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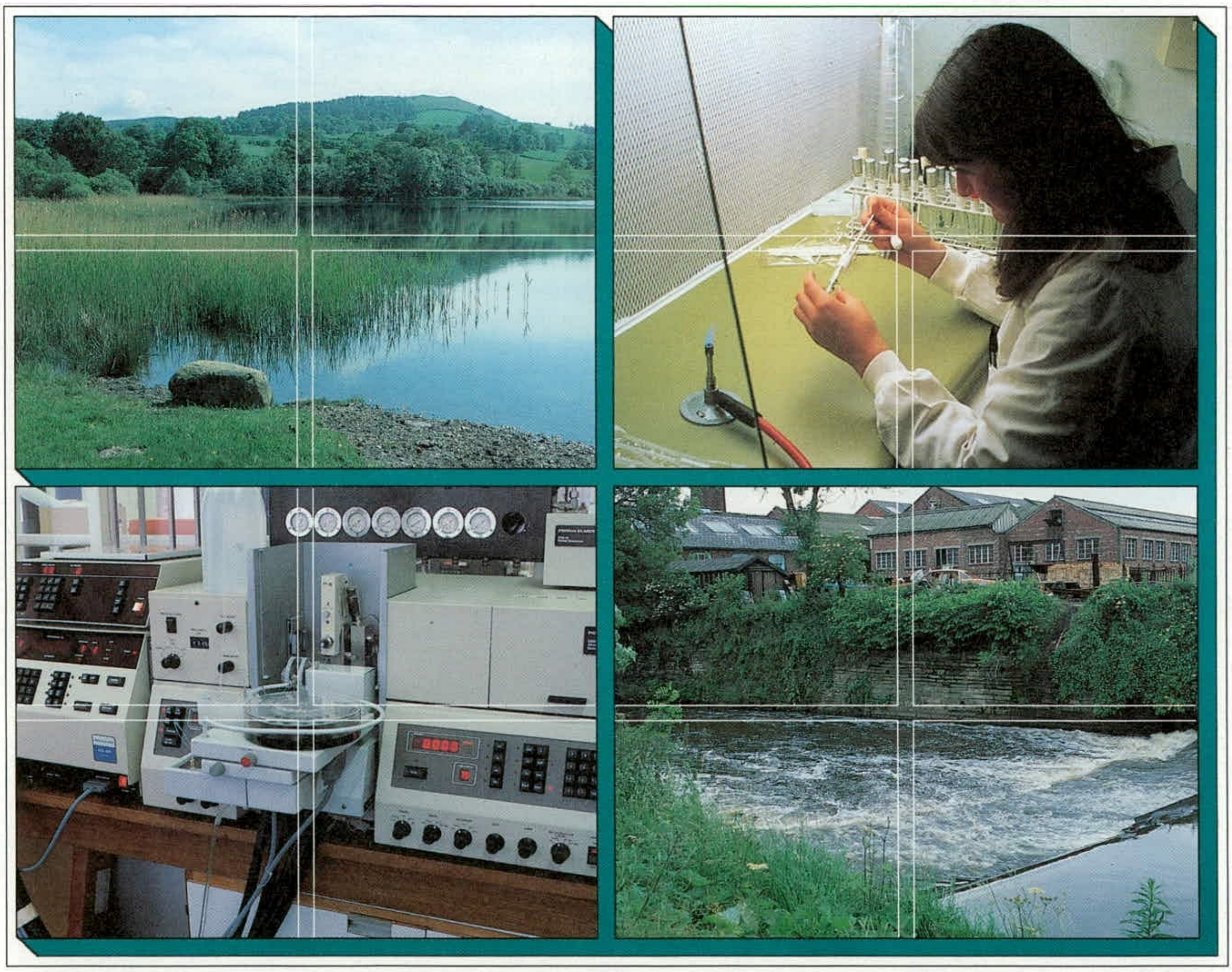

Natural Environment Research Council

POSSIBLE EFFECTS OF THE PROPOSED POLLAN DAM UPON SALMONID POPULATIONS IN THE CRANA RIVER SYSTEM

by

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ABSTRACT

This report is a preliminary assessment of the factors to be considered when establishing a regime of compensation flows suitable for Salmonid fish, downstream of the proposed Pollan dam.

The basic fishery resource is outlined and the life-stages of Salmonid fish described briefly.

The primary physical and chemical effects that can be associated with impoundment schemes, and may be deleterious to the fishery, are identified. Those impacts most relevant to the River Crana are highlighted and recommendations are given for future investigation with special reference to the established of compensation flows.

1. INTRODUCTION

This report primarily concerns the establishment of a suitable regime of compensation flows for the proposed Pollan dam, with regard to the needs of salmonid fishes. As the flow requirements vary at different points in the life cycle it is necessary first to describe the salmonid life cycle. There is then a general account of the possible impacts of the scheme upon salmonid fishes, mainly, but not entirely, in terms of streamflow and related effects such as gravel movement, gravel compaction and silt deposition. The flow requirements of each life cycle stage of the salmon and trout have been defined as quantitatively as possible and this information is then considered in terms of compensation releases. Finally there is an account of future work which may be required.

2. THE RESOURCE

Between 1980 and 1987 the declared average estuary net catches for the Crana River were 459 salmon and 122 sea trout per annum. The weights of these fish are not at present available. Making what is probably a conservative assumption that the salmon average 10 lb (4.5 kg) and the sea trout 2½ lb (1.1 kg), this fishery yields about 2200 kg of salmonids at a value of, say £4 per kg (c. £2 per lb) and, thus, with a market value of £8,800. This economic valuation of the net fishery is probably a gross underestimate (Stansfield, 1989), and does not take into account the social importance of the employment generated by such a fishery.

Between 1975 and 1987 the catch by anglers in the Crana averaged over 100 salmon and a similar number of sea trout. An unpublished report prepared for Welsh Water by A. Radford of Portsmouth Polytechnic indicated that the market value of a salmon fishery in England and Wales could be estimated by multiplying the 5-year average salmon catch by

£954 (1984 prices). On this basis the Crana River rod fishery would have had a sale value of £95,000 in 1984. As the ratio of demand to supply for salmon fishing is probably lower in Donegal than in England and Wales, this may be something of an overestimate.

Evaluations of this type are open to considerable criticism and must be regarded only as very approximate estimates. They give some indication of the financial value of the fishery with which we are concerned, but its social and tourism value must also be considered.

3. THE SALMONID LIFE CYCLE

We are concerned with two species: the trout (Salmo trutta L.) in both its resident ("brown trout") and sea going ("sea trout", "white trout", "sewin") forms and the Atlantic salmon (Salmo salar L.)

3.1 Spawning

The female parent selects a place where there is clean, running water and clean gravel of a suitable type. She excavates a pit in the streambed. She does this by turning on her side and then, with swimming-like movements of her body she creates suction which lifts the gravel off the bottom to form a pit. This gravel is displaced a little downstream by the current. At intervals she "tests" the pit by lowering her anal fin into its bottom; apparently this is to assess the flow of water through the gravel below the pit. When satisfied, she deposits eggs in the pit and the male fertilises them with milt. The female then digs another pit upstream of the first one and the spoil from the second pit covers the eggs in the first pit. This process continues until one or more egg pockets are produced within an oval structure called a "redd". A female may dig one or more redds during the course of a spawning season but the most usual number is one per female. If a pit is constructed and the female finds it unsatisfactory, she will move off and make a redd elsewhere, leaving behind a "false redd" or "trial scrape".

Salmon and trout spawn during autumn and winter. In upland and northern areas with severe climates spawning mainly occurs between October and December and may be confined to a period of only two or three weeks, whereas in areas with less severe conditions the spawning period may be later (November to March) and extend over several months. Within any given river the trout generally tend to spawn earlier than the salmon and to make more use than do salmon of small headstreams as spawning sites. Spawning trout (even quite large sea trout) can sometimes be found in streams less than 50 cm wide.

3.2 Eggs and Alevins

The period of life within the gravel extends from the time when the eggs is laid to the time when the "alevin" emerges from the gravel and becomes a "fry". Three important events can be recognised in the process of intragravel development. After some time the eye pigment of the embryo becomes visible through the casing of the egg. This event is known as "eyeing". At a later stage the egg hatches to give rise to an "alevin". The alevin remains in the gravel and subsists on its yolk sac. When the yolk sac is almost exhausted the alevin emerges from the gravel, acquires pigmentation in its skin, fills its swim bladder with air so as to attain neutral buoyancy, and begins to take external foods. This event is termed "swim-up" and at this point the young fish ceases to be described as an alevin and is described as a "fry". Shortly after swim-up the fry leave the immediate vicinity of the redd and adopt individual feeding stations and territories. They are then termed "parr".

The speed at which eggs and alevins develop is mainly controlled by temperature, though other factors such as low oxygen concentration and mechanical shock can have some influence. At any given constant temperature, if the time from egg laying to hatching is taken as 100%, then the times to eyeing and swim-up are about 50% and 170% respectively.

3.3 Free-swimming stages

The free-swimming stages of salmonids require clean, well-oxygenated water; and adequate food supply, space and cover (hiding places). At most stages and in most conditions the fish are territorial. Parr compete with one another for feeding/living territories and adults for spawning sites.

Feeding and growth are largely controlled by temperature. The relationship between growth rate and temperature differs between species, as do water velocity preferences and requirements.

Some trout remain close to their place of birth throughout their lives, whilst others, when a few years old, become "smolts" and go to sea, but return later (usually to the stream in which they were reared) to spawn. These two strategies are merely the extremes of a wide range of intermediate patterns of migration. In general, females tend to move downstream more readily and for longer distances than males. Most salmon go to sea, though some male parr may become sexually mature and take part in spawning before going to sea. Salmon, also, usually "home" and try to return to spawn in the stream of their birth.

4. POSSIBLE IMPACTS OF THE SCHEME ON SALMONID POPULATIONS

4.1 In the region upstream of the proposed dam

The information at present available (notes by Mr P. Kelly, Fisheries Officer, 20 May, 1991) suggests that there are brown trout in this area but that, as spawning ground is limited migratory salmonids (salmon and sea trout) do not use this reach as spawning or nursery area. These statements need to be verified. If salmon/sea trout do not use the area above the dam site, then no fish pass will be needed at the dam. If the brown trout which occur upstream of the dam site (video by Chairman of Buncrana Anglers Association) are recruited mainly as a result of spawning in scattered small gravel patches upstream of the dam site, then a self-maintaining brown trout fishery in the reservoir is a distinct possibility. If recruitment to the trout population upstream of the dam site is primarily or entirely by immigration from downstream, then regular stocking may be necessary in order to maintain a trout fishery within the reservoir.

Unstocked upland reservoirs in the U.K. can yield 2-4 brown trout ha^{-1} $year^{-1}$ with a weight of 0.7 to 0.9 kg ha^{-1} $year^{-1}$ and a mean catch per angler visit of 0.5 to 1.5 fish. In stocked upland reservoirs the catch is proportional to rate of stocking and yields of 5 to 68 trout ha^{-1} $year^{-1}$ with a weight of 1 to 18.5 kg ha^{-1} $year^{-1}$ can be obtained. Such fisheries give 0.7 to 1.6 fish per angler-visit (Crisp & Mann, 1977). The economics of the operation depend upon the relationship between demand for angling (cost of a day's fishing) and the costs of stocking and management.

It is important to note that future additional development of coniferous forest and/or peat extraction within the catchment of the proposed dam could lead to deterioration of the fishery potential of the reservoir.

4.2 <u>In the Crana River between the dam site and the confluence of the Camowen River</u>

Notes by Mr P Kelly dated 20 May, 1991, indicate that the principle spawning grounds in the whole Crana River system are in the 2.4 to 3.2 km of river immediately downstream of the dam site. This would include c. 0.7 km between the dam sites and the confluence of the Camowen River (20% of the river length regarded as the principle spawning area) which is likely to be most affected by the downstream effects of impoundment and abstraction. The impoundment will have rather less effect on the remaining 1.7 to 2.5 km of spawning ground below the confluence of the Camowen River.

Inspection on 15 & 16 July, 1991, indicates that suitable gravel beds may occur as far downstream as Illies. This supports Mr Kelly's statement. However it is important to verify the suggestion that this portion of river just downstream of the dam is the principal spawning area in the whole Crana system.

Physical and chemical consequences of dam construction and operation which may be important to salmonids are:

(a) Silt and organic debris may be released during felling of timber and other aspects of preparation and construction work. This may be deposited downstream and infill gravel interstices.

(b) After construction, the new reservoir will act as a settlement vessel and the silt-free water downstream will have greater competence, at any given discharge, to move silty bed material.

(c) Coarse gravel will be trapped in the reservoir and so the gravel in the River Crana upstream of the confluence with the Camowen River cannot be replenished naturally if inadvertently scoured out.

(d) Operation of the reservoir will lead to reduced total annual discharge and a modified temporal discharge pattern. Such changes will modify wetted area, water velocity and temporal and spatial patterns of silt deposition and gravel movement (Crisp, 1989).

(e) The reservoir will modify the water temperature pattern in the downstream river. The amount of modification will depend upon the size of the reservoir, upon whether or not temperature stratification occurs and upon the draw-off levels. In a reservoir of this size, downstream temperature effects would not be expected to be large. They are likely to attenuate over a distance of a few km downstream of the point of release (Crisp, 1987).

(f) Should an oxycline develop during summer, then hypolimnial releases may contain deoxygenated water and complexes of manganese and iron. Reoxygenation would be expected within a few hundred metres of the release point (Edwards & Crisp, 1982) but the deposits of precipitated iron and manganese might be a problem.

4.3 <u>In the remainder of the Crana River system</u>

The catchment of the proposed Pollan dam is only c. 14% of the total Crana River system. At the confluence of the Camowen River the effects of impoundment will be partially alleviated by the entry of a river whose catchment is of similar size. The entry of other tributaries further downstream will further reduce the effects of impoundment. However, the proposed Pollan dam will have no effect on salmonid habitat in unregulated tributaries and relatively little effect in most of the length of the mainstream river.

The suggestions that the spawning grounds of salmon (and sea trout?) are almost entirely confined to the area (c. 3.2 km of river length) immediately downstream of the proposed dam is of crucial importance and requires close examination.

5. HABITAT NEEDS OF SALMONIDS, WITH SPECIAL REFERENCE TO FLOW

5.1 General comments

The general requirements of salmon and trout are very similar, but there are some differences in the temperature and water velocity preferences of the two species and these are indicated, where appropriate. Separate treatment is given to various life stages because their requirements vary.

As far as possible, the needs are expressed quantitatively. There are, however, some difficulties which arise from the fact that the flow requirements of salmonids are often best defined as water velocities, whereas engineers and hydrologists usually work with discharges.

It is assumed that the general effect of the impoundment will be to reduce discharge and water velocity, to some degree, in the downstream river and that effects of increased velocity need not be considered.

5.2 Spawning fish

Upstream movement occurs throughout the year but is often most apparent in the autumn, as spawning time approaches. Such movement occurs mainly when flow is somewhat higher than average, but not at extreme values. Cragg-Hine (1985) developed earlier studies by Stewart to show that, in Lancashire rivers, the fish were inactive at discharges of 0.03 $m^3 s^{-1}$ per m of river width but that movement peaked at 0.08 to 0.20 $m^3 s^{-1}$

per m of river width and reduced above a value of 0.20 m^3s^{-1} per m of river width. These values appear to be broadly applicable to rivers elsewhere. In some rivers a minimum river flow must be exceeded before fish will move upstream from the estuary. It is not clear whether or not this is true in the Crana River but provision should be made to cope with such problems if they arise. Provision of water for release as occasional artificial freshets during the period June-August would be helpful.

Salmonids prefer spawning sites where water velocity at 0.6 depth exceeds 15 cm s^{-1} but is less than 2 female body lengths s^{-1} and they generally prefer water deeper than their own body depth (i.e. deeper than c. 0.2 body lengths (Crisp & Carling, 1989). According to the Chairman of the Buncrana Anglers Association (on video) the Crana salmon are mainly between 8 and 15 lb with some as heavy as 20 lb. These weights correspond approximately to body lengths of 70, 86 and 94 cm, respectively. There is no comparable information about the Crana sea trout. However, verbal reports indicate that, as in some other rivers in Western Ireland, the Crana sea trout stocks have collapsed in recent years.

The ideal salmonid spawning gravel is a clean gravel of 20-30 mm mean grain size with less than 15% of fine (<1 mm diameter) sediment. There must also be an adequate intragravel flow of well-oxygenated water. The maximum size of gravel in which a salmonid can spawn is limited by her size and an appropriate guide is the equation $P = 0.5L + 4.6$, where P is median grain size (mm), and L is fish length (cm) (Kondolf, in press).

5.3 Intragravel stages

The egg and alevin stages are dependent upon intragravel seepage water to deliver oxygen and remove toxic waste products. Silt deposition can harm these stages by reducing intragravel flow and causing asphyxiation. It can also prevent emergence of alevins from the gravel at swim-up time. These relationships cannot yet be fully quantified but they are of crucial importance. It is clear that eggs and alevins will not tolerate intragravel dissolved oxygen concentrations of much less than 5 mg l^{-1} for sustained periods and that survival rates are much reduced when the volume of "fines" (<c. 1.0 mm diameter) exceeds 10-15% by volume of the bed material.

The duration of the intragravel stages is mainly influenced by temperature. If the dates of the spawning period are known and water temperature data are available it is possible to predict the time taken to egg hatching and to swim-up (Crisp, 1981, 1988) and, hence, the period when the intragravel stages are present and are vulnerable to washout by spates or (more likely in the present context) the effects of silt deposition.

5.4 Free-swimming juveniles

Fry and parr of salmon and trout have rather different temperature preferences and the modified annual temperature cycle downstream of a reservoir may alter the balance of favourability of the habitat between the two species. However, this effect is unlikely to be significant in the Crana.

Tests in experimental stream channels and in several field studies have shown that juvenile trout prefer water depths of more than 20 cm and velocities at 0.6 depth of 25 cm s^{-1} or less. Young salmon actively avoid low velocities (<15 cm s^{-1}) and prefer depths of less than 20 cm. Changes in flow regime may, therefore, modify the relative suitability of the habitat for the two species.

5.5 Downstream movement of smolts

The downstream movement of smolts occurs mainly in spring and early summer and is accomplished partly by downstream drift and partly by active downstream swimming. This downstream movement may be inhibited by very low flows. However, if conditions are suitable for the upstream movement of adult salmonids it is unlikely that there will be any problems for smolts.

6. RECOMMENDED REGIME OF COMPENSATION FLOWS

A prescription for a regulated flow regime must await further limited field work as is specified below (paragraph 8.5). In this section the rationale behind the procedure is outlined.

In order to recommend flow regime, the requirements of various life-stages need consideration as does the propensity for bed materials in the river to be scoured and washed away or to be silted either permanently or temporarily (Carling, 1988). Excessive scour and siltation are disadvantageous to salmonid spawning but information is required about the channel geometry and the nature of the bed materials to calculate critical discharges.

Gravel-beds in rivers can be divided into two vertical components; the armour or surface layer consists of coarse cobbles with little silt content. This coarse layer needs to be broken-up by competent high flows if the sub-armour is to be scoured out. The sub-armour consists of finer gravels than are found in the armour and often the interstitial space between the gravel particles may be partially or completely filled by fine silts (Carling, 1987; 1988).

Fine silt is deleterious to salmonid recruitment, and a $1m^2$ bed area may contain up to 28 kg of silt once fully silted, at which stage some 30% of the bed material by weight will be silt and sand. Consequently if the natural gravel is very clean to a considerable depth (30-40cm), there is the possibility that a moderate quantity of fines washed downstream during construction can be stored within the bed without significant adverse effects. However once the gravel is heavily silted then, the armour needs to be entrained in order to flush out fines. In contrast, low flows which may move silt off of the bed surface will only clean-out the gravels to a depth of c. 1 median grain-size. Such surface flushing is important in many regulated streams, as lateral silt bars may develop in shoal areas, reducing the area of exposed spawning gravels.

Flows capable of flushing out fines at depth, will mobilize much coarse gravel. If the natural supply of gravels has been cut-off by dam construction, then spawning beds may be scoured-out irrevocably by exceptionally high flows. In addition bank erosion may increase to compensate for the lack of transportable bed material. The bed immediately below dams therefore frequently degrades, coarsens and compacts until it has little ecological value.

Natural river gravels are turned over by flows close to bankfull at least once a year; at least 80 to 90% of the stream width is affected. Regulated flows are rarely of this magnitude, but depending on the local circumstances flows in the range 10 to 60% of bankfull will winnow the surface layers across at least 60% of the bed width. Discharges in excess of 60% bankfull begin to mobilize the armour and, to a greater or lesser extent, assume a similar flushing role to natural flows.

The reach immediately downstream of the dam site and upstream of the confluence with the Camowen River is consequently most at risk from regulation. Further downstream the Crana River benefits from natural hydrography passing down the Camowen and regulated releases from the impoundment, which may flush out fine material. However, reduced flows in the immediate vicinity of the reservoir may lead to the deposition of any fines passing through the reservoir, and this can be exacerbated by fines from the Camowen settling preferentially in the 'slack water' upstream of the confluence. In addition some localized widening of the channel and degradation of the bed can be expected, as the reach is steep and has unstable, eroding banks especially in the vicinity of the farmhouse.

If the competence of the Crana is reduced, then any bedload introduced by the Camowen may not be readily transported. Consequently, immediately downstream of the confluence channel-narrowing may occur as gravel is deposited on the left bank. This may result in localized bank retreat on the right bank as currents are deflected.

Date requirements to enable calculations of preferred regulated flow regimes are outlined in section 8.5.

7.0 OTHER RECOMMENDATIONS.

7.1 Preimpoundment Preventative Measures

Many problems in managing channels downstream of impoundments can be exacerbated by poor management during the commissioning phase. To minimize fine particle production unnecessary disturbance to the soils in the catchment should be avoided. For example, extraction of timber and peat should be conducted so as to produce as little detritus as possible. For example stumps can be left in situ, and machinery should avoid crossing and turning in the river. Buffer zones of undisturbed riparian vegetation 20 to 50 m wide are very effective in 'absorbing' sediment washed down slope.

Consideration should be given to the provision of effective sediment sumps in the construction area, wherein turbid runoff can be pumped so that fines are entrapped.

An EC Directive sets a guideline maximum of 25 mg l^{-1} suspended solids, but natural turbidity levels in similar rivers occasionally peak at 100 mg l^{-1}. It is recommended that a turbidity meter is installed downstream of the dam-site and upstream of the confluence with the Camowen to monitor turbidity during construction. Turbidity should be kept as low as possible and sediment control procedures reviewed if concentrations exceed 100mg l^{-1} or are sustained close to 100 mg l^{-1} for more than 24 hr. Monitoring should be the responsibility of a fisheries liaison officer, not associated with the contractor.

If possible, testing of scour valves should be avoided until turbidity in the reservoir has declined, and the increase to peak test velocity should be gradual (over several hours) to prevent roll-wave formation. Consideration needs to be given to the potential scour that might occur with maximum scour velocities. Maximum velocity and discharge through the scour valves might need to be avoided as this can lead to irrevocable damage to spawning gravels downstream of the reservoir. However, given large areas of disturbed peat in the catchment area, pulses of organic rich water are to be expected during commissioning as this material will collect as a slurry behind the dam, and settle-out only slowly.

7.2 Water quality and draw-off levels

The provision of two or (preferably) more draw-off levels and a suitable scheme of simultaneous draw-off at different levels would permit some degree of management to mitigate some of the effects of impoundment upon downstream water quality with special regard to water temperature and dissolved oxygen.

7.3 Possible use of the reservoir for regulation rather than direct supply.

Use of the reservoir to regulate river flow, with water abstraction at some downstream point, would avoid most of the possible harmful effects of the impoundment upon salmonid fishes. The arguments against such an approach do not appear to be particularly compelling.

7.4 Remedial Measures

It should be noted that advise can be provided should remedial action be required. For example, suitable spawning beds can be reconstructed if natural gravels are flushed out, and, artificial raking and winnowing of heavily silted gravels can restore spawning areas, and specific advice can be given regarding the use of flushing-flows to disperse surface silt or organic detritus.

8. FUTURE WORK WHICH MAY BE NEEDED

8.1 Interpretation of results from electrofishing survey

(1a) Is there any evidence that the part of the system upstream of the dam site is used as a spawning/nursery area by salmon or by sea trout?

(1b) Do brown trout occur upstream of the dam site? If so, is it likely that recruitment to the population is from spawning upstream of the dam site?

(2) What are the present population densities of juvenile salmon and trout (especially 0 group) in the length of the Owennasop River (c. 0.7 km) between the dam site and the confluence of the Camowen River and in the c. 2.5 km of river immediately below the confluence?

(3) How do the estimates in "2" above relate to comparable estimates from the rest of the Crana River system downstream of the dam site in terms of (i) population densities (ii) approximate population numbers (i.e. mean population density x estimated river area)?

This will give some indication of the importance of the different parts of the system as nursery area for salmon and trout. It will also give useful pointers to the location of probable spawning areas.

8.2 A survey of gravel beds and redds

A visual survey of the river system by an experienced person would give a preliminary indication of the locations and areas of possible suitable spawning beds in the Crana River system. A limited amount of freeze coring could be needed to confirm or moderate the results of the visual survey.

In the final analysis, however, the only real judge of the suitability of a potential spawning site is a fish. Redd counts are already available for the lower reaches of the system. Ideally, counts are needed for the whole system, with a breakdown of the data between different parts of the system and between salmon and trout.

8.3 Collection of data on water temperature

It is unlikely that proposed Pollan dam will cause extensive downstream temperature effects. However, it will probably have some minor, local effects and these would be worth recording.

A more important reason for acquisition of water temperature data is for use in predicting the period of intragravel development of salmonid eggs and alevins. These stages are particularly vulnerable to flow-related effects and information on the period during which they are present in the gravels is of practical importance, particularly for the portion of river just downstream of the proposed dam, when determining compensation flows.

If desired, I.F.E. could advise on suitable equipment, costs, siting and operation.

8.4 Monitoring

In a letter to Ms Phee Morkel from Buncrana Anglers Association (28 February, 1991) there is reference to a need for "full time monitoring to be maintained .....". Should this request be met, there will be a need to design a suitable programme and to put it out for tender.

8.5 Recommended Regime of Compensation Flows

Following a site visit on the 15/16 July 1991, it is recommended that suitable compensation flows are calculated for at least two sites on the River Crana. These are between the impoundment and the confluence with the River Camowen and in the vicinity of Illies. To accomplish this the following procedure will be required:

a) At each site, three channel cross-sections approximately 100m apart should be surveyed and the channel slope through this reach should also be recorded. Bank tops and the edge of vegetation should be marked on the sections.

b) At each cross-section three freeze-cores should be collected to provide information on substratum size, bed roughness and potential stability. Cores will also be analysed to indicate the present quality of the spawning gravels within these reaches.

c) Data from (a) and (b) will be used in an hydraulic flow simulation to calculate bed stability, flushing-flows, critical water depth and velocities for salmonid life stages.

d) The results from (c) will be related to existing discharge regime and available compensation flow within the proposed impoundment.

e) A preferred compensation flow regime will be identified with reference to fisheries (see section 5 above) and available water. Any potential problems and benefits with this regime will be noted.

f) Information is required about the peak design (theoretical) discharge from scour valves (if available) and this data should be sought from the Contracting Engineer as soon as possible.

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