I. EXECUTIVE SUMMARY

The overabundant proliferation of aquatic weeds in South African water conveyance systems cause a series of operational problems. Filamentous algae, such as *Cladophora glomerata* and pondweeds impede flow and reduce the capacity of irrigation canals to a significant extent. In worst case scenarios, irrigation scheme managers are faced with situations where they are unable to deliver water at the downstream ends of canal systems. This situation also contributes to water losses, crop losses and structural damage to concrete-lined canals.

This report is the product of a research project funded by the Water Research Commission to investigate the possible application of sterile (triploid) grass carp (*Ctenopharyngodon idella*) as biological control agent on aquatic weeds in concrete-lined irrigation canals. The aims of the project were *firstly* to investigate the suitability of a concrete-lined irrigation canal as grass carp habitat; *secondly* to test the efficacy of sterile grass carp as bio-control agent on filamentous algae; *thirdly* to evaluate the economic feasibility of this biological approach against the current chemical, physical and mechanical control methods; and *fourthly* to propose a management plan for the operational application of triploid grass carp as bio-control agent in irrigation canals.

To achieve the goals set for the project, the Ramah-3 Canal near the town of Orania, was selected to serve as experimental canal. This canal can be regarded as a typical South African concrete-lined canal, and is located in the Orange-Riet River Canal System, downstream of the Vanderkloof Dam.

As the majority of local irrigation canals are concrete-lined, skepticism existed amongst local scientists if the fish will be able survive in canals with a presumed high constant flow and low diversity of hydraulic biotopes. It was therefore a priority to establish the suitability of concrete-lined canals as habitat for this herbivorous fish specie.

The study found that flow velocities in the Ramah Canal System never exceeded 1 m/s, even under high flow conditions (full capacity and 110% plus conditions) of more than 5 m^3/s. It was found that grass carp thrived at flow rates ranging from 0.48 to 0.80 meter/second, moving with ease upstream and downstream in a 16 km long experimental section of the Ramah-3 Canal.

The sterile grass carp controlled the algal biomass in the Ramah Canal to significant levels. *Cladophora* was efficiently controlled at stocking rates of 3 to 7 fish per km canal. Triploid grass carp retrieved from the canal system after a six-month experimental period were found to be in an excellent physiological condition and displayed a mean weight increase of more than 300%. An ideal stocking protocol will probably be 10 individuals of 20 – 30 cm in length per kilometer canal, with a 10-15% annual supplementation figure.

Civil structures, such as culverts, super-elevated canals and bridges will provide the fish with sufficient protection against possible predators. A few possible adaptations to the existing canal operation regimes should ensure that triploid grass carp could be managed as an effective biological control agent. This should be determined on a site-specific basis and could include additional civil structures such as sanctuary dams and small in-line fishways to ensure free migration throughout the target system.

An attempt was made to conduct a brief economic analysis, based on information on expenditures of local irrigation schemes on aquatic weed control in their canals. The outcome of this brief investigation was in line with overseas findings in that biological control with sterile grass carp will be more economical than the currently applied control methods of herbicidal and mechanical or physical control.

It can be concluded that the fish adapted to the artificial conditions experienced in a concrete-lined canal and perform their task as bio-control agent with ease. The authors are of the opinion that this bio-control technique will contribute to the current *Integrated Aquatic Weed Management Programmes* (IAWMPs) of the Department of Water Affairs and Forestry. Site-specific conditions for each irrigation scheme will however, dictate a different approach to the aquatic weed problem. It is therefore strongly recommended that suitable qualified specialists should develop all aquatic weed management programmes on a site-specific basis.

II. OPSOMMING *(Executive summary in Afrikaans)*

Die oormatige groei van wateronkruide in Suid Afrikaanse watervoorsieningstelsels veroorsaak 'n reeks van bedryfsprobleme. Draadagtige alge, soos *Cladophora glomerata* en ook watergrasse lei tot die belemmering van vloei, en het 'n beduidende vermindering in die kapasiteit van kanale tot gevolg. In sekere gevalle word die bestuurders van besproeiingskemas gekonfronteer met situasies waar daar nie aan die water aanvraag op die stelsel voldoen kan word nie. Hierdie situasie dra by tot water verliese, gewas verliese en strukturele skade aan beton belynde kanale.

Hierdie verslag is die produk van 'n navorsingsprojek wat deur die Waternavorsingskommissie befonds is, en het dit ten doel om die moontlike toepassing van steriele (triploïde) graskarp (*Ctenopharyngodon idella*) as biologiese beheeragent op wateronkruide in beton belynde kanale te ondersoek. Die vooropgestelde doelwitte van die projek was om *eerstens* die geskiktheid van 'n beton belynde kanaal as graskarp habitat vas te stel; *tweedens* om die effektiwiteit van steriele graskarp as bio-agent op draadalge te evalueer; *derdens* om die ekonomiese lewensvatbaarheid van hierdie biologiese benadering tot wateronkruidbeheer vas te stel; en *vierdens* om 'n bestuursplan vir die aanwending van triploïde graskarp as bio-agent in besproeiingskanale op te stel.

Ten einde die vooropgestelde doelwitte van die projek te bereik, is die Ramah-3 Kanaal naby die dorp Orania geselekteer as eksperimentele kanaal. Hierdie kanaal kan as 'n tipiese Suid Afrikaanse beton belynde kanaal beskou word, en is in die Oranje–Rietrivier Kanaalstelsel, stroomaf van die Vanderkloofdam, geleë.

Aangesien die meerderheid van plaaslike kanale met beton belyn is, het daar skeptisisme onder sommige plaaslike wetenskaplikes bestaan omtrent die oorlewingsvermoë van die vis, in veronderstelde kondisies van hoë vloeitoestande en 'n gebrek aan hidrouliese biotope. Gevolglik is dit as 'n prioriteit beskou om die geskiktheid van beton belynde kanale as habitat vir hierdie herbivore visspesie vas te stel.

Van die belangrike bevindings van die studie was dat die vloeisnelhede in die Ramah kanaalsisteem nooit 1 m/s oorskry het nie. Selfs onder vol kapasiteit vloei toestande (5 m^3/s) van 110% plus, waartydens die kanaal oorgeloop het, is vloeimetings van laer as 1 m/s

aangeteken. Dit is waargeneem dat graskarp gefloreer het onder vloeitoestande van 0.48 – 0.80 m/s, en met gemak stroomop en –af beweeg het in 'n 16 km lange eksperimentele seksie van die Ramah-3 Kanaal.

Die steriele graskarp het die alg biomassa in die Ramah Kanaal tot beduidende vlakke beheer. *Cladophora* was effektief onder beheer gebring teen besettingsdigthede van 3 tot 7 vis per kilometer kanaallengte. Daar is verder gevind dat triploïde graskarp, wat na 'n eksperimentele periode van 6 maande uit die kanaal herwin is, 'n uitstekende fisiologiese kondisie en 'n massa toename van sowat 300% gepresenteer het. Na raming sal die ideale protokol vir besettingsdigtheid waarskynlik in die orde van 10 individue, met 'n lengte van 20 tot 30 cm en 'n aanvullingsyfer van 10 – 15% per jaar wees.

Verder is daar gevind dat siviele strukture soos duikpype, oorvloei kanale en brue, voldoende beskerming teen predatore van die vis sal bied. 'n Moontlike paar veranderinge aan bestaande bedryfsprosedures sal verseker dat triploïde graskarp effektief as biologiese beheeragent in kanale bestuur kan word.

'n Oorsigtelike ekonomiese analise is gemaak deur huidige uitgawes van besproeiingskemas aan wateronkruidbeheer, met geprojekteerde koste vir biologiese beheer met graskarp te vergelyk. Die uitslag van hierdie oorsigtelike ondersoek was in lyn met oorsese bevindings dat biologiese beheer meer ekonomies as die huidige chemiese en meganies-fisiese beheer metodes sal wees.

Die gevolgtrekking kan dus gemaak word dat die vis aangepas het by die kunsmatige kondisies van 'n beton belynde kanaal, en hul funksie as biologiese beheeragent met gemak kon uitvoer. Die outeurs is van mening dat hierdie biologiese beheertegniek sal bydra tot die huidige Geintegreerde Wateronkruidbestuursprogramme (IAWMPs) van die Departement van Waterwese en Bosbou. Liggingspesifieke kondisies van elke besproeiingskema sal egter 'n unieke benadering tot die wateronkruid probleem op elke afsonderlike stelsel dikteer. Gevolglik word dit sterk aanbeveel dat toepaslik opgeleide spesialiste alle wateronkruidbestuursprogramme op 'n liggingspesifieke basis sal ontwikel.