1. Introduction

Background

Design of typical conveyance systems such as engineered channels and the rehabilitation techniques applied to natural waterways have been the subjects of extensive research in the last decade for their improvement and consistency with the ecological sustainability and protecting environmental values.

One of the key conveyance systems that forms an integral component of many urban development proposals is the construction of grass-lined, concrete invert trapezoidal channel systems. These channel systems are designed to cater for either the runoff generated from the development site or to compensate for the conveyance requirement that might have been lost due to piping or modification of the natural watercourse. These channel systems not only destroy the ecosystem, but also are contributing factors to transport of significant volumes of sediments. Hydraulically, they may be very efficient, but in terms of sediment retention for improved water quality and ecological health these channels are ineffective. As part of its commitment to continually improve the ecological values of its waterways, in 1996, Brisbane City Council prepared a guideline titled, ‘Hydraulic Geometry of Brisbane Streams – Guidelines for Natural Channel Design’. The 1996 Guideline has been reviewed during the last four years for its suitability and application to urban areas, particularly Brisbane. The results of this review, along with relevant planning and design tools including many other features of natural conveyance systems, are included in the current Guideline.

Brisbane City Council's Strategic Link

Brisbane City Council recognised the need for the use of this Guideline to achieve better environmental outcomes for the city's existing and constructed waterways. The Guidelines are consistent with the principles of ecologically sustainable development (ESD). The City Plan (October 2000) 'Stormwater Management Code' and 'Waterway Code' emphasise the use of this Guideline. Apart from new developments, the Guideline is also to be used in all Council and community projects that involve waterway restoration, erosion control works and habitat enhancement. Figure 1 shows the relationship between NCD and the desired environmental outcomes through relevant planning and legislative links.

Objectives

The primary focus of the Guidelines is not to re-create an existing conveyance system into a natural-looking waterway. In an urban environment most of the waterways are heavily modified and attempts to re-create/transform them into an undisturbed/pristine state are expensive and time-consuming with limited success. The objective of the Guideline is to assist practitioners through following steps in undertaking waterway rehabilitation works:
Introduction

- Choosing the appropriate site and deciding the extent of works
- Setting the environmental and social goals based on desired environmental values.
- Planning the project
- Undertaking step-by-step design using the appropriate tools to address all aspects of natural features and desired goals
- Considering critical factors during and after construction
- Evaluating and monitoring.

Using the Guidelines, practitioners are expected to construct and rehabilitate creeks and drainage channels to achieve natural and/or desirable social and ecological outcomes while minimising the impacts of flooding by fulfilling the drainage requirements. The Guidelines aim to balance all aspects of engineering and environmental issues. The Guidelines also promote ecologically sustainable development that incorporates naturally functioning waterway systems.

The NCD principles and techniques outlined in the Guideline are primarily applicable for urban creeks and constructed drainage channels. Many of the concepts cannot be applied directly to river systems without appropriate modifications. For guidelines on the rehabilitation of the river systems, refer to Land and Water Resources Research and Development Corporation's (LWRRDC) document ‘A Rehabilitation Manual for Australian Streams, 2000’.

Mission statement:

To minimise erosion, flooding and maintenance while maximising ecological and aesthetic values of waterways
How do the guidelines assist me

<table>
<thead>
<tr>
<th>SITUATION</th>
<th>TYPICAL APPLICATIONS</th>
<th>SPECIFIC OUTCOMES</th>
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<tr>
<td>COUNCIL PROJECTS</td>
<td>• Flood mitigation • Waterway restoration • Erosion control works • Habitat enhancement</td>
<td>Self-sustaining systems which meet Council's commitment to protecting the built and natural environment.</td>
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<td>COMMUNITY PROJECTS</td>
<td>• Habitat enhancement • Waterway Restoration</td>
<td>Guidelines provide a reference to assist experienced individuals in the community to produce sustainable ecological and drainage outcomes.</td>
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DEVELOPMENT UNDER CITY PLAN

CODE OR IMPACT ASSESSMENT REQUIRING CONSIDERATION OF THE WATERWAYS AND STORMWATER MANAGEMENT CODES

WATERWAYS CODE
Purpose: ‘...protect and enhance the water flow, water quality, ecology and open space and recreation and amenity values of the City’s Waterways and Brisbane River and their corridors, in an ecologically sustainable way.’

STORMWATER MGT CODE
Purpose: ‘...ensure that the design of channel works as part of development maximises the use of ‘natural channel design’ principles where possible to establish (for new channels) or enhance (for existing waterways) waterway corridors’.

DEVELOPMENTS THAT: • Propose works within a waterway corridor defined under City Plan • Propose drainage works involving construction of new channels • propose restoration of existing channels or waterways as part of meeting development standards

Guidelines are a referenced document under the CITY PLAN and assist developers in providing acceptable solutions to the following performance criteria:

WATERWAY CODE
General criteria
• P1 The natural functions of Waterways as landscape and environmental corridors must be preserved.
• P4 Where a site includes degraded land identified for rehabilitation in a Catchment Management Plan, SMP† = Stormwater Management Plan. WMP§ = Waterway Management Plan or a rehabilitation plan approved by Council, it must be implemented and maintained at the landowner’s expense.

STORMWATER MGT CODE
• P1 Maximize use of natural channel design principles and water sensitive urban design principles
• P8 Any channel works that are part of the development or major drainage system or flood mitigation works must maintain and/or enhance the environmental values of the waterway corridor or drainage corridor.

HIGH LEVEL OUTCOMES
• CONVEYANCE SYSTEM CONTROL TO MINIMISE STORMWATER POLLUTION AND ENHANCED WATERWAY VALUES UNDER BRISBANE CITY COUNCIL’S URBAN STORMWATER MANAGEMENT STRATEGY
• CONTRIBUTE TO ECOLOGICALLY SUSTAINABLE DEVELOPMENT UNDER THE INTEGRATED PLANNING ACT
• MEET CORPORATE AND INDIVIDUAL DUTY OF CARE UNDER THE ENVIRONMENTAL PROTECTION ACT

FIGURE 1

Use of guidelines

Natural Channel Design (NCD) is important for all waterways, but especially important where the waterway provides a link with bushland reserves or forms an important part of an aquatic or terrestrial movement corridor. A city-wide network of ‘natural’ channels—whether natural in formation, or constructed to appear and operate as natural channels—is essential for the protection of both terrestrial and aquatic biodiversity.

There are no universally agreed-upon design guidelines/techniques that can be applied to all situations. Design relationships presented in these guidelines are essentially empirical functions based on survey data. Thus, the relationships presented here should be used with extreme caution when applied outside the original survey area.

However, many of the relationships presented relate strongly to universally accepted hydraulic principles and therefore should be applicable around the world, while others will only apply to the immediate Brisbane or similar urban areas from where the data was obtained.

Therefore, these guidelines are generally suggested for use by professionals experienced in open channel hydraulics and creek engineering.

The guidelines are not intended to provide sufficient information to allow ‘any’ person to design creek rehabilitation works. As a minimum, the design team should consist of an ecologist, hydraulics engineer, local vegetation expert, and in some cases, a soils expert.

An ecologist is required to effectively incorporate the channel features described in Appendix A. An engineer is required to integrate the channel into floodplain and to review the channel sizing calculations presented in Chapter 3. The vegetation expert is required to select vegetation that best satisfies the habitat requirements of the ecologist and the flood and velocity control requirements presented by the engineer (Chapter 4).

A soils expert is often required because many watercourses flow through areas of unstable soils. In Brisbane, the creeks often have a layer of stable clayey soil overlying highly erosive sandy soils. As a result, channel rehabilitation works can initiate severe erosion problems.

From a hydraulic point of view, NCD concepts mainly deals with two aspects of a channel:

(i) channel geometry; and
(ii) the low flow pool-riffle system.

The channel geometry equations can be used in a wide variety of situations. However, pool-riffle systems can only be used when there is a regular low flow and there are only small quantities of coarse-sediment flowing in the watercourse (i.e. the relationships are generally not suitable for sandy creeks and rivers).

It is also noted that outside the Brisbane region, a creek system may require different low flow systems depending on the local hydrology, sediment load, canopy cover and known aquatic species.
The concepts presented in these guidelines can generally be used in the following situations:

- The enhancement of open, grassed, overland flow paths during the development of rural lands into urban areas.
- The determination of minimum corridor widths during catchment and development planning.
- The design of flood mitigation works that involve relocation, widening or deepening of a watercourse.
- The planning and/or management of floodplain vegetation for the control of flooding.
- The rehabilitation or reconstruction of a channelised or otherwise degraded watercourse.

The basic principles of NCD are to maintain the hydraulic conveyance requirements of engineered or affected channels, while improving environmental values. This holistic approach combines the disciplines of hydraulic engineering, fluvial geomorphology and in-stream and riparian ecology. NCD also encompasses non-scientific/engineering principles such as community requirements. (Brisbane City Council, 1996)

The value of a healthy ecosystem to the social and physical well-being of humans and their environment should not be underestimated. Therefore, it is important for a drainage system to not only continue to provide protection from flood and erosion hazards, but to also address social and environmental concerns such as:
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- Preservation of an ecosystem's integrity by conserving or promoting diverse communities and species and the processes that support them.
- Development of a self-sustaining system to minimise long-term maintenance costs and any adverse downstream impacts.
- Design and/or incorporation of attractive 'natural' features to improve and integrate the landscape of the watercourse.

The principles of NCD do not aim to produce an oasis of nature in the middle of a city, but to retain, restore and/or rehabilitate the natural features of a watercourse that will be compatible with the greater environment in which it is located.

Photo 2. Habitat features added to a concrete drainage channel, Brisbane

Design approach

NCD principles can be applied to a watercourse in one of two ways:

(i) the 'Field of Dreams' Method; and
(ii) the Integration Method.

The 'Field of Dreams' Method is based on the principle: "Build it and they will come" (as in the Kevin Costner movie "Field of Dreams"). In this method, desirable channel features are built into a watercourse for the ecosystem that either historically existed in the area, or that the community currently desires. Upon building the channel, you wait and see what animals inhabit the watercourse and how it sustains floods and other urban influences.

Generally this method is not desirable, but in some circumstances it may be the only option. At worst, this approach should result in the formation of a channel that could be...
modified in the future to a more appropriate system as further knowledge of the local environment is obtained.

The Integrated Method is based on establishing ecological features that are likely to be both sustainable and ecologically desirable for the environmental conditions that exist or will exist within the channel in both the short and long-term. Some of the environmental conditions that need to be considered include: catchment geology, hydrology, corridor links, water quality and vegetation.

Whichever method is used, it is important not to concentrate on pure aesthetics, but to build something that 'nature' would have built given the modified geology and hydrology of the catchment. Generally it is not advisable to try to entice platypus, frogs and other creatures into environments they would not normally inhabit.

Unfortunately, we cannot have a natural creek in an unnatural catchment, but by incorporating the principles of NCD we can have a creek that looks and behaves very similar to a natural system.

Regime Theory

"The relations between width, depth and discharge are collectively known as regime theory. Regime essentially means equilibrium, where there is no net erosion or deposition, and sediment in equals sediment out. Regime theory and hydraulic geometry are very similar concepts. Hydraulic geometry is a broader concept and describes all aspects of river form, of which width and depth (described by regime equations) are a part." (Brisbane City Council, 1996)

Background

In 1996 Brisbane City Council released the document "Urban Stream Rehabilitation – Principles and Guidelines". This document provided basic ecological and engineering considerations, but did not incorporate the necessary regime equations applicable for the Brisbane region.

Later in 1996 the first series of regime relationships for Brisbane's waterways were published in Council's new guideline: "Hydraulic Geometry of Brisbane Streams – Guidelines for Natural Channel Design". This document presented techniques and methods that had originally been developed for other regions of Australia and around the world.

Following release of the 1996 guidelines Council embarked on a process of surveying a number of selected waterway reaches and comparing the observed channel and bed geometry with the adopted regime relationships at the time.

Large format aerial photos where used to locate examples of pool-riffle systems that had not been artificially created nor modified. Four urbanised sites where surveyed in Brisbane City as well as two natural systems within a catchment west of the city.

The design equations provided within these Guidelines have been developed from the analysis of this survey data.
Symbols

\begin{itemize}
\item \( D \) \hspace{1em} [m] Channel depth from bankfull water level to channel invert
\item \( D_{10} \) \hspace{1em} [m] Nominal rock diameter of which \( N \% \) of the rock is smaller, i.e. 10\% of the rock is smaller than the \( D_{10} \) rock size. Rock size is measured as the diameter of a sphere with an equivalent volume to the individual rock
\item \( D_{p} \) \hspace{1em} [m] Maximum pool depth
\item \( d/s \) \hspace{1em} [-] Downstream
\item \( F_i \) \hspace{1em} [m] Riffle fall measured from riffle crest to the low flow pool level within the downstream pool
\item \( F_t \) \hspace{1em} [m] Total channel fall across the proposed rehabilitation area equals upstream channel invert level minus downstream channel invert level
\item \( L_1 \) \hspace{1em} [m] The valley length measured along a smooth straight or curved path (not including the channel meanders) from the upstream end of the channel reach to the downstream end of the channel reach
\item \( L_2 \) \hspace{1em} [m] Length of a meandering watercourse channel measured along the channel centreline
\item \( L_3 \) \hspace{1em} [m] Length of the low flow channel measured over a given reach of the watercourse
\item \( L_m \) \hspace{1em} [m] Straight line distance between successive channel meanders, or meander inflection points
\item \( L_p \) \hspace{1em} [m] Length of a low flow pool measured at the low flow water level
\item \( L_r \) \hspace{1em} [m] Riffle length measured from the riffle crest to the upstream end of the downstream low flow pool
\item \( N \) \hspace{1em} [-] Number of riffles within a reach
\item \( n \) \hspace{1em} [-] Manning’s roughness value
\item \( q \) \hspace{1em} [m\(^3\)/s/m] Discharge per unit width for a nominated design event
\item \( Q \) \hspace{1em} [m\(^3\)/s] Discharge
\item \( Q_i \) \hspace{1em} [m\(^3\)/s] Bankfull discharge
\item \( Q_{uds} \) \hspace{1em} [m\(^3\)/s] Bankfull discharge immediately downstream of the works
\item \( Q_{uds} \) \hspace{1em} [m\(^3\)/s] Bankfull discharge immediately upstream of the works
\item \( Q \) \hspace{1em} [N][m\(^3\)/s] The peak design discharge at a given location that is expected to occur on average once every ‘\( N \)’ years, i.e. the \( Q_{100} \) is the expected peak discharge during the 1 in 100 year design storm
\end{itemize}
Symbols

\( R_c \) [m] Channel bend radius measured to the centre of the channel, or the low flow channel meander radius measured to the centre of the low flow channel.

\( R_o \) [m] Bend radius measured to the outer bank of the channel at the elevation of bankfull flow.

\( S \) [m/m] Slope.

\( S_o \) [m/m] Average channel slope over a selected reach.

\( S_r \) [m/m] Slope of downstream face of riffle.

\( S_i \) [-] Sinuosity = \( L_2/L_1 \) or \( L_3/L_2 \).

\( u/s \) [-] Upstream.

\( V \) [m/s] Average flow velocity.

\( W \) [m] Channel top width measured at the height of the lower bank.

\( W_p \) [m] Maximum pool width measured at low flow water level.

\( W_r \) [m] Riffle bed width.

\( \Delta \) [m] Average meander displacement, or half the amplitude of the meandering channel centreline or low flow channel centreline.

\( \Theta \) [deg] The angle measured between two consecutive inflection points.