance from the pumping well. This results in the formation of a cone shaped depression in the water table centered around the pumping well, commonly referred to as the "cone of depression." Initially these changes in water level occur rapidly, but they slow progressively until at some point a steady state is achieved and the size and shape of this depression of the water table will not change further with time. The size and shape of the cone of depression depend on a number of factors, including the pumping rate, the duration of pumping, and the characteristics of the underlying water bearing geological formations. When pumping ceases, the process is reversed with the water table returning to essentially pre-pumping conditions over a period of time.

The size and shape of the cone of depression, and hence the effects of pumping on other groundwater users, can be estimated with reasonable accuracy from pump test data. It is for this reason that pump testing is required before permission is granted to put a high capacity well into production, and one of the key elements of the assessment is the prediction of the potential lowering of the water table at various distances from the pumping wells to ensure that the lowering of the water table will not affect the availability of water to other nearby wells.

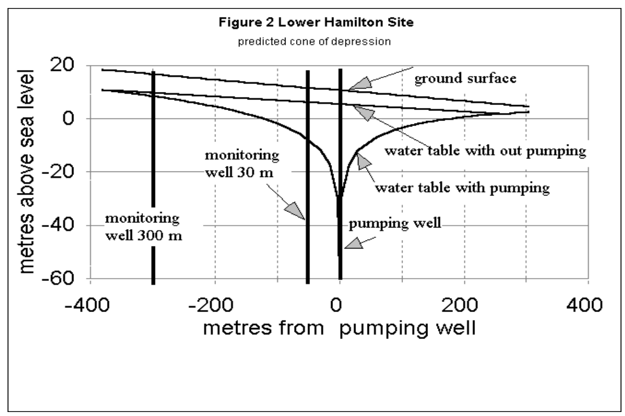

Figure 2. Predicted size and shape of the cone of depression for the irrigation well in Lower Hamilton.

Figure 2 is a cross section illustrating the predicted size and shape of the cone of depression for the irrigation well at the Lower Hamilton site, based on information gained from the pump testing of the well at the time the application was being assessed. These calculations assume a pumping rate of 200 igpm, and a pumping duration of 48 hours.

The cross section illustrates that under these conditions, the water table should be lowered by approximately 7.5 metres at the monitoring well 30 metres from the pumping well, and about 0.4 metres or 40 centimetres at the monitoring well 300 metres from the pumping well.

Results of the 1997 and 1998 field seasons:

The observation of water levels in the closest monitoring well during the 1997 irrigation season show that the maximum depression of the water table in the observation well nearest the pumping well was in the range of 10 metres under similar pumping conditions, with water levels recovering to near pre-pumping levels quickly after pumping is stopped. In 1997 and 1998, the effects of pumping on the water table elevation in the observation well 300 metres from the pumping well are less clear because they are so minor as to be difficult to separate from the normal decline of the water table through the summer periods. Water levels from this well during an extended period of pumping suggest that the water table is lowered by about 13 centimetres in comparison with the 40 centimetres predicted from the pump test data analysis.

This information would suggest that the influence of pumping on water table elevations, under normal operating conditions is essentially negligible at the distances we would expect between irrigation wells and nearby domestic wells. At this particular site the nearest residential wells are a little more than 300 metres from the irrigation well, and the effect on the water table at these sites would be expected to be similar to that seen in the more remote monitoring well. Equally important, these observations also suggest that the predictions made from the pump test data during the assessment process provide a reasonably accurate estimate of conditions that could be expected during the irrigation season.

While it is important to be able to determine the immediate impact of pumping on water table conditions in the vicinity of an irrigation site, it is also important to examine the overall longer term implications of groundwater extraction.

Figure 3 shows a record of water table elevations for the period July 8 to October 16, 1997, at the two monitoring wells in Lower Hamilton (Site 7) as well as from the observation well in the center of the study area ("local observation well"). For comparison, a record for the same period of time is shown from the long term observation well station in Summerside. The Summerside observation well is located in a serviced area of the City and should be unaffected by heavy pumping activity. For this

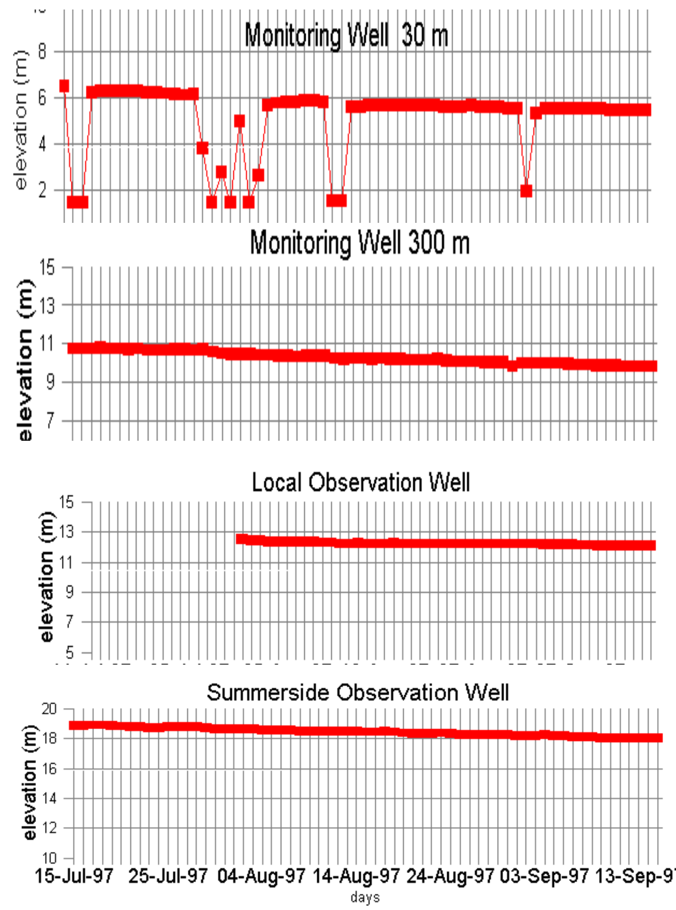

Figure 3 Water table elevations for the period of July 8 tp October 16, 1997.

reason one would expect it should reflect general background conditions for the water table, and is useful as a basis for comparison with areas subject to heavier pumping stresses. Figure 4 presents the similar results for the 1998 growing season for three of the wells.

For all of the observation wells shown in Figures 3 and 4, one can note a gradual decline in water levels throughout the period of record. This represents part of the normal "recession" in groundwater elevations seen throughout the year, with maximum elevations seen in the spring, normally declining relatively rapidly at first during the months of May and June (not shown), followed by a more gradual decline throughout the summer and early fall. The periods represented on Figures 3 and 4 cover the period of relatively gradual lowering of water levels.

Periods of pumping activity are readily picked out on the line showing water levels for the monitoring well nearest to the pumping well (monitoring well 30 m) in Figure 3. The actual amount the water table is lowered in this observation well under operating conditions in 1997 is very similar to that predicted at the time the allocation was issued, with measured water levels during various pumping cycles being in the range of five to 10 metres depending on the duration of the pumping cycle. This is not surprising when one considers that the data used for the prediction is based in part on water levels measured from this well during the initial pump testing conducted through the Groundwater Exploration Permit process.

Water levels are seen to recover quickly to pre-pumping levels, although as noted earlier there is an natural overall lowering of the water table during the period of the year.

As noted above, the effects of pumping are not so easily observed for the monitoring well located 300 metres from the pumping well, and the trend of this line is roughly similar to that seen in the local observation well in the center of the study area, and the long term groundwater observation well in Summerside in both 1997 and 1998 (Figures 3 and 4, respectively). In 1998, there was evidence of a small amount of recharge reaching the water table at the end of the period of record in all wells.

Based on the data shown on these graphs, it would appear that the effects of pumping are limited to the immediate area of irrigation wells, and only for the period of time during and immediately after pumping. Water table elevations during non-pumping periods even at this relatively short distance to a production well appears to be virtually unaffected. Further from the production well, impacts appear to range from minor, but perceptible at a distance of 300 metres during the period of pumping, to essentially negligible during non-pumping periods.

Finally a comparison of the trend for the observation well in the central portion of the study area (Local Observation Well) with the record for the long term station in Summerside (Summerside Observation Well) shows very little difference in the rate of decline of the water table. Here we are able to compare the rate of decline in the water table in an area with a relatively high density of irrigation wells with the natural rate of decline in an area where pumping activity is very limited. The fact that the rate of decline in both wells is very similar suggests that under pumping conditions similar to those observed during the 1997 and 1998 summer seasons, irrigation activity exerts little if any influence on the overall water table conditions within the watershed.

Groundwater Withdrawals considered in a "Water Budget" Context:

Because both groundwater and surface water flow is controlled primarily by topography, it is useful to assess groundwater extraction issues on a "watershed" basis. Using this approach, it is possible to construct a "water budget" for the area, allowing a more meaningful perspective from which to assess potential groundwater extraction impacts.

While a full "water budget" includes an accounting of all sources and movements of water through the hydrosphere, for our purposes here, the critical components to consider are the availability of groundwater, and the rate at which it is being extracted. In many cases, if we are confident that the amount of extraction does not exceed the recharge of groundwater to the area, we can further simplify the process, by simply comparing the presumed rate of recharge and the opposing amount of groundwater extraction.

Since the total amount of water potentially pumped by the irrigation wells in the study area during the irrigation season represents only 5% to 10% of the annual volume of recharge, the use of this simplifying assumption is appropriate in this case. As an aside, the use of the term "potentially pumped" is particularly important here, because unlike most municipal or industrial high capacity wells, the amount of water actually extracted from these wells will depend on weather conditions and crop rotations. Therefore the "allocated amount" represents the maximum withdrawal allowed from these wells and may exceed actual withdrawals by a significant degree.

Table 1 presents information on a variety of aspects related to pumping conditions at the irrigation sites and how they relate to the overall availability of groundwater within the study area.

The first column indicates the location of each site by reference to the number marking the site's location on Figure 1, and the second column indicates the pumping rate, in imperial gallons per minute (igpm), approved for each site under the Groundwater Exploration Permit process. The third column records the actual hours of pumping at each site. As noted above, the actual amount of pumping is expected to be far less than the period assumed in the assessment of a groundwater allocation, since the allocation is granted under the assumption that pumping is continuous during the irrigation season.

Table 1
Groundwater Exploration Permits for Irrigation in the Baltic River and Shipyard River Watersheds (33 km^2)

Map #	Allocation (pumping rate in gallons/min)	actual hours of pumping in 1997	% of irrigation season pump is operating[1]	average rate of withdrawal for irrigation season (igpm)[1]	total withdrawal for irrigation season (millions of gallons)	total withdrawal as % of annual recharge to the watersheds[3]
1	175 igpm	n/a	23[2]	41[2]	1.16	0.048
2	175 igpm	73.5	15	27	0.77	0.032
3	300 igpm	137.3	28	84	2.47	0.103
4	200 igpm	125.8	26	53	1.51	0.063
5	150 igpm	n/a	23[2]	35[2]	0.99	0.041
6	170 igpm	92.75	19	32	0.95	0.040
7	200 igpm	128.5	26	52	1.54	0.064
Total	1370 igpm			324	9.39	0.391
1998 Irrigation Details from Site 7						
7	200 igpm	173	24[4]	48	2.08	0.087

1) average withdrawal during pumping period determined from records for the period July 28 to August 16. 1997
2) average pumping period and withdrawal estimated from other sites
3) assumes annual recharge to the watershed equals 30% of precipitation
4) average withdrawal during pumping period determined from records for the period July 20 to August 18, 1998

These records indicate, that on average, these wells are pumping during less than one quarter of the irrigation season (see column 4). One of the consequences of this fact is that the average rate of water withdrawal during the irrigation season is far lower than the rate assumed in the granting of an allocation, and the overall rate of extraction for the study area is only in the range of 324 igpm. Average pumping rates for each site and the total pumping rate for the study area as a whole is shown in column five.

The last two columns of the table show the estimated total withdrawal of water from each site and the percentage of the total annual recharge to the watershed this volume of water represents. The results indicate that groundwater extraction from individual sites represents an extremely small portion of the available recharge to the watershed, and even the combined impact of all sites represents less than half of one percent of the available annual recharge to the area.

From this perspective it can be appreciated that even if in other years the amount of irrigation activity doubled, or if the assumptions about the rate of recharge were in error by a substantial amount, irrigation sites at the density seen in the study area are unlikely to create effects that could be readily measured in the field, let alone have serious consequences with respect to the availability of groundwater.

Conclusions and Recommendations:

Information collected from additional groundwater monitoring activity carried out in the Baltic area during the 1997 and 1998 irrigation seasons indicate that even with the relatively high density of irrigation wells in the study area, the effect of this groundwater extraction on water table conditions is limited to the immediate vicinity of the pumping wells, and under conditions similar to the 1997 and 1998 growing seasons, even these impacts are restricted to the period during and immediately after pumping activity.

Furthermore, the actual behaviour of the water table in response to the pumping activity is very much in line with the effects that are predicted during the assessment of the site through the Groundwater Exploration Permit process.

Another important piece of information gained during the study is the fact that the actual duration of pumping averaged one quarter or less of the duration assumed when applications for irrigation wells are assessed. This in effect provides a considerable margin of safety with respect to long term impacts of pumping, although it has little or no bearing on short term effects in the vicinity of the irrigation wells.

In summary, data from the observation wells installed in the study area, and from water budget calculations, indicate that the current level of irrigation activity poses no threat to existing groundwater users, or to the integrity of the groundwater resources in the area as a whole. In fact, in spite of the relatively high density of irrigation wells in the study area, overall groundwater extraction levels appear to be far below many other watersheds supporting municipal or industrial water demands.

The current process for assessing the impacts of irrigation wells appears to be adequately protective of groundwater resources as a whole, and in the protection of the interests of individual well owners.

While the assumptions made with respect to the actual duration of pumping appear to be highly conservative, it is not recommended to change the existing process, as the extent of pumping can be expected to vary somewhat from year to year in response to varying weather conditions. Nonetheless, the result of the work outlined above indicates that the current process provides a sufficient margin of safety to accommodate substantial adjustments to the actual pumping schedules at irrigation sites without concern over the availability of groundwater.

The fact that the most significant impacts of irrigation wells appear to be localized in the immediate vicinity of the pumping site underlines the importance of continuing to assess the location of irrigation wells with respect to domestic wells, and in continuing to acquire sufficient information to allow accurate prediction of localized effects on water table levels.

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