

IN THE MATTER of the Resource Management Act 1991

AND

IN THE MATTER of an application pursuant to Section 201 for a
Water Conservation Order on the Hurunui River.

**STATEMENT OF EVIDENCE OF DAVOR BEJAKOVICH
ON BEHALF OF
THE NORTH CANTERBURY FISH AND GAME COUNCIL**

Dated 6 March 2009

1. INTRODUCTION

Qualifications and experience

- 1.1 My name is Davor Bejakovich. I am a Senior Fish and Game Officer employed by Fish and Game New Zealand, North Canterbury Region, Christchurch.
- 1.2 I hold a BSc degree in Biology and MSc degree in Ecology from the University of Belgrade, former Yugoslavia.
- 1.3 I have more than 20 years experience in the field of animal ecology. I worked for eight years as a research scientist at the Institute for Biological Research, University of Belgrade, Yugoslavia. Since arriving in New Zealand I worked for nine years as a scientist (Entomology, Herpetology), team leader (Entomology) and forest surveillance and response manager at the Ministry for Agriculture and Forestry and have worked for the last four years in my current role.
- 1.4 I have spent the last four years developing expertise in fish screening criteria for sportsfish, which was identified by the Fish and Game as one of the critical issues for the

maintenance of self sustaining sports fish populations in Canterbury rivers. In 2006, I compiled Criteria for Fish Screen Design in Canterbury - Sports Fish that is widely accepted by other Fish and Game regions nationally. The 2006 report has been peer reviewed and endorsed by overseas fish screening experts, and was produced as a supporting document for the Canterbury Regional Council's Fish Screen Working Party (Jamieson et al. 2007).

- 1.5 I confirm that I have read and agree to comply with the Environment Court Code of Conduct for Expert Witnesses (31 July 2006). This evidence is within my area of expertise, except where I state that I am relying on facts or information provided by another person. I have not omitted to consider material facts known to me that might alter or detract from the opinions that I express.

Scope of Evidence

- 1.6 My evidence includes the following:
- Description of the sports fish in the Hurunui River.
 - Characteristic of sports fish populations and their seasonality in relation to fish screen design.
 - Description of the risks posed by water intakes to juvenile sports fish.
 - Biological criteria for effective fish screen design for sports fish populations.
 - Fish and Game recommended criteria for the design of an effective fish screen for sports fish.
 - Response to Ecan submission on fish screen specification for smaller intakes.
 - Comparison of recommended criteria with Ecan's Proposed Natural Resources Regional Plan provisions
- 1.7 In preparing my evidence, I have relied on the work of leading international experts in fish screen design and accepted best practice guidelines. I have not addressed the criteria for effective fish screen design for native fish but adhering to the sportfish screening requirements as discussed in this evidence will provide a high level of protection for a number of native species (Jamieson *et al.* 2007).

Summary of findings

- 1.8 The installation of effective fish exclusion barriers (fish screens) is of critical importance for maintaining the outstanding Brown trout and sustainable Chinook salmon fishery in the Hurunui River.

2. SPORTS FISH POPULATIONS AND THEIR LIFE CYCLES IN THE HURUNUI RIVER

- 2.1 The Hurunui River supports an extensive range of aquatic habitats from pristine alpine-based spring-fed streams in the mountain areas to the estuarine habitats in the lower reaches. These habitats combine to support an extensive range of fish faunas. The quality of the Upper Hurunui Brown trout fishery is nationally outstanding (Evidence of Martin Unwin and Don Jellyman).
- 2.2 Two major sports fish species are resident in the Hurunui River waters: Brown trout (*Salmo trutta*) and Chinook salmon (*Oncorhynchus tshawytscha*). The Brown trout fishery is nationally outstanding while the Chinook salmon fishery is regionally significant. Rainbow trout (*Oncorhynchus mykiss*) were released in the river in the past but failed to establish a significant fishery.

Brown Trout (*Salmo trutta*)

- 2.3 The Hurunui River, especially the Upper Hurunui, supports a nationally outstanding Brown trout fishery (Unwin and Jellyman, evidences in full).
- 2.4 Based on data collected from an intensive program in the Rakaia River (Fox *et al.* 2003) trout can spend significant portions of their life cycle in the estuaries and lagoons of these Canterbury braided rivers or in the sea.
- 2.5 Brown trout spawn from mid April to September (McDowell, 1990; Graynoth *et al.*, 2003). Brown trout are capable of spawning more than once in their lifetime and may either remain resident in the river or migrate to the lower reaches of the river and lagoon before returning to spawn. They require clean, relatively silt free, well-aerated gravel to spawn. In

Canterbury rivers, Brown trout spawning occurs throughout the river systems, although mostly in the tributaries higher up in the catchments. Based on Fish and Game staff experience and recent electro fishing surveys (Evidence of Roger Young) the majority of trout spawning in the Hurunui River catchment occurs in the Upper Hurunui and tributaries.

- 2.6 Female trout lay 2,000-3,000 eggs that are then fertilised by the male. After about 40 days the eggs hatch into alevins, which are 20 mm in length. Alevins leave the redd once they have absorbed the yolk sac attached to their stomachs. Alevins emerging from gravels are up to 25-30 mm in length and are called fry. As the fry mature they begin to gather in shoals in the lower reaches of the spawning streams dropping downstream during the night with peak migration occurring during moonless nights (Fox *et al.*, 2003). More detailed data on brown trout biology in Canterbury are available from research carried out in the Glenariffe Stream (Fox *et al.*, 2003) and the Waitaki River system (Glova and Boubée, 2002; Graynoth *et al.*, 2003).
- 2.7 Based on the research in the Rakaia River catchment (Fox *et al.*, 2003) the downstream migration of juvenile brown trout from the spawning grounds to the main river occurs all year round, with peak migration occurring during September-January (86% of the recorded migrants). Significant numbers of juveniles migrate until late April with reduced numbers present from May to August. The average size of the fry increases from 28 mm in September to 78 mm in February.
- 2.8 It is likely that the mainstem of the Hurunui River serve as a significant rearing ground for juvenile trout that have emigrated from the spawning streams (Graynoth *et al.*, 2003). As the juvenile fish move downstream a trigger to move out to sea is activated in a number of juvenile fish. Significant numbers of juvenile brown trout occur in the lower reaches and coastal lagoons of the Canterbury rivers. It is very likely that the same applies for the juvenile trout population in the Hurunui River.

Chinook Salmon

- 2.9 Chinook salmon (*Oncorhynchus tshawytscha*) now forms the basis and the most significant part of a sports fishery along the east coast of the South Island. The Hurunui River provides a regionally significant salmon fishery (Unwin, evidence in full).
- 2.10 Salmon are anadromous fish, beginning their life in freshwater, migrating down the full length of the rivers to the ocean where they spend most of their lives before migrating back to freshwater to spawn. Salmon are famous for their extreme homing ability and most return to their streams of origin to spawn. The spawning run of salmon in the Hurunui River starts in November, reaching a peak in February and lasting well into May.
- 2.11 Most of the spawning occurs in the streams in the upper reaches of the Hurunui River, mainly South Branch and tributaries (North Esk River and Homestead Stream) and North Branch and tributaries (Landslip Stream). Spawning occurs from mid March to the end of June, peaking in late April and early May. The female lays an average of 4,600 eggs (ranging from 2,300-6,500) in a nest (redd) buried in the stream bed. Adult Chinook salmon die after spawning.
- 2.12 The eggs hatch and fry emerge from August to November. Most (over 90%) of the newly emerged fry (33-36 mm in length) migrate into the mainstem immediately, within hours, after hatching from early August to October. This rapid downstream dispersal may be partly a reflection of their limited swimming abilities immediately after emergence, but can also be interpreted as an adaptive mechanism to facilitate maximum uptake of suitable rearing habitats (Unwin & Taylor, 2007). These fry gradually disperse downriver over the next three months occupying rearing habitats in the mainstem of the river, entering the ocean from November to January as fingerlings 60 - 90 mm in length (Hopkins and Unwin, 1987; Davis and Unwin, 1989).
- 2.13 A smaller proportion of the emergent fry, around 5%, remain in their natal streams (where they hatch) for at least three months after hatching, at which time they appear to migrate downriver relatively quickly so as to reach the ocean at about the same time (i.e., November-January) as the earlier wave of river resident fry.

- 2.14 Both of these life history variants are known as ocean-type fry, in accordance with their tendency to spend all but the first three months of their first year of life in the ocean (Unwin and Lucas, 1993), followed by a further 1 to 3 years while they grow to adulthood.
- 2.15 The second main life history variant, known as stream-type fry, remain in freshwater for all of their first year of life before migrating to the ocean as yearlings averaging 100-110 mm in length during August and September (Unwin and Lucas, 1993). However, the freshwater habitats used by stream-type juveniles are poorly known; a few remain in their natal stream for the whole of their first year, but the great majority are thought to take up residence within the mainstem of the braided rivers. The precise nature of the habitats occupied by these fish remains unclear.
- 2.16 Adult salmon return to spawn after one to four years in the ocean. Most of the spawning salmon in Canterbury have spent one or two years in salt water. Salmon are famous for their homing behaviour and around 90% of salmon will go to spawn in the stream where they originated from.
- 2.17 Although there is a considerable amount of published research available on Chinook salmon in some of the Canterbury rivers, a significant gap remains for the understanding of migratory behaviour and juvenile trout and salmon dynamics in braided rivers. Unwin & Taylor (2007) conclude that this reflects the general tendency of researchers to target small streams in which field work can be most readily managed, rather than the large mainstem rivers where most juvenile rearing takes place.

3. SPORTS FISH CHARACTERISTICS OF RELEVANCE FOR WATER INTAKE DESIGN

- 3.1 Due to the migratory habits of the Brown trout and Chinook salmon populations in the Hurunui River and the patterns of spawning and migration of fry of both species, relatively small juvenile fish can be encountered throughout the river system. Based on the research conducted in a number of Canterbury rivers, Brown trout fry as small as 25 mm and Chinook salmon of 30 mm upwards are likely to be found even in the lower reaches of the river (Davies *et al.*, 1983; Unwin, 1986; Davis and Unwin, 1989; Webb, 1999).

3.2 The migration of juvenile Brown trout from the spawning grounds (Fox *et al.*, 2003) downstream to the main river occurs all year round, with peak migration occurring during September-January (86% of the recorded migrants). Significant numbers of juveniles migrate until late April with reduced numbers present from May to August. The average size of the fry increases from 25 mm in September to 125 mm in July (Table 1.).

Table 1. Seasonal size variation (minimum length and minimum for 95% of fish) of juvenile brown trout encountered in the lower reaches of the Rakaia River (Jamieson et al., 2007; Table 5.)

Length	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	July
min	95	25	25	30	40	50	65	60	75	85	90	125
95%	105	25	25	35	45	55	70	75	85	95	105	125

3.3 Most newly emerged Chinook salmon fry begin migrating downstream within a few hours of emergence, reaching their respective mainstem shortly thereafter (Unwin and Taylor, 2007). This process lasts for more than three months starting in August. Upper reaches of the Canterbury rivers are colonized first, with fry becoming abundant in lower reaches two to three months later (September to November). The size of Chinook salmon juvenile fish to encounter intake structures on the Rakaia and Rangitata River systems vary with the season and gradually increase from August (when salmon and trout fry start to emerge) to the later parts of the year (Table 2). It is safe to assume that juvenile salmon migration pattern in the Hurunui River will follow very similar timeline.

Table 2. Seasonal size variation of juvenile Chinook salmon encountered in the lower reaches of two Canterbury rivers.

* Data (min and max length) for the Rakaia River (Hopkins and Unwin, 1987);

** Data (min and max length) for the Rangitata River (Webb, 1999);

*** Data (minimum length and minimum for 95% of fish) for the Glenariffe Stream, a tributary of the Rakaia River (Jamieson et al., 2007; Table 3.).

	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	July
*		33-60	33-87	36-87	42-90	50-100	63-111	72-124				
**	32-47	30-57	30-87	35-102	35-118	73-120	80-132	79-132	87-154			
***	30-35	30-35	28-35	28-35	34-40	38-45	45-50	50-55	55-60	60-65	65-70	30-35

3.4 Total production of salmon fry from an individual spawning stream ranges from several hundred thousand to several million fry (Unwin and Taylor, 2007), depending on the size of the spawning run in that stream, which by far exceeds the rearing capacity of the

stream resulting in the majority of fry migrating to the mainstem in search of rearing habitat.

- 3.5 Salmon and trout fry and fingerling migration is significantly higher during freshes and high flows and occurs mostly during the night, and more so during moonless nights (Unwin, 1986; Davis and Unwin, 1989; Fox *et al.*, 2003). The majority of migrating juvenile salmon are encountered in the top 0.5 m of the water column (Glova and Boubée, 2002).
- 3.6 Migrating salmon fry display positive rheotaxis (orient themselves head into the current). Salmonid fry use their swimming ability to maintain position in the current. During migration juvenile salmon swim against the current but net speed is lower than that of the water column and fish are slowly moving downstream. The sustained swimming speed (speed fish are able to maintain for longer periods of time) for juvenile salmon and trout is around four body lengths per second or 0.11 to 0.15 ms⁻¹.
- 3.7 Salmon and trout fry have a strong preference for bank side movement and keep to the edges of the main channels, near to the banks of the streams and rivers (Unwin, 1986; Hopkins and Unwin, 1987; Fox *et al.*, 2003; Unwin & Taylor, 2007).

4. **IMPACTS OF WATER INTAKES ON SPORTS FISH**

- 4.1 Sports fish are susceptible to water abstraction through the deterioration of their habitat due to the lowering of the flow, changes in water quality (e.g., increase in water temperature during summer low flows), delays in downstream migration and losses of juvenile fish to poorly designed or maintained intake structures.
- 4.2 There are many mechanisms that can cause migrational delay and significant loss and/or mortality of juvenile sports fish on the water intake structures. These include:
 - physical contact with the fish screen resulting in injury or death (impingement);
 - passing of the fish through the screen openings, if screening material opening size is too large, or over the screen (entrainment or entrapment) in the canal network (or turbines);

- predation in the screen fore bay;
- predation at the bypass and bypass outfall in the river; poor water quality in the approach canal;
- inappropriate water flow (turbulence) in the approach canal or bypass structures;
- debris accumulation on the screen and/ or bypass;
- too high approach velocity and/or too low sweep velocity; and
- excessive delays due to a poor bypass design where there are poor hydraulic guidance conditions (Nordlund, 1996).

4.3 The migratory life cycle of Brown trout and Chinook salmon in the Hurunui Rivers, detailed in the previous section of this evidence makes them particularly susceptible to intake structures and screens. The disruption to the downstream migration of juveniles and post-spawning fish and also the upstream migration of spawning adults can seriously impact on the health and sustainability of salmon and trout fisheries (Fox et al., 2003). Fish and Game research indicates that sports fish losses to unscreened races are substantial (Unwin *et al.*, 2005). It is generally accepted that the proportion of fish lost to the unscreened (or poorly screened) water intakes is at least proportional to the flow diverted from the river (Glova and Boubée, 2002; Unwin *et al.*, 2005). Fish and Game staff in North Canterbury region rescue thousands of entrained sports fish each year on screened intakes, designed and implemented in 70s and 80s (such as the Amuri scheme with 5 mm mesh as a screening material).

5. **BIOLOGICAL CRITERIA FOR EFFECTIVE FISH SCREEN DESIGN**

- 5.1 The design of any fish screen should be such as to enable migrating and resident fish safe passage past the intake structure. A successful fish screen requires a barrier to prevent fish entering the intake structure with suitable water velocity at the screen and a suitable escape route or bypass (Turnpenny *et al.*, 1998; Jamieson *et al.*, 2007).
- 5.2 Various criteria must be taken into account when designing an effective fish screen including (Bates, 1988; Katopodis, 1992; Nordlund, 1996; Glova and Boubée, 2002; Anon., 2002; DWA, 2006; Anon., 2006; Jamieson et al., 2007):

1. Fish species to be screened and their respective life cycles including:
 - Life stages likely to be encountered
 - Size of the fish
 - Swimming ability of the fish
 - Migration patterns (position in water column and river channel, etc.).
2. Water velocity at the screen (approach and sweeping components)
3. Maximum screening material opening size
4. Location of the intake structure
5. Effective escape route
6. Effectiveness of screening.

Fish Species

- 5.3 Composition of the fish community to be encountered at the intake structure will have a critical influence on the fish screen design. Screening objectives will depend on the life cycle of the fish species at the intake, their swimming ability, migrational patterns and seasonality.
- 5.4 As discussed above, two species of sports fish species inhabit the Hurunui River, Brown trout and Chinook salmon.

Life stages and size of the fish

- 5.5 An effective fish screen must be able to safely exclude the smallest and weakest life stage encountered in the particular area of the water intake (Bates, 1988; Katopodis 1992; Anon., 1995b; Nordlund 1996; and others). The safe exclusion of those fish requires the physical prevention of access (including avoidance of entrainment in diversion and bypass channels) and the prevention of harm via impingement on the face of the screen.
- 5.6 As stated earlier in my evidence (see Tables 1 and 2) trout and salmon fry as small as 25 mm are likely to be encountered on the proposed intakes.

Fish swimming ability

- 5.7 The swimming ability of a fish is a primary consideration in designing any fish screen. Research shows that fish swimming ability varies depending on a number of factors related to the particular fish biology, physiology and characteristics of the environment (Bates, 1988; Anon., 1997). Environmental variables such as water temperature and dissolved oxygen levels, as well as fish size, stage of development and fish health are all significant factors affecting fish swimming ability (Nordlund, 1996).
- 5.8 Fish swimming speeds have been categorised based on the ability of the fish to maintain a particular speed before muscle fatigue occurs (Nordlund, 1996; Turnpenny *et al.*, 1998, and references therein): burst (or darting) speed, prolonged speed and sustained (or cruising) speed. *Burst* speed is a survival response used for moving away from situations such as predators or ascending riffles and can only be maintained for very short periods of time (up to 20 s). It requires high energy exertion and is used infrequently. Fish can take many hours (up to 24 hours) to recover from burst speed related exhaustion. *Prolonged speed* can be maintained for longer periods of time, up to 200 minutes before fatigue occurs. The *sustained speed* can be maintained for long periods of time and is used for routine movement such as foraging.
- 5.9 As discussed, above, during migration juvenile salmonids swim against the current but net speed is lower than that of the water column and fish are slowly moving downstream. Using their lateral lines juvenile fish are able to sense velocity changes and tend to avoid abrupt changes in velocity and turbulence. If contact is made with an obstacle, juvenile fish use burst speed to manoeuvre away from the obstacle (Nordlund, 1996; Williams, video footage 2007). An effective fish screen design has to be based on the sustained speed of the fish species and respective life stages likely to encounter the screen.
- 5.10 Based on the size of Brown trout and Chinook salmon fry the range of sustained swimming speed is 0.11 - 0.15 ms⁻¹.

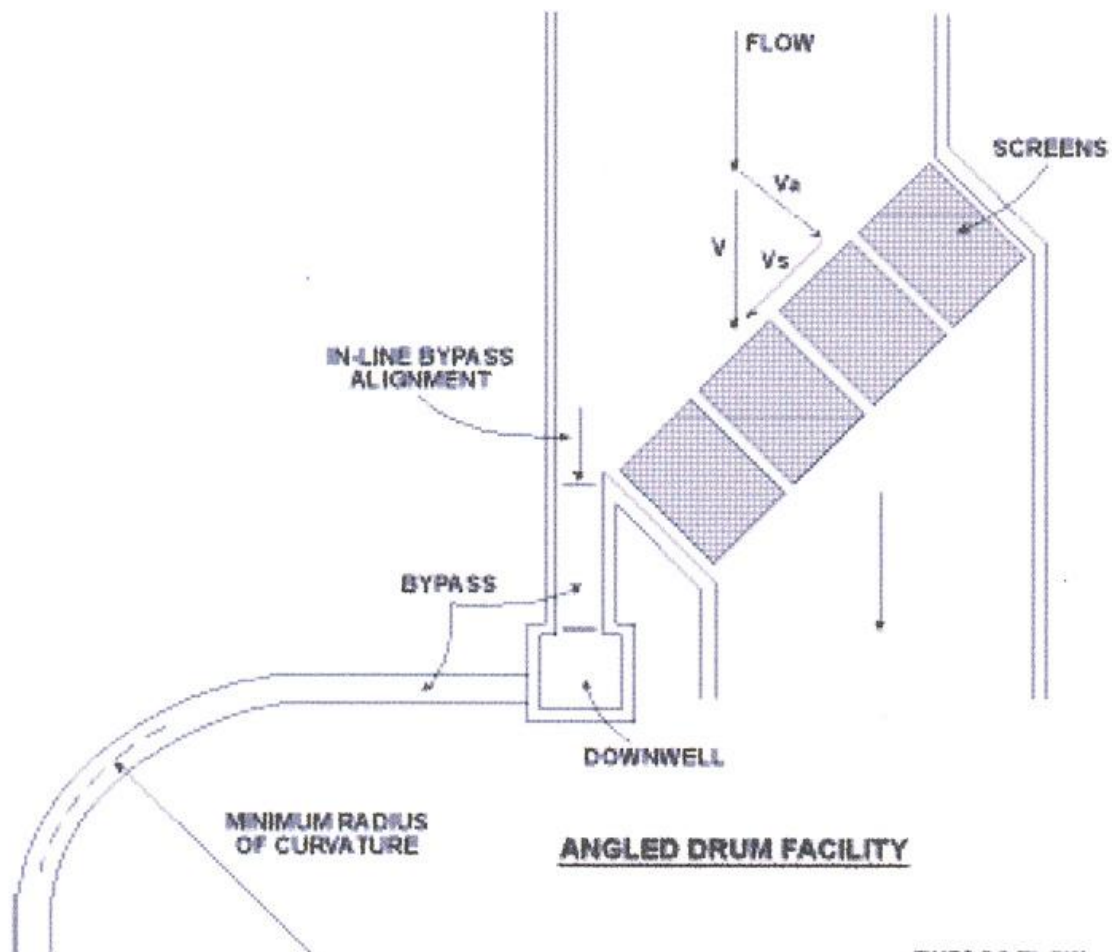
Movement of fish in the water column

- 5.11 The relative position of fish in the water column and in the river channel will have significant implications for effective design of a fish screen and its components (e.g. bypass).
- 5.12 The majority of migrating juvenile salmon and trout are encountered in the top 0.5 m of the water column (Glova and Boubée, 2002) and near the banks of the streams and rivers (Unwin, 1986; Hopkins and Unwin, 1987; Fox et al., 2003) making them especially susceptible to diversion into the water intakes operating on the sides/banks of waterways.

Water velocity at the screen

- 5.13 The water velocity at the screen greatly influences the survival rate of juvenile fish diverted to the water intakes. If the velocity at the screen is too high fish will be impinged upon the screen and damaged or killed. Fish can also be impinged and carried over the screen into the race. The survival of fish in these situations is largely determined by their swimming ability, which in turn is determined by their size or length and other physiological parameters (Nordlund, 1996). An effective fish screen has to provide water velocity low enough that fish can voluntarily keep themselves from being impinged or entrained through the screen.
- 5.14 The velocity of the water moving through the intake channel can be broken into two components (Figure 1), approach velocity (V_a) and sweeping (or transport) velocity (V_s).

Figure 1. Water velocity and by-pass location (V_a – approach velocity; V_s – sweeping velocity)



5.15 Approach velocity is the water velocity component into or perpendicular to the face of the screen. It is considered to be the velocity measured at about the edge of the boundary layer at the screen face (7.5-10 cm in front of the screen, Nordlund, 1996). Approach velocity at the screen has to match the swimming ability of the fish present at the time of the screen operation. It should be maintained at a level low enough to prevent juvenile fish coming in contact with the screen, being impinged or over exerted and disoriented (Bates 1988; Turnpenny *et al.*,1998).

5.16 To ensure the maximum approach velocity does not exceed sustained swimming speed of fish at the water intake, the fish screen has to be of a sufficient size. The total

submerged open screen area required is calculated by dividing the maximum diverted flow by the maximum approach velocity on the assumption that there is no screen clogging (for more details see Appendix 1).

- 5.17 Sustained swimming speed is the safest guideline for defining the approach velocity when designing an effective fish screen (Nordlund, 1996; Turnpenny *et al.*, 1998; Nordlund and Bates, 2000). It is widely accepted that four body lengths per second is the sustained swimming speed for a number of salmonid species. Based on the size and sustained swimming speed of juvenile salmonid fish species Fish and Game propose a maximum approach velocity of 0.12 ms^{-1} .
- 5.18 Sweep velocity is the water velocity component parallel to the face of the screen. The angle of the screen to the flow determines this component of water velocity. Lower angles of the screen to the flow ensure higher sweep velocity and shorter exposure of the fish to the screen. The successful guidance of the fish to the escape route at the downstream end of the screen depends on this component of water velocity.
- 5.19 Sweep velocity utilises the ability of juvenile fish to sense velocity changes and water turbulence (at the face of the screen) and move to the areas of lower turbulence avoiding contact and impingement on the screen (Nordlund, 1996). Overseas research (summary in Bates, 1988; and Turnpenny *et al.*, 1998) showed significantly higher survival of juvenile salmonids where oblique angles of the screen to the flow were adopted ensuring sweep velocities at the screen were higher than approach velocity. A review of the literature on fish screens operating in the USA (Bejakovich, 2005a) showed that all screens on major intakes are placed at an angle to the incoming flow (ranging from 15° to 26°).
- 5.20 Water movement even in the straight intake channel is not uniform resulting in inconsistent and uneven water velocities near the screen face. Bed and wall friction tend to reduce marginal velocities and increase the velocities in the mid channel and near the water surface (Turnpenny *et al.*, 1998). The situation is more complicated in curved intake channels. Understanding water velocity profiles is significant for the effective screen and bypass position design as fish will tend to select areas of lower water velocity in preference to areas of higher velocity and increased turbulence. To ensure relatively

uniform water velocity approaching the screen, the intake channel should be relatively straight with a smooth bed and walls.

Maximum screening material opening size

- 5.21 The screening material opening size needs to be designed so as to exclude all at risk fish species and life stages from the water intake. Fish should be stopped from passing through the screen by the bony part of its head (Bates, 1988; Turnpenny *et al.*, 1998). The size of the openings of the screening material is critical for the successful operation of fish screens and safe passage of the juvenile fish. The opening size therefore depends on the size of the smallest life stage encountered.
- 5.22 Fish screens are constructed using different types of screening material. Any material used has to ensure smooth outside surface to prevent fish damage when in contact with the screen. Three materials are commonly used: woven wire mesh, perforated plate and profile bars. Woven wire mesh is mostly used for rotary drum and to a lesser extent for flat panel screens. Perforated plates are used for construction of flat panel screens and much less for rotating drum screens. Profile bars are most commonly used for flat panel screens.
- 5.23 Due to the different geometry of the opening in different materials used for fish screens, a different maximum opening size is recommended to provide effective protection against juvenile fish entrainment. Based on the extensive review of overseas literature on fish screening for salmonids (Bejakovich, 2006 – Appendix 1; Jamieson *et al.*, 2007), to ensure effective protection of the Brown trout and Chinook salmon juveniles, at the Hurunui River intakes (for fish size see Tables 1 and 2 above), following maximum screening material opening size is recommended for fish screens in Canterbury:
- 2 mm for profile bar screens;
 - 3 mm for woven mesh screens; and
 - 3.2 mm for perforated plate screens (round openings).

Location of the intake structure

- 5.24 Ideally a fish screen should be positioned flush with the banks of the river at the very beginning of any water intake to avoid diverting fish out of the river and subsequent delays in the downstream migration. However this is often impractical or impossible and the water has to be taken through the specially designed intake channels.

Effective escape route

- 5.25 In the case where a fish screen is positioned away from the river, its effectiveness is critically dependent on the provision of an effective escape route for the juvenile fish as pointed out by Dr Glova (evidence in chief, Canterbury Regional Council and Selwyn District Council hearing of applications by Central Plains Water Trust and Central Plains Water Ltd, February 2008). A screen placed at the end of the intake channel with no escape route serves purely as a trap for juvenile fish (Turnpenny *et al.*, 1998). The entrance to the escape route or bypass should be positioned in such a way as to maximise the chances of the fish locating it. All the fish that are diverted past the screen must freely and voluntarily enter the bypass. The bypass canal should always be placed at the downstream end of the screen (Figure 1), ideally in the cleft formed by the screen and the bank, or as close as possible to it (Nordlund, 1996; Anon., 1997; Turnpenny *et al.*, 1998; Nordlund and Bates, 2000; and others). Also, the travel time of the fish over the face of the screen (60 seconds is recommended by USA experts) should be taken into account as fish have to reach the bypass before they become exhausted and disoriented from traversing the screen. On large screens there may be a need for a number of bypasses to be installed.
- 5.26 Juvenile salmonid fish tend to avoid the areas of abrupt changes in velocity and turbulence (Nordlund, 1996; Nordlund and Bates, 2000). The flow entering a bypass should therefore be smooth. A sufficient amount of flow at the intake must be allocated for the bypass channel (2-5% of intake flow by UK standards). To prevent fish from swimming back and getting caught on the screen, the water flow in the bypass channel should accelerate slightly and gradually to a velocity higher than the escape capability of the fish. To enable all the fish to escape safely the bypass entrance should cover the entire depth of the intake channel depth of the screen (Nordlund and Bates, 2000). The

entrance to the bypass needs to be an open channel due to the juvenile fish responding to visual clues and actively avoiding darkened areas (e.g. pipes, tunnels etc.). Ideally, the bypass entrance should blend visually with the surrounding area so as not to repel fish from entering (Turnpenny *et al.*, 1998). Most important of all criteria for the effective bypass design is ensuring that fish are returned into the river as soon as possible.

- 5.27 Technical design details for effective fish screen and bypass designs are readily available (for design information see Nordlund 1996; Turnpenny *et al.*, 1998; Nordlund and Bates, 2000; Anon., 2004; and others).
- 5.28 One of the distinguishing characteristics of the Hurunui River is the braided riverbed. It is of crucial significance for any effective fish screen and bypass design to ensure that juvenile fish are returned to a flowing braid that joins the mainstem of the river thus ensuring unimpeded and safe passage for both migrating and resident fish. The responsibility for mitigating the environmental effects of abstraction shall extend to the point where the bypass water enters the mainstem (Jamieson *et al.*, 2007).

Effectiveness of screening

- 5.29 Fish screens should provide safe and unimpeded passage for migrating and resident sports fish. Most overseas agencies fish screen standards are committed to 100% fish screen effectiveness in order to protect endangered salmonid species (Bates, 1988; Anon., 1995b; Nordlund, 1996; Anon., 1997; Nordlund and Bates, 2000; Anon., 2004; Anon., 2006).
- 5.30 In the light of the recent decline in salmon and trout numbers in the North Canterbury region and elsewhere in the country, and taking account of the nationally outstanding values of the Brown trout fishery and salmon fishery in the Hurunui River, Fish and Game is seeking, as close as possible to, 100% effectiveness of fish screens installed at the water intakes on the river.

6. RECOMMENDED CRITERIA FOR THE DESIGN OF AN EFFECTIVE FISH SCREEN FOR SPORTS FISH

6.1 Inadequate fish screening can have a potentially significant adverse impact on fish populations. Based on the general design principles for an effective fish screen and biological criteria discussed earlier in my evidence, Fish and Game have compiled a set of criteria for a fish screen design that would ensure a satisfactory level of protection for sports fish in Canterbury Rivers including the Hurunui River. These criteria were endorsed by an independent review of fish screen design criteria, other Fish and Game Regions and overseas experts (Jamieson *et al.*, 2007; Bates, 2006; Nordlund, personal communication).

6.2 In summary, the following fish screen design criteria are recommended (full set of design criteria is available in the Appendix 1) to protect sports fish in the Hurunui River:

- Fish screen at the point of water diversion from the mainstem (or as close as practical)
- Maximum approach water velocity of 0.12 ms^{-1}
- Sweep velocity parallel to the face of the screen that is equal or greater than approach velocity
- Maximum screening material opening size:
 - 2 mm for profile bar screens;
 - 3 mm for woven mesh screens; and
 - 3.2 mm for perforated plate screens (round opening).
- Effective bypass system ensuring fish return undamaged to the mainstem
- Effective maintenance and operation of the screen.

6.3 In order to protect the fishery in the Hurunui, Fish and Game seek that the design criteria be included as a requirement for any point of abstraction in the river (upper and lower).

7. ALTERNATIVE SCREEN REQUIREMENTS FOR SMALL WATER TAKES

7.1 In ECan's submission to this application it proposes more relaxed fish screen criteria for very small intakes of up to 10 l/s than proposed in the application. I agree that for smaller intakes less than 10 l/s a more liberal and cost effective standard (approach

velocity of 0.12 ms^{-1} and screen aperture size of maximum 3 mm) is likely to be sufficient to protect the fishery for a reasonable number of such smaller intakes.

8. COMPARISON OF THE RECOMMENDED WCO CRITERIA WITH PROVISIONS IN THE PROPOSED NATURAL RESOURCE REGIONAL PLAN

8.1 Environment Canterbury, Department of Conservation and Fish and Game all have regulatory responsibility relating to fish and fish passage. Environment Canterbury has various relevant responsibilities that fall under Part II of the RMA including the protection of the habitat of trout and salmon with additional protection provided under the Conservation Act 1987. Fish and Game and the Department of Conservation also have statutory responsibilities relating to sportsfish under the Conservation Act 1987. Fish and Game and the Department of Conservation also have statutory responsibilities relating to sportsfish under the Conservation Act. One of the effects of abstraction from surface waterways in Canterbury includes fish being diverted, entrained or killed via abstraction and intake structures.

8.2 The effects of surface water abstractions on fish have been recognised by Environment Canterbury, and after undertaking a section 32 analysis it supports the need for fish exclusion measures in the Proposed Natural Resources Regional Plan (PNRRP) via Schedule WQN12. Schedule WQN12 ("Fish screen standards") provides design guidelines for fish screens that are intended to apply throughout the Canterbury region and that are intended to "prevent the intake of fish". The guidelines specify a maximum mesh size or slot width which varies depending on the distance of the take from the coast. The guidelines also require that the velocity of flow at and through the screen ("approach velocity") is to be such that fish and fish fry are prevented from being trapped on the screen. The guidelines require the screen to be positioned to ensure unimpeded fish passage to and along the waterways to avoid the entrapment (entrainment) of fish at the point of abstraction, and to prevent fish stranding. This is consistent with Fish and Game's recommended criteria (this evidence) to ensure safe approach velocity, effective escape route to the mainstem (para 6.2 above). However Schedule WQN12 comes short of recommending the appropriate approach velocity (0.12 ms^{-1} as defined based on swimming capability of juvenile sportsfish in my evidence) for sportsfish in the

Hurunui River and omits to establish the significance of sweeping velocity for effective fish screen operation.

- 8.3 Ecan's submission in opposition to the Hurunui Water Conservation Order application concurs that screen material aperture and approach/sweep velocity in the application are consistent with the recommendations of the independent NIWA ("Fish screening: good practice guidelines for Canterbury" Jamieson *et al.*, 2007) produced for the specially formed Ecan's Fish Exclusion Working Group¹ but seeks an amendment to the approach velocity clause in the application to read "average approach velocity of 0.12 ms⁻¹. I can not accept the proposed change to the recommended criteria of the maximum approach velocity (0.12 ms⁻¹) as it could lead to a significant deterioration of the fish screen effectiveness by creating areas of relatively high velocity resulting in the fish impingement on the screen and injury or death.
- 8.4 Schedule WQN12 specifies a maximum screen aperture size of 2 mm for intakes within 2 km of the coast, 3 mm when between 2 – 8 km from the coast or in a recognized trout spawning stream, and 5mm elsewhere. This system appears to have been designed primarily to cater for native fish, as 5 mm aperture size has been shown to enable the entrainment of large numbers of sportfish juvenile life stages. I propose an aperture size consistent with the extensive literature reviews (Bejakovich, 2006; Jamieson *et al.*, 2007) that is more conservative than one proposed by the NRRP WQN12 (as per 6.2 above) throughout the Hurunui River system, in recognition that sportfish fry will use the entire mainstem for rearing purposes (Young and Unwin, evidences in full). This will also ensure a high level of protection for native fish species (as per Charteris, 2006 and Jamieson, 2007).
- 8.5 At the recent NRRP hearing (Stage 28 in February 2009) that addressed Schedule WQN12, the Officers Report recommended fish exclusion standards and guidelines, based on the findings of the NIWA guidelines ("Fish screening: good practice guidelines for Canterbury" Jamieson *et al.*, 2007). The weight that can be attributed to the Officers

¹ The Fish Exclusion Working Group comprises representatives of Irrigation New Zealand, Fish and Game, Department of Conservation and the Regional Council. Sustainable Farming Funding was secured to advance a project that sought to provide an agreed position on fish screening requirements according to best practice and international and national research findings. NIWA were engaged to 'oversee' the project and provide additional technical advice and scientific review (Jamieson *et al.*, 2007).

Report is addressed in evidence by Ms Marx. However, in my opinion, the provisions in Schedule WQN12 (either in its notified form or as recommended by the Officers Report) do not adequately provide for fish exclusion to the standard I consider appropriate to protect the Hurunui fishery.

9. SUMMARY AND CONCLUSIONS

- 9.1 The Hurunui River supports a nationally significant Brown trout fishery and regionally significant Chinook salmon fishery. The installation of effective fish screens is of critical importance for maintaining these fisheries. Recommended fish screen design criteria are proposed which take into account the life stages and characteristics of these species.

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