INSTITUTE of HYDROLOGY

A27 Westhampnet Bypass,

Addendum to Hydrogeological Study.

INSTITUTE of HYDROLOGY

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A27 WESTHAMPNETT BY-PASS, CHICHESTER. HYDROGEOLOGICAL STUDY.

Soakaways and Alternative Route.

Institute of Hydrology.
Wallingford.

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List of Contents

A27 WESTHAMPNETT BY-PASS, CHICHESTER.
HYDROGEOLOGICAL STUDY.

Note on Soakaways to Control Water Levels and on the Hydrological Impact of an Alternative Route.

1. INTRODUCTION

A hydrogeological study undertaken by the Institute of Hydrology in October 1989 on the potential hydrological impact of the proposed A27 Westhampnett By-pass, indicated that water levels in Church Farm Pit (Westhampnett Water Park) are likely to rise as a result of the proposed construction of an embankment for the dual carriageway along the southern edge of this pit.

At present there is no satisfactory way of economically disposing of water from Church Farm Pit without causing potentially adverse effects on the River Lavant, the flow in local drains or pits to the south. The vehicle parking area in the northwestern corner of the pit is at particular risk from flooding. Whilst the predicted increase in water levels from the construction of a permeable embankment is small, about 0.2 to 0.3m, winter water levels now reach critical levels such that flooding of this area is more likely to occur as a result of the proposed roadline.

Following a meeting on 21 November 1989 with the Consultants to discuss the implications of the conclusions from the hydrogeological study, the Institute of Hydrology were requested to examine the following proposals:

- the use of a soakaway connected to the Church Farm Pit as a means of preventing the potential impact on water levels resulting from the roadline
- the potential impact on water levels of an alternative course for the roadline.

This note has been prepared as a preliminary assessment of these proposals before discussions are held with the National Rivers Authority, Southern Region, regarding the hydrological impact of the roadline.

2. SOAKAWAYS AS A PREVENTATIVE MEASURE

2.1 General

In the case of the Church Farm Pit, there are practical problems of transferring water across roadlines or south into Shopwyke North Pit where there are low level installations. The volumes of water involved can also be relatively large: the natural rate of inflow to Church Farm Pit from recharge derived from the River Lavant has been estimated as 21000 m3/d and pumps have been operated in the past at rates of 10000 m3/d to stabilise water levels and prevent flooding. Such flows would exceed the capacity of local minor water courses, such as that along the eastern edge of Church Farm Pit, and potentially result in surface water flooding downstream.

The Southern Water Authority and its predecessor have been examining the problem of rising water levels in the area east of Chichester for more than 20 years, in particular to protect installations constructed on former working levels within the Church Farm Pit and in the Sopwyke North Pit immediately to the south. The rise in regional water levels is thought to be due mainly to the effects of gravel extraction and subsequent infilling, although the problem has been exacerbated by a period of higher rainfall over the past few years compared to the early 1970's.

Recently, the NRA have begun to consider the transfer of excess water from open pits by pumping or gravity drainage to soakaways located in adjacent areas of unworked gravels. This method of controlling water levels has apparently been applied recently with some success to dispose of excess water from the Shopwyke pits. By making use of aquifer storage, soakaways offer an attractive alternative to pumping directly to water courses or into adjacent pits, particularly since pumping is usually required when surface flows and pit water levels are high, and provide a means of "short-circuiting" the barriers to groundwater flow caused by the sealing and infilling of gravel pits.

However, there are also some disadvantages in using soakaways to control pit water levels:

- they are less flexible in terms of water level control if only gravity drainage is used
- they may cause an unacceptable rise in groundwater levels elsewhere, which may indirectly give rise to higher surface water flows in local watercourses or even groundwater flooding
- the depth to water level and the aquifer properties of the gravels must be suitable to accept the additional recharge and any overlying clays should be thin if trenches are used
- the rate of acceptance often decreases with time due to clogging from fine material or algal growth and may require occasional cleaning
- they could be affected by or prevent future gravel extraction in the immediate area or downgradient of the soakaway
- the transfer of water from one drainage system to another is also considered undesirable by SWA
- they may result in pollution of the aquifer.

The use, location and design of soakaways therefore needs to be carefully planned at both the local and more regional scale.

2.2 Soakaway Trench

The preliminary design of the new by-pass includes a soakaway trench on the southern side of the road some 400m east of Church Farm Pit between about chainages 1100 and 1250m. This will be used to dispose of rainfall run-off along the by-pass between the Tarmac and Maudlin roundabouts. The use of this soakaway to assist in controlling water levels in Church Farm Pit has been considered in this report.

The preliminary design of the run-off trench is based on a rainfall intensity of 21.8 mm/h and a road surface area of 6.7 ha. The trench will be trapezoidal in section with a depth of 2m, a width of 7.5m at the top and 3.5m at the base, and a length of 133m. The trench will be open and have a volume of about 1500m3. It will be situated in a low topographic area near the southeastern corner of the infilled Dairy Lane (Coach Road) Pit. The top of the trench will be at about 14.5m OD and the base at 12.5m OD.

The ground level at the site of the soakaway trench is lower than the highest recorded water levels in Church Farm Pit, which could allow gravity drainage to the soakaway. The gravel deposits have not been worked in or to the south of this particular area (whilst there is an application to extract gravel from the area immediately south-east of this pit as far as Coach Road, this will not affect the area of the proposed soakaway, although it may aggravate the rise in water levels in Church Farm Pit).

The use and design of the soakaway trench needs to take into account the following main factors, which are considered in more detail below:

- the thickness of surface clays
- the elevations of the intake and soakaway
- the rate of inflow into the pit and future water levels
- the capacity of the pipe
- the dimensions of the soakaway
- the acceptance rate of the gravels.

At this stage the wider regional aspects have not been examined. The owners of the installations in Church Farm Pit would be likely to benefit by including a soakaway in the roadline proposals to dispose of water from this pit. However, the soakaway may only be required to prevent an unacceptable rise in water levels in Church Farm Pit resulting from the roadline construction.

2.3 Ground Conditions

Several trial pits and two boreholes have been drilled in the area of the soakaway. These include TPA 11 and 12, TPC 3 and 4, and BH 5 and 6.

BH 5 was drilled to a depth of 10m (6.16m OD). This encountered sandy to very silty clay to 3.0m (13.16m OD) and Valley Gravels from 3 to at least 10m. TPA 11 and 12, which are at or close to the site of the soakaway, recorded clay to 1.3 and 0.3m depth overlying Valley Gravels to 2.4 and 3.3m, and Marine Gravels to the pit depths of 3.5 and 3.8m. The borehole logs suggest that the London Clay occurs at an elevation of about 5m OD beneath the road line adjacent to the Dairy Lane Pit.

The presence of Marine Gravels, which are usually more clayey, at shallow depth recorded in the trial pits contrasts with the thick sequence of Valley Gravels recorded at the boreholes. It is possible that a buried valley cut into the Marine Gravels passes south or south-east through BH 5. If so, this would provide a distinct advantage for a soakaway in this area. However, the sequence at either the boreholes or the trial pits may have been identified incorrectly.

In the area of TP12 a trench 2m deep will be in contact with the Valley Gravels, which occur to a depth of 3.3m (or more if the Marine Gravels have been identified incorrectly). The surface clays increase in thickness further west until at BH5 they exceed the planned depth of the soakaway.

Water levels occur at a depth of about 3.3m in winter (Feb 1987) and show an annual fluctuation of about 1 to 2m. The saturated thickness of gravels above the London Clay is about 7 to 8m. Earlier borehole data for the Dairy Lane Pit indicates a hydraulic gradient of about 1:200 in a southeasterly direction.

Permeability tests have been carried out at depths of 1.5 and 3.0m at BH5 within the surface clay deposits. Despite the clayey sequence, falling head tests could not be performed due to the high acceptance rate and constant head tests were used with an assumed head of 0.1m. A volume of 1.125 m3 was accepted in about 2.5 minutes (0.073 m3/s). The tests at both depths gave a permeability value of 15500 m/d, which is so exceptionally high for the sequence that the test results must be considered as doubtful, even though the acceptance rate was high.

In contrast, pumping tests at the Pulverisation Plant site gave a permeability value of 180 m/d. This is much more consistent with sand and gravel deposits, which typically would have permeabilities of between 10 and 300 m/d. This would suggest a T of about 1500 m2/d for the aquifer thickness at BH5 and a natural groundwater flow of about 1000 m3/d over a width of 130m (the proposed length of the soakaway trench) with a gradient of 1:200. Further tests are required to confirm the apparently very high permeabilty in the soakaway area indicated by the constant head tests.

2.4 Volume and Discharge Rate

A permeable embankment will reduce the pit storage by about 45000 to 65000m3 over the present seasonal range in water levels of about 13 to 15m OD respectively. Whilst this represents a loss in total storage of only 4%, the reduction in storage could cause an increase in the rate of water level rise by 10 to 15% (assuming an annual rise of 2m) and an overall rise of 0.2 to 0.3m. The rate at which water needs to be removed to avoid this increase is at least about 2000 to 3000 m3/d.

The critical elevation for water level control will depend on a variety of factors, such as the elevation of the drains and vehicle park apron in the north-west area or to meet the needs of local users of the water park. Discussions with local interests are required to determine an acceptable water level. However, direct flooding of the car park area could occur if water levels exceed about 15m OD and this level has been adopted for this preliminary assessment.

Obviously, no discharge would take place (unless pumped) with water levels less than 15m OD. However, a lower elevation may be desirable for other reasons and, in addition, no account is taken of any future regional rise in water levels.

Water levels will rise more quickly than in the past due to the loss in storage volume. The rate at which water would have to be removed once the elevation of the intake is reached would have to be greater to maintain water levels at this elevation. Without a form of control the discharge rate would depend mainly on the pipeline capacity.

A correspondingly greater volume would be removed with an intake set at a lower elevation than 15m OD, although a constraint would be the discharge level into the soakaway. The minimum intake elevation would be about 13.5m OD.

When the water level reaches the intake level, water would be continuously discharged to the soakaway as it would be impractical to control the rate of discharge. If the discharge exceeds the acceptance rate of the soakaway then flooding of the soakaway area could result as the ground level at the soakaway is about 14.5m.

It is likely therefore that a gravity fed scheme would actually remove a greater quantity of water than is required to prevent the additional rise in water level caused by the embankment and even lead to flooding in the area of the soakaway. It may therefore be necessary to install a control valve on the pipeline as an emergency measure to prevent any such flooding.

The highest water level observed was about 15.5m in May 1987. This represents a volume of about 105000 m3 above an elevation of 15m OD. Pit water level records indicate that the initial rise in water level at the start of the winter takes place at about 0.1 m/d, or 21000 m3/d. Hence, without a controlled discharge, this volume of inflow becomes more important than the increase in the volume caused by the roadline if water levels are to be prevented from exceeding the critical level. As there would be no effect of the pipeline until an elevation of 15m was reached, the discharge required would also have to remove a further 3000 m3/d to prevent a rise to 15.8m OD, which is also about the lowest ground elevation of the sides of the pit.

For design purposes, three alternative discharge rates have been examined:

(a) a rate of 3000 m3/d, related to the potential impact of the roadline only

(b) a rate of 10000 m3/d, being the rate of pumping that is believed to have been required to stabilise water levels in the past (probably after the first, main rise in water levels has taken place)

(c) a rate of 25000 m3/d, being that needed to reduce the rate of water level rise during the initial, main recharge event if water levels during this time rise above 15m OD and to offset the effects of the roadline.

As a preliminary estimate for design purposes it has been assumed that the intake would be at an elevation of 15m OD in the southeastern corner of the Church Farm Pit. The distance to the western end of the planned soakaway would be about 375m.

The rainfall run-off discharge level into the soakaway can be set close to ground level. This would make use of the full volume of the soakaway (the dimensions are capable of storing one hour of rainfall run-off at an intensity of 21.8mm/h from a paved area of 6.68ha without any infiltration through the soakaway). However, the pipe from the pit would have to be set at least 0.5m below ground level to overcome a head loss of about 1m, or at about 14m

OD. This reduces the effective storage volume to 1000 m3 for the pit water and the total infiltration area of the soakaway trench below the pipe entry level of 14m OD is about 900m2.

The water level data for the soakaway area provide differing values for the depth to water in this area. The monitoring data from BH5 and BH6 suggest that the maximum water level in the soakaway area is about 13.5m OD (2.3 to 3.3m bgl), which is consistent with water level data from the boreholes drilled in Dairy Lane Pit. Water was struck at a depth of 3.3m (11.4m OD) at TPA12 in November 1986, when perhaps water levels were close to their seasonal low. For design purposes we have assumed a water level of 12m OD, or 2.5m bgl at the soakaway location. This is about 0.5m below the base of the soakaway and restricts the available aquifer storage.

Since, without a form of control, more water is likely to be removed than would be required to offset the effects of an embankment, the owners of the installations at Church Farm Pit would benefit from a soakaway. A shared cost of the soakaway and pipeline would therefore seem justified.

3. ACCEPTANCE RATE

3.1 Discharge rate of 3000 m3/d

A pipe diameter of 9 inches would be required to remove the minimum quantity of pit water of 3000 m3/d (125 m3/h) necessary to offset the emplacement of an impermeable embankment with a head difference of 1m. The pipe velocity would be about 0.75m/s. Without infiltration the soakaway could accommodate 8 hours of flow from the pit at this rate.

In the following calculations a square basin with sides of 20m has been used for simplicity to examine the ability of the soakaway to accept an inflow rate of 3000 m3/d, or 7.5m/d infiltration rate, assuming a T of 1500 m2d, a specific yield of 0.15 and a retention time of 8 hours, or 0.33 days.

Using n = L/ (4Tt/S) = 20/ (4x1500x0.33/0.15) = 0.17

The head increase at the edge of the basin x/L = 0.5 and from plots of x/L against hS/Wt for values of n, then hS/Wt = 0.05 and the head increase at x/L is:

h = (hS/Wt)Wt/S = 0.05x7.5x0.33/0.15 = 0.82m

With these conditions the water level elevation below the edge of the basin would be 12.8m, or 0.3m above the base of the soakaway. The difference between the pipe inlet level and the rest water level is 2m. This indicates that the maximum acceptance rate using the above equations would be 18.2 m/d, or 7300 m3/d and that with an input rate of 7.5m/d it would take 0.8 days before the water level rose by 2m.

Conversely if the water table is to be kept lower than the base of the basin, then the rise in water level would need to be limited to 0.5m with an assumed water table elevation of 12.0m OD. In this case the acceptance rate would have to be reduced to 4.5m/d, or 1800 m3/d. The shallow water levels limit the use of soakaways by restricting the amount of available storage. This has to be offset by a high transmissivity.

These estimates are based on the permeability value derived from the pumping test at the Pulverisation Plant, which, whilst consistent with the type of deposits, is considerably less than the permeability values obtained from the constant head tests. The total infiltration area of the proposed soakaway trench is also about 1000m2 compared to the area of 400m2 used in the above calculations which represents only the floor area of the soakaway. Hence, even with rather conservative values, the proposed soakaway trench should be capable of removing the rise in water level resulting from the embankment construction.

The rate of acceptance is likely to decrease with time due to clogging. This may be as much as 50%.

3.2 Discharge Rates of 10000 and 25000 m3/d

A pipeline diameter of 12 inches could accommodate a flow of 10000 m3/d with a head difference of 1m. The pipe velocity would be about 1m/s. However, unless the permeabilities are really as high as indicated from the constant head tests, the above estimates indicate that the acceptance rate of the proposed soakaway would not be capable of removing this discharge rate.

The diameter of the pipeline required to remove 25000 m3/d would be excessive and the acceptance rate of the proposed soakaway would not be sufficient to cope with this high discharge rate.

The storage volume of the soakaway would be fully utilised within 2.5 hours at 10000 m3/d and within 1 hour at 25000 m3/d. The inflow may also take place when run-off is occuring into the soakaway from the road itself.

Consequently, the size of the soakaway would have to be considerably increased to accommodate these discharge rates. The area of high permeabilities was considered from the results of the roadline investigations to be limited to the south side of the roadline between chainages 700 and 1400m. Even so, the surface clays extend to depths of 2 to 3m in part of this area which would reduce the availability of sites for a soakaway trench. Alternative methods, such as large diameter wells, may have to be considered.

However, given the doubts concerning the permeabilty estimates in particular, it would be advisable to undertake further investigations before more detailed designs can be examined.

4. ALTERNATIVE ROADLINE ROUTE

An alternative route has been considered for the causeway area which separates Church Farm Pit from Shopwyke North Pit. This includes an embankment on the south side of the causeway into Shopwyke North Pit but only intrudes into the southwestern part of Church Farm Pit. The proposed route is shown in Figure 1.

The embankment constructed into Church Farm Pit would have a volume of about 12000 m3. This represents a loss of storage of under 1%, assuming a water level of 15m OD and an average bed level of 8.5m OD. If the embankment is constructed of permeable material with an assumed porosity of 30%, the loss in storage reduces to about 0.3%. This would have no discernible effect on water levels in Church Farm Pit.

The northeastern corner of Shopwyke North Pit is presently used as a silt lagoon. It would seem to be close to being filled, although a new bund has been constructed on its western side which may be intended partly to provide additional storage.

A permeable or impermeable embankment on the south side of the causeway would have no significant effect on water levels in Shopwyke North Pit or on the seepage from Church Farm Pit, since the seepage is controlled by the made ground and silts on the base and sides of Church Farm Pit, which would not be disturbed, and by the silts and industrial fill in Shopwyke North Pit.

Another advantage of the more southerly route would be the reduced impact on seepage from Church Farm Pit, which is thought to take place preferentially from the southeastern corner of this pit. A planning application has been submitted to extract gravel from the area immediately east of the northeastern corner of Shopwyke North Pit. The northern edge of this new pit would be close to the southeastern corner of Church Farm Pit. As this edge would possibly be sealed, the seepage taking place in this particular area would be reduced with potential effects on the water levels in Church Farm Pit. If the roadline is constructed before the gravel is extracted from this area, then the northern boundary of the new pit would have to be moved at least 75m south. This would then still allow seepage to move southeast into the undeveloped area east of the lower part of Coach Road and therefore reduce the impact on water levels that would otherwise result from the gravel extraction.

The very limited effects on water levels in Church Farm Pit of the alternative route would not require water level control measures and the costs of constructing a pipeline to the soakaway.

5 ~~4.~~ CONCLUSIONS AND RECOMMENDATIONS

The following conclusions are drawn from this brief initial appraisal of the use of a soakaway to prevent the predicted rise in water level resulting from the proposed route of the Westhampnett By-pass and in regard to the potential hydrological impact of an alternative route.

1. It should be possible to use the proposed rainfall run-off soakaway trench to remove the volume of water resulting from the loss in storage caused by a permeable embankment.

2. However, due to the practical constraints of controlling the intake of water, the pipeline and soakaway would inevitably remove far more water than would be required to simply overcome the additional rise in water levels caused by the roadline. The amount of water involved is likely to exceed the acceptance rate of the soakaway trench.

3. Due to doubts concerning, in particular, the estimates of permeability of the gravel deposits and of water levels in the area of the proposed soakaway, a reliable appraisal of the ability of the aquifer to accept higher flows or to prepare an alternative preliminary soakaway design is not possible until such information has been obtained. At this stage, it is considered unlikely that soakaways offer a practical, economic means of controlling particularly high water level conditions.

4. The use of a soakaway should be examined in a more regional planning context. A numerical modelling approach would be appropriate.

5. As there would be a benefit to others if water levels in Church Farm Pit are controlled by a soakaway scheme, the costs of implementing such a scheme would not necessarily need to be funded solely by DoT.

6. The alternative roadline route would have an insignificant effect on water levels and the embankment would not need to be constructed with permeable material.

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No	AMENDMENT DETAILS	BY	DATE

A27 WESTHAMPNETT BYPASS

ALTERNATIVE ROUTE AVOIDING DAIRY LANE

ORIGINAL DRG SIZE 594 - 841 (A1)	DRAWN	DATE	DOC. SHEET No.
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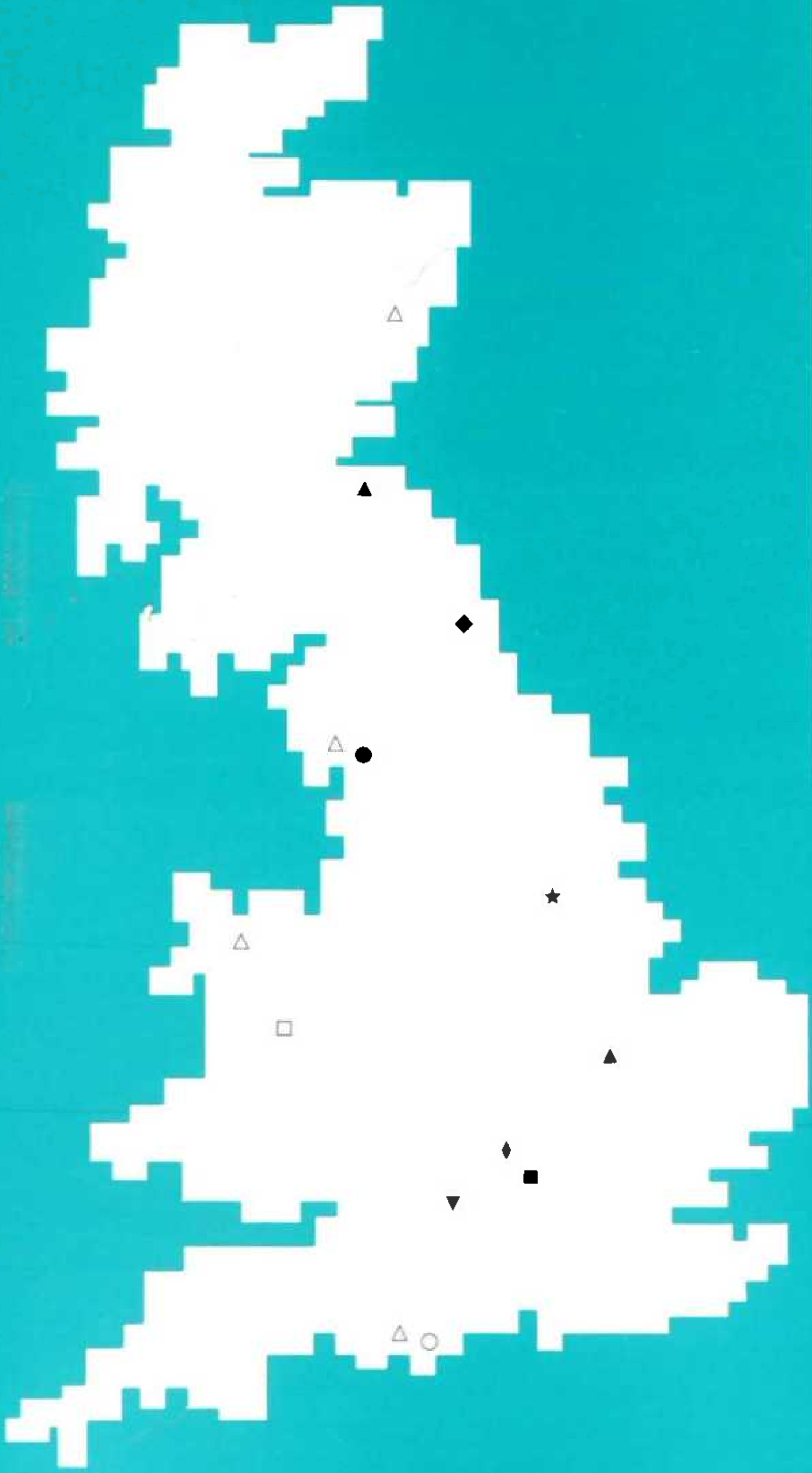

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