covered with grass and in general appear to be wide and strong enough to withstand the short periods during which a flood in the River Glen is likely to exceed 14.0' O.D. There is no fear of prolonged floods of several weeks or even months duration such as are liable to occur in the South Level area high level carriers. These conditions are extremely dangerous, as apart from other influences including the carrying of pumped water from many Internal Drainage Boards' pumping plants, the prolonged spells of flood conditions tend to make even the strongest banks "tired" with such a weight of water against them for such long periods. In that area also a great deal of the land is below sea level, whereas the general level of the land surrounding the River Glen, in this district, is between 7 and 8 O.D.

I have no knowledge of the general foundation and consolidation of the Glen banks, but I am of the opinion that should failure occur it would be due to a "blow out" of the toe of a bank or through general settlement, which unless correct methods were at once adopted would result in a breach.

The other major consideration with regard to pumping additional water into the River Glen is the effect on Tongue End doors, with the resultant effect on the Bourne Eau overfall. In this case I am also of the opinion that unrestricted pumping is not desirable as during a "flat" flood these doors may remain closed for considerable periods when pumping is in operation, whereas under the present regime the doors would be capable of discharging the Bourne Eau water.

I have obtained certain information from Mr. E. Bain, Engineer to the River Welland Catchment Board, in connection with various floods which have been experienced in the River Glen. This information comprises a longitudinal section of the River from Surfleet Sluice to Kate's Bridge together with cross sections and a number of water levels from which it has been possible to make certain deductions. It is unfortunate that no float runs or discharge observations have been made, but various values for a co-efficient of rugosity have been used in conjunction with different values for discharge until interpolated back-water

curves have been satisfactorily constructed to agree with mean observed levels in the River at flood conditions. From these deductions various back-water curves have been constructed for the River, which appear to agree, within reasonable limits, with observations which have been taken from time to time, and a drawing (Fig. 1) has been prepared showing three back-water curves which most vitally effect the possibility of pumping into the River Glen.

The length of the River has been plotted for some distance up stream and down stream of the Tongue End reach with the following curves.

Curve One - a normal flood line in the River Glen with a discharge of approximately 500 cu.secs., which concurs to all intents and purposes, with the mean of various water level observations made during a flood in the Glen, extending from January 22nd to February 3rd, 1941.

Curve Two - indicates a calculated water level at various points in the River with the same upland discharge (approximately 500 cu.secs) and pumping an additiond discharge of approximately 50 cu.secs. from Bourne South Fen and Thurlby Fen. (It will be noticed that a high figure has been taken for discharge of these pumps, as there is a considerable amount of spring water and also the possibility of a quantity of highland water ultimately reaching the fen through the Car Dyke bank failing). and bore at BOURNE. No evidence of this!

Curve Three - indicates the calculated water levels at various points on the River with an upland discharge of approximately 550 cu.secs., and no pumped discharge from Bourne South Fen and Thurlby Fen. nearly 790 cusecs

Comparison between Curve one and two shows that if pumping is carried to a level in the River Glen of approximately 14 O.D., the effect on the water level in the River becomes infintisimal in a distance of about 2 miles upstream to the pumping station.

Comparison between Curve two and three shows that with a highland discharge raising the water level to approximately 14 O.D. (without the pumping station having been in operation) opposite

the proposed pumping station, all influence on the water level curve is lost.

Assuming that pumping is stopped, at a level of 14 O.D. in the River Glen, the only adverse effect on the River would be a minute loss of reservoir capacity at the downstream end towards Surfleet Sluice. The popular theory in this connection is that this reservoir loss would extend over the length of the River downstream of the Pumping Station, but this is not the case as the effect of the shut off wave would have travelled some considerable distance downstream before the full reservoir capacity of the River comes into operation.

It has been shown that the condition of the Glen in itself would not be adversely affected provided pumping were not carried out to a level in excess of 14 O.D. at a point in the River opposite the Tongue End Pumping Station, and it is now necessary to regard the effect of this pumping only on the Bourne Eau overfall. The point at which the Bourne Eau discharges into the River Glen is approximately $\frac{3}{4}$ of a mile downstream of the Tongue End Pumping Station, and in this reach of the River approximately 3" is gained in water level with the result that if pumping stops at 14 O.D. the water level outside the Tongue End doors would be approximately 13.75 O.D., ie., about 3" below the average level of the overfall.

Two Typical Time/Height curves (Fig. 2) in the River Glen opposite the Bourne Eau outfall, during flood periods, have been plotted. These show a "rapid" and a "slow" flood, and it will be seen that at any level over 14 O.D. the curve remains exactly the same whether pumping has been in operation or not. It will be seen from these curves that from a level <u>below</u> 14 O.D. the Tongue End doors will not remain subject to an increased level in the River Glen for a longer period if pumping has been in operation, than would have been the case if no pumping had been carried out. In view of the previous remarks, it is safe to assume that pumping could be carried out until a level of 14 O.D. is reached in the River Glen opposite the proposed pumping station.

From the past records available, it would appear that a flood in the Glen is very rarely in excess of 14 O.D. at Tongue End for

a period of more than 48 hours, although this period has been exceeded, and it is with this period of 48 hours that consideration has now to be given.

Assuming that a satisfactory pumping station is constructed, the drains in Bourne South Fen and Thurlby Fen could be kept to a fairly low level by means of pumping into the Glen and a considerable reservoir capacity would be available in the drains, and to a lesser degree in the Fen itself to accommodate any water, even assuming that the pumps were to be 100% out of operation for the full period of 48 hours. This extreme condition need not, however, prevail, as a certain amount of water could be pumped through Heathcotes Tunnel either by means of a header reservoir or by scaling on to the Tunnel. Previous mention has been made in this report as to the possibility of the failure of this Tunnel under hoop stress when pumping is taking place, but in view of the fact that there would be a considerable head of water on the crown of this Tunnel to oppose any hoop stress, the possibility of failure is minimised and the greater the height of water in the Glen the greater becomes the factor of safety of the Tunnel in this respect. After various improvements now in hand, including the Vernatt's Drain 1941 Improvement Scheme, have been carried out in the Deeping Fen area, the Counter Drain will have an increased reservoir and discharge capacity, and the capacity of this drain together with the capacity of the drains in Bourne South Fen and Thurlby Fen should be able to accommodate the residue of a run-off from some 3000 acres of fen in a reasonable manner.

The future behaviour of the River Glen may be affected by improvements to upland water courses (e.g. War Agriculture Executive Committee Schemes), or influence on the discharge at Surfleet Sluice due to Welland water levels changing for some reason. It may be pointed out that the change of behaviour that will take place as a result of these extraneous causes will in no way alter the observations made above. reasons?

Previous Reports in connection with The Bourne South Fen and Thurlby Fen Pumping Plant discharge. Mr. C. E. Farren in a report dated May 16th, 1938, in connection with Sir Gilbert

Heathcote's Tunnel, expressed the opinion that there is no danger of the tunnel collapsing either under the weight of the river bank or the water of the River Glen. At a later stage in his report, he expressed the opinion that the Tunnel should not be subjected to a discharge head greater than 8" above the soffitt of the tunnel arch when the level of the water in the River Glen is 10' above O.D., but points out that a greater head can be used for discharge through the Tunnel when the water in the Glen is proportionately higher. Mention is also made as to certain works of reinstatement required to the masonry of the Tunnel.

Mr. E. Latham in a report dated November 1st, 1938, re Bourne South Fen and Thurlby Fen Drainage Board's proposed new system of drainage expressed the following remarks in the summary of his report: "Summarizing the remarks made in this report, I am of the opinion that it will not be possible for the Board (The River Welland Catchment Board) at any public enquiry to resist an application to pump the drainage from the Bourne South Fen and Thurlby Fen Drainage Board areas into the River Glen." In the context of this report, Mr. Latham refers to the possibility of some limitation as to pumping levels, but makes no definite suggestion as to level.

The late Major R. G.Clark, in a report dated May 28th, 1940, expresses the opinion that the Heathcotes Tunnel should be generally re-conditioned, and at a later date, the 8th October 1940, the opinion isexpressed that it would be in order to pump into the River Glen up to a level of 14 O.D., and he also has put forward certain suggestions with regard to the way in which this level should be controlled.

The Chief Engineer to the Ministry of Agriculture & Fisheries - Captain J.C.A. Rosevear, first made the suggestion that the water should be pumped into the Glen up to a level of 14 O.D., and is still of this opinion.

Opinion. After carrying out a comprehensive examination of the past, present and anticipated future conditions, I am of the opinion that a new pumping station could be constructed near

Tongue End to discharge the Bourne South Fen and Thurlby Fen water into the River Glen until such time as the River Glen attained a water level of 14 O.D., opposite the pumping station. After this level had been reached in the Glen, the remainder of the water from the Fen concerned could be passed at a low velocity through Heathcotes Tunnel (this Tunnel would require reinstatement).

The Scheme would provide adequate drainage for Bourne South Fen and Thurlby Fen, would in no way injure the stability of the River Glen banks, would not increase the high flood level in the River Glen and would not impose an increased period of downstream water level in excess of 14 O.D. against the Tongue End doors.

In conclusion, I should like to thank Mr. Edgar Bain, Engineer to the River Welland Catchment Board, for his kindness in placing much useful information at my disposal for the compiling of this report.

SGD. E. G. TAVERNER.

ENGINEER.

Diagrams have been prepared in connection with this report as follows:-

Figure 1. Typical backwater curves of the River Glen from the Railway Bridge near Counter Drain Station to Kate's Bridge.

Figure 2. Typical Time/Height curves in the River Glen at Tongue End near the Bourne Eau doors.

Figure 3. A small key plan showing the salient features mentioned in the context of this report.

Note. All levels referred to are based on Ordnance Datum Liverpool.