NEMS
NATIONAL ENVIRONMENTAL MONITORING STANDARDS

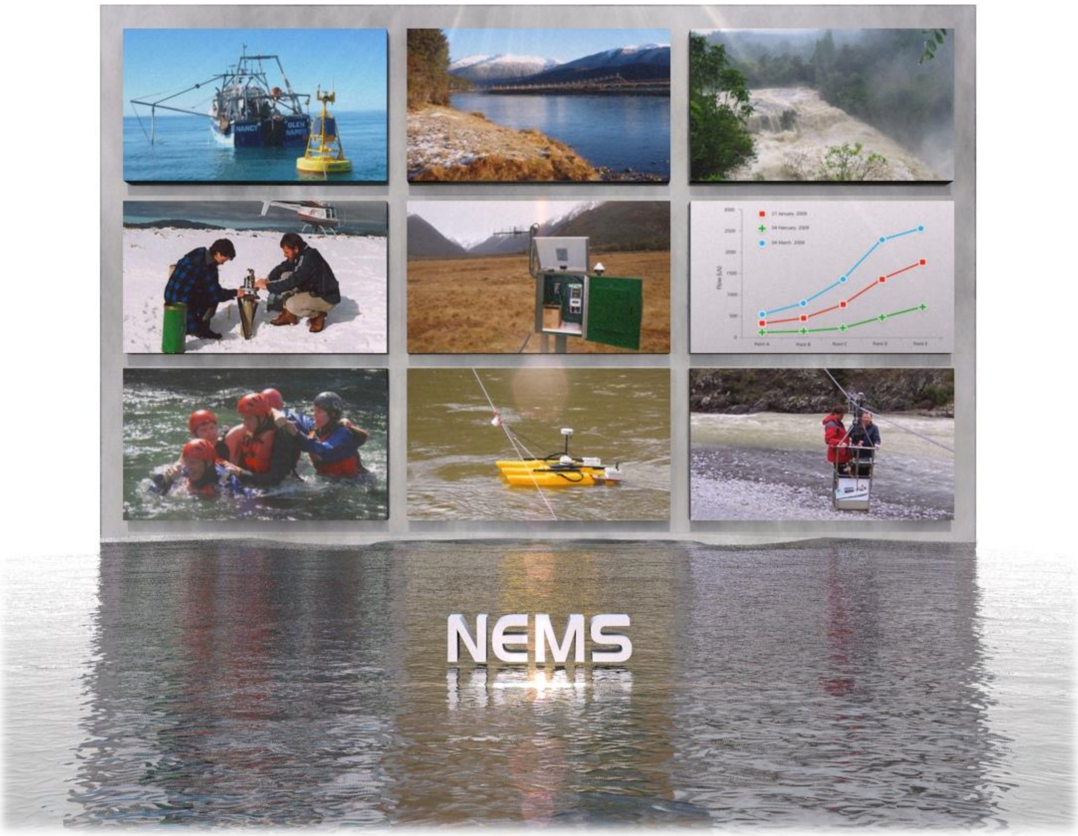
National Environmental Monitoring Standard

Hydrological and Meteorological Structures

Code of Practice

Version: 1

Date of Issue: July 2016



The National Environmental Monitoring Standards

The following National Environmental Monitoring Standards (NEMS) documents can be found at www.lawa.org.nz:

Standards

- Dissolved Oxygen
  Measuring, Processing and Archiving of Dissolved Oxygen Data
- Open Channel Flow
  Measuring, Processing and Archiving of Open Channel Flow Data
- Rainfall
  Measuring, Processing and Archiving of Rainfall Intensity Data for Hydrological Purposes
- Rating Curves
  Construction of Stage-Discharge and Velocity-Index Ratings
- Soil Water
  Measuring, Processing and Archiving of Soil Water Content Data
- Turbidity
  Measuring, Processing and Archiving of Turbidity Data
- Water Level
  Measuring, Processing and Archiving of Water Level Data
- Water Meter Data
  Measuring, Processing and Archiving of Water Meter Data for Hydrological Purposes
- Water Temperature
  Measuring, Processing and Archiving of Water Temperature Data

Codes of Practice

- Hydrological and Meteorological Structures (this Code)
- Safe Acquisition of Field Data In and Around Fresh Water
- Site Surveys

Supplementary Material

- Glossary
  Terms, Definitions and Symbols
- National Quality Code Schema

Implementation

When implementing the Standards, current legislation relating to health and safety in New Zealand and subsequent amendments and the NEMS Codes of Practice shall be complied with.

Limitations

It is assumed that as a minimum the reader of these documents has undertaken industry-based training and has a basic understanding of environmental monitoring techniques. Instructions for manufacturer-specific instrumentation and methodologies are not included in this document.

The information contained in these NEMS documents relies upon material and data derived from a number of third-party sources.

The documents do not relieve the user (or a person on whose behalf it is used) of any obligation or duty that might arise under any legislation, and any regulations and rules under those Acts, covering the activities to which this document has been or is to be applied.

The information in this document is provided voluntarily and for information purposes only. Neither NEMS nor any organisation involved in the compilation of this document guarantee that the information is complete, current or correct and accepts no responsibility for unsuitable or inaccurate material that may be encountered.

Neither NEMS, nor any employee or agent of the Crown, nor any author of or contributor to this document shall be responsible or liable for any loss, damage, personal injury or death howsoever caused.

Development

The National Environmental Monitoring Standards (NEMS) steering group has prepared a series of environmental monitoring standards on authority from the Regional Chief Executive Officers (RCEOs) and the Ministry for the Environment (MfE). The strategy that led to the development of these Standards was established by Jeff Watson (Chairman) and Rob Christie (Project Director), and the current steering group comprises Phillip Downes, Martin Doyle, Michael Ede, Glenn Ellery, Nicholas Holwerda, Jon Marks, Charles Pearson, Jochen Schmidt, Alison Stringer, Raelene Mercer (Project Manager) and Jeff Watson.

The development of these Standards involved consultation with regional and unitary councils across New Zealand, major electricity-generation industry representatives and the National Institute for Water and Atmospheric Research Ltd (NIWA). These agencies are responsible for the majority of hydrological and continuous environmental-related measurements within New Zealand. It is recommended that these Standards are adopted throughout New Zealand and all data collected be processed and quality coded appropriately to facilitate data sharing. The degree of rigour with which the Standards and associated best practice is applied will depend on the quality of data sought.

The lead writer of this document was Jeremy Walsh of NIWA, with workgroup members Phil Downes of Environment Canterbury Region Council and John Porteous and Graeme Horrell of NIWA. The input of NEMS members into the development of this document is gratefully acknowledged; in particular, the review undertaken by the NEMS steering group.

Funding

The project was funded by the following organisations:

- Auckland Council
- Bay of Plenty Regional Council
- Contact Energy
- Environment Canterbury Regional Council
- Environment Southland
- Genesis Energy
- Greater Wellington Regional Council
- Hawke's Bay Regional Council
- Horizons Regional Council
- Marlborough District Council
- Meridian Energy
- Mighty River Power
- Ministry for the Environment
- Ministry of Business, Innovation and Employment – Science and Innovation Group
- National Institute of Water and Atmospheric Research Ltd (NIWA)
- Northland Regional Council
- Otago Regional Council
- Taranaki Regional Council
- Tasman District Council
- West Coast Regional Council
- Waikato Regional Council.

Review

This document will be reviewed by the NEMS steering group in February 2018, and thereafter every two years.

Signatories

NEMS Project Director	NEMS Chair	MfE

Table of Contents

Terms, Definitions and Symbols

Relevant definitions and descriptions of symbols used in this Code of Practice are contained within the NEMS Glossary available at www.lawa.org.nz.

Normative References

This Code of Practice should be read in conjunction with the following references:

- AS/NZS 1664.1:1997 *Aluminium structures – Limit state design*
- AS/NZS 1170:2002 *Structural design actions Standard*
- Health and Safety at Work Act 2015
- NEMS *Glossary*
- NEMS *Open channel flow*
- NEMS *Water level*
- (New Zealand) Building Act 2004
- (New Zealand) Building Regulations 1992, Schedule 1 (The Building Code)
- NZS 3109:1997 *Concrete construction*
- NZS 3404 Part1:1997 *Steel structures Standard*
- NZS 3603:1993 *Timber structures Standard*
- Resource Management Act 1991.

About this Code of Practice

Background

This Code of Practice has been developed following discussion and consultation with all regional and unitary councils within New Zealand as well as the National Institute for Water and Atmospheric Research Ltd (NIWA). Between them, these agencies undertake the majority of environmental data acquisition within New Zealand.

Objective

The objective of this Code is to document or reference commonly used designs of hydrological and meteorological structures, and considerations in implementing these designs, including:

- suitability for use in new construction (covering compliance with the New Zealand Building Code)
- design considerations; for example, loading and stability, and
- construction techniques.

Scope

The scope of the Code covers construction of hydrological and meteorological structures that are likely to be built in future, including:

- 'standard' steel stilling wells
- slack-line cableways
- catwalks
- stairways and access ladders, and
- meteorological masts.

Exclusions

The following structures are excluded:

- manned cableways
- concrete stilling wells
- weirs and flumes.

Note: For the construction of weirs and flumes, refer to NEMS 'Water Level – Measurement, Processing and Archiving of Water Level Data'.

1. Legislative Requirements

1.1. Background

All building works should comply with the most recent Building Act requirements and related standards and the Resource Management Act. The Building Act establishes the regulatory regime covering building work in New Zealand.

Under the Building Act, key requirements for building work are:

- All building work, regardless of whether a building consent is required, must comply with the New Zealand Building Code.
- All building work, unless exempt, requires a building consent.

Note: The most recent Building and Resource Management Acts are available from the New Zealand Legislation website http://www.legislation.govt.nz.

In order to build a new hydrological structure or meteorological mast, it may be necessary to obtain a resource consent from the relevant consenting authority.

1.2. Hydrological Structures

Some consenting authorities have a clause in their regional plan that classes the installation of structures for river monitoring purposes as a permitted activity.

Note: The permitted activity rule may have provisos relating to, for example:

- *safe passage of fish*
- *limits on the restriction imposed on the cross-sectional area, and/or*
- *adequate maintenance of the structure.*

1.3. Meteorological Masts

The need for a consent to construct a mast, and any requirements imposed by the consenting authority may depend on the location (urban or rural) and height of the mast.

1.4. Resource Consent

For all new building work, the relevant consenting authority should be consulted:

- as to whether a resource consent is required, and
- on any conditions imposed with or without consent.

2. Stilling Wells

2.1. Background

Stilling wells are commonly built to what was a 'standard' Ministry of Works and Development (MWD) design. Figure 1 (below) illustrates the design.

The stilling well itself is made either of spiral-welded pipe or standard rolled sections, 1200 mm in length and 600 mm in diameter. It incorporates a watertight hatch in the top section for inspection and levelling of instrumentation. A watertight hatch is also provided at the bottom of the tower for inspection of the float and counterweight system and flushing of sediment.

A steel recorder housing bolts to the top section. A platform or catwalk may be required to provide access to the recorder housing.

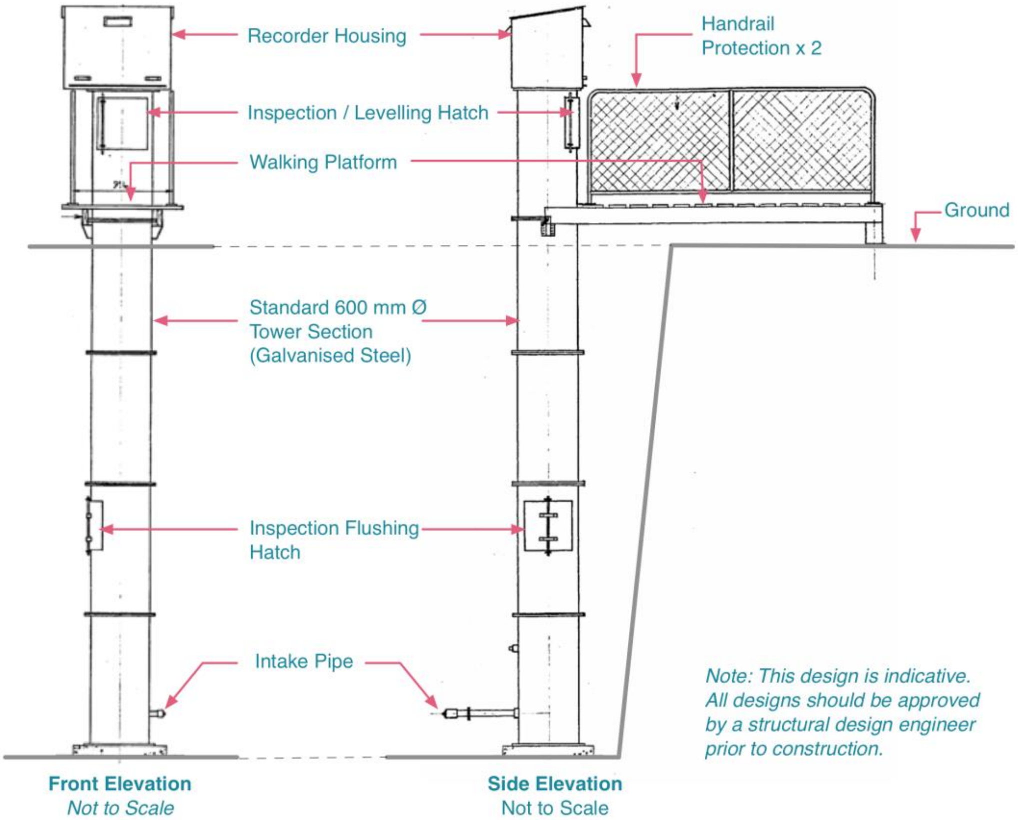


Figure 1 – Typical stilling well and housing setup – MWD 'standard' steel stilling well

Source: NIWA Field Manual.

Note: Other designs and materials may be as good or better in certain situations. Alternatives include pipes made of concrete, plastic (PVC), spiral-welded steel or fibreglass and corrugated culvert pipes.

2.2. Acceptable Design

2.2.1. Steel Stilling Well Design Drawings

The MWD steel stilling well design is documented in the Ministry of Works and Development design drawings listed in Table 1 below. The design drawings themselves can be found in Annex C.

Table 1 – MWD steel stilling well design drawings

Drawing	Title
6/721/6/7603/601	General Assembly
6/721/6/7603/602/R1	Instrument Housing
6/721/6/7603/603/R1	Type 'E' Cylinder
6/721/6/7603/604/R1	Type 'D' Cylinder
6/721/6/7603/605	Type 'C' Cylinder
6/721/6/7603/606	Type 'B' Cylinder
6/721/6/7603/607	Type 'A' Cylinder
6/721/6/7603/608/R1	Door Latch Type 1
6/721/7/7603/601	Platform

Note: The MWD design drawings do not cover foundation details or bracing requirements for the stilling well.

2.2.2. Approval

Prior to any site work or construction, the stilling well design (including foundation and bracing details) should be approved by a certified engineer who has competency in structural design.

2.2.3. Compliance

All new building work should comply with the most recent New Zealand Building Code.

Note: Use of the MWD design alone does not guarantee compliance.

2.3. Linear Stilling Well Design

2.3.1. Design

A problem in measuring water levels in coastal sites or on lakes or harbours is that the long-period waves of interest are of much smaller magnitude than the short-period wind waves, which act as noise. For example, in lakes, seiching is typically in the order of 0.1 to 0.2 metres, whereas wind waves may be 0.5 metres or higher.

Seelig (1977) provides a methodology (called linear stilling well design) for designing a stilling well that accurately measures water level fluctuations of interest and damps out undesirable short-term fluctuations.

The linear stilling well design consists of a well and orifice pipe. A unique characteristic of the design is that no nonlinear water level amplifications occur; that is, water levels inside the well respond linearly to fluctuations outside the well.

A key requirement is that the orifice pipe be free from fouling since the response characteristics of the well are sensitive to even small pieces of debris in the orifice. Because of this, the method is recommended for short-term operation in clear water areas only.

Under the linear stilling well design, the theoretical length of the orifice pipe, L_p, is given as:

$$L_p = 48790 \frac{\beta_2 D_p^4 T}{D_w^2} \quad (1)$$

where: L_p is the length of the orifice pipe in metres

D_p is the inside diameter of the orifice pipe in metres

T is the wave period in seconds

D_w is the inside diameter of the stilling well in metres, and

β_2 is a dimensionless frequency parameter.

Figure 2 plots the amplitude response curve for the linear stilling well design as a function of the dimensionless frequency parameter, β_2.

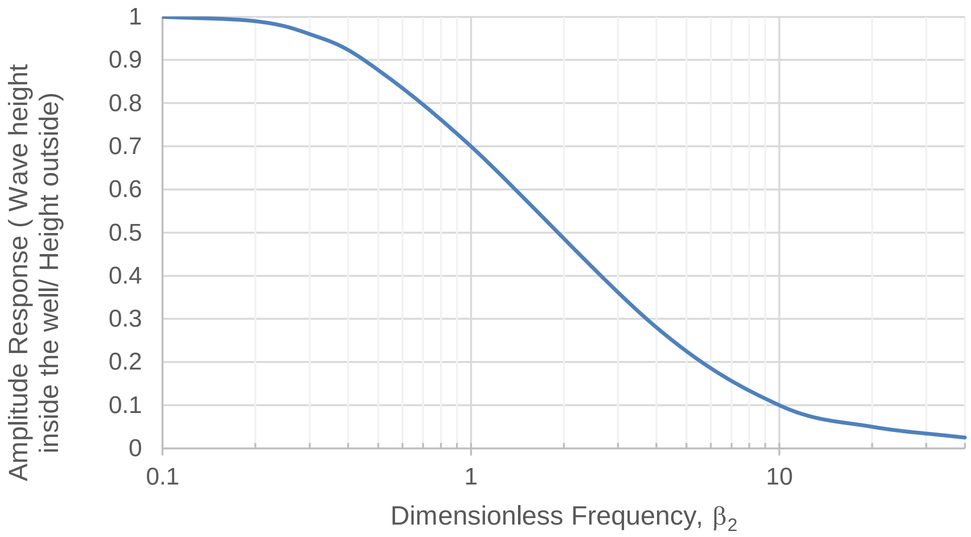


Figure 2 - Amplitude response curve for a linear stilling well

Source: Seelig, 1977.

Generally, it is desirable to have β_2 less than or equal to 0.45 for the long-period waves to be measured. At the same time, β_2 should be taken as 10 or greater when considering the short-period wind waves.

Note:

- $\beta_2 = 0.45$ *corresponds to an amplitude response factor of 0.9, meaning that 90% of the amplitude of the long-period wave to be measured will be retained.*
- $\beta_2 = 10$ *corresponds to an amplitude response factor of 0.1, meaning that 10% of the amplitude of the short-period wind wave will be retained; or alternatively, that 90% of the amplitude of the short-period wave will be damped.*
- $\beta_2 = 20$ *corresponds to an amplitude response factor of 0.05, meaning that 5% of the amplitude of the short-period wind wave will be retained; or alternatively, that 95% of the amplitude of the short-period wave will be damped.*

Example

A 600-mm stilling well is required to damp out 95 % of the amplitude of wind waves with a period of 10 seconds. The period of the long waves is unknown, so design is based on damping the short-period wind waves. Assume a 20-mm diameter orifice pipe is to be used.

Applying equation (1), the length of the orifice pipe required is given as:

$$L_p = 48790 \frac{\beta_2 D_p^4 T}{D_w^2} = 48790 * \frac{20 * 0.020^4 * 10}{0.60^2} = 4.3 \text{ m}$$

2.3.2. Foundations

For stilling wells, a mass concrete foundation is generally required. The foundation should be of a size and depth that is determined by specific design.

If the channel is likely to degrade, the bottom of the foundation should be at least 0.5 metres below the maximum predicted scour depth.

If adopting the MWD steel stilling well design for the construction of a new stilling well, it will be necessary to consider foundation details and bracing requirements for the structure.

Foundation details and bracing requirements should be determined by specific design, taking account of the site geometry, along with soil and/or rock properties.

Note: Foundations that sit directly on bedrock are preferable, otherwise a substantial concrete mass poured into hard alluvium is required.

Construction of Concrete Foundations

For concrete foundations, there are two methods that can be used:

- dry construction method, or
- wet construction method.

Where practicable, the dry construction method should be used.

The wet construction method should only be used where:

- concreting into still water, and
- an accelerant is added to the concrete mix to reduce setting time.

Procedure – Dry Construction Method

Follow these steps to create concrete foundations using the dry construction method.

1. **Set up the bottom stilling well section.**
2. **Box up the foundation space.**
   This creates a form into which the concrete will be poured.
3. **De-water the site.**
   Note: A submersible pump can be used for this.
4. **Pour a 100-mm minimum thickness layer of blinding concrete.**
   Allow 24 hours for the concrete to set before continuing with Step 5.
5. **Pour concrete into the form and vibrate it to remove any air.**
   Allow 24 hours for the concrete to set before continuing with Step 6.

Important: Poured concrete used for foundations must:

- be well mixed, and
- not be dropped from a height.

6. **Remove the form.**
   Allow 7 days for the concrete to cure.

Procedure – Wet Construction Method

Follow these steps to create concrete foundations using the wet construction method.

1. **Set up the bottom stilling well section.**
2. **Box up the foundation space.**
   This creates a form into which the concrete will be pumped.
3. **Pour a 100-mm minimum thickness layer of blinding concrete.**
   Allow 24 hours for the concrete to set before continuing with Step 4.
4. **Pump concrete into the form and vibrate it to remove any air.**
   When pumping, ensure the exit end of the hose is kept within the concrete body.
   Allow 24 hours for the concrete to set before continuing with Step 5.
5. **Remove the form.**
   Allow 7 days for the concrete to cure.

General Design Considerations

The stilling well should:

- be firmly founded so that subsidence will not occur
- have sufficient height and depth to allow the float to freely travel up and down the full range of water levels
- where practicable, be vertical
- be watertight, so that water can only enter and leave through the intake pipe, and
- not allow the float and counter-weight system to come in contact with the walls.

2.3.3. Strength and Stability

The strength and stability of the stilling well tower in the MWD steel stilling well design depends on the catwalk. The catwalk acts as a compression strut between the tower and the bank, and on the provision of lateral tension bracing (typically guy wires that are anchored to ground).

Bracing

Bracing requirements are to some extent site specific and may depend on local topography, soil depth and type, and/or rock type.

Note: The MWD steel stilling well design drawings do not give any guidelines on requirements for these bracing elements.

At steep walled sites, it may be possible to support the tower using side braces that are bolted to rock on the sides. More typically, towers are built without such direct support and use tension bracing.

The bracing requirements should be determined by specific design.

The design should consider:

- the bracing requirements in both upstream and downstream directions

  For a typical tower, tension bracing is likely to be required in both upstream and downstream directions.

- the number of bracing elements, and

  For a tower up to 6 metres in height, one set of bracing at top level may be adequate. For towers greater than 6 metres in height, two or more sets of bracing may be required.

- any catwalk-anchoring requirements.

  If used as a bracing element, ensure the catwalk is adequately anchored to the tower at one end, and to a concrete abutment that is keyed into ground at the other end. The abutment and end connections must be designed such that the catwalk main members are capable of transmitting a design longitudinal force from the tower through the abutment to ground.

2.4. Hydraulic Design

2.4.1. Intake Pipe Sizing

The stilling well should be connected to the lake or river by means of a suitably sized intake pipe fitted with a static tube.

River Sites

For river sites, a relatively large intake pipe can be used to allow the recorder float to respond quickly to water level changes. The general guideline is to use a ratio of 12:1 between stilling well and intake pipe diameter. This means that for the MWD steel stilling well with its 600-mm diameter section, a 50-mm intake tube should be used.

Lake and Sea-Level Sites

For lake and sea-level sites, a smaller pipe may be required to:

- dampen out short-term fluctuations, and

  Short-term fluctuations can result from, for example, surging water and wind waves.

- preserve long-term fluctuations.

  Long-term fluctions can result from, for example, tide and seiche.

For sizing intake pipes that are to be deployed at lake and sea-level sites, see Section 2.3: 'Linear Stilling Well Design'.

2.4.2. Aggradation and Degradation

In rivers, alternative intake pipes may be required at a range of levels to allow for possible bed aggradation or degradation.

The lowest intake pipe should be set at least:

- 150 mm below the lowest anticipated water level (but considerably further if degradation of the bed is possible)

  Note: This is a very important decision that may impact considerably on the usefulness of the structure over time.

- 300 mm and preferably 1 metre above the bottom of the stilling well, to avoid blockage by sediment.

2.4.3. Intake Pipe – Flow Control

Active Intake Pipe

- The active intake pipe, which is the intake pipe that is connected to the static tube, is recommended to have a simple on/off valve fitted.

Note: A simple on/off valve is needed so that flow into and out of the stilling well can be shut off to allow filling of the well and then opened to flush sediment during de-silting operations.

Inactive Intake Pipes

- Inactive intake pipes need to be closed under normal operations. This can be achieved by, for example, stop-ending the pipe or using a simple on/off valve (e.g. a gate valve).

2.4.4. Static Tube

Where velocity past the river end of the intake is at times high (i.e. above 1.5 m/s) drawdown of the water level in the well may occur. To reduce this, a capped and perforated static tube should be attached, oriented parallel to the direction of flow (± 10°).

For more information on static tubes and intake pipes, see NEMS *Water Level* and/or the NEMS *Glossary* of terms.

3. Slack-Line Cableways

3.1. Background

Slack-line cableways are commonly used for carrying out flow gaugings on small rivers and streams.

The components of a slack-line cableway comprise: a static ropeway, suspended between anchor ends; a traveller; a horizontal positioning mechanism; and a lifting mechanism. In operation, the traveller runs on the ropeway and functions as an unmanned 'cable car'.

All operations are carried out from the bank.

3.2. Manual Winch Slack-Line Cableway

In the manual winch slack-line cableway, the horizontal positioning and lifting mechanisms are non-motorised.

3.2.1. Horizontal Positioning Mechanism

The horizontal position of the traveller is controlled by means of a manual winch that feeds a line across the span and over a pulley mounted on the far side and back to the traveller.

3.2.2. Lifting Mechanism

A separate line from a gauging reel feeds out to the traveller, runs over a pulley mounted on the traveller, and connects to a current meter and counterweight, thereby suspending these from the traveller.

The gauging reel controls the vertical position of the current meter.

Figure 3 shows a flow gauging being carried out on a manual winch slack-line cableway.

Figure 3 – Flow gauging from a manual winch slack-line cableway

Photo: Courtesy of John Fenwick, NIWA.

3.2.3. Span

The span of a conventional manual winch slack-line cableway is limited by the length of the gauging reel.

'A'-type gauging reels are 30 metres in length, but extended range reels, of 60 metres, are available and these are typically used when doing a slack-line gauging. Assuming an extended range reel and allowing for 4 metres vertical travel (which is typically what is required), this means that the maximum span is limited to around 54 metres.

Note: This span refers to the distance between the near-side 'A' reel mounting point to the far side of the active channel, not the active channel width or the cable span.

3.2.4. Maximum Load

A maximum load of 100 kilograms applies, as it is difficult to manhandle a direct drive gauging reel with a higher load than this.

3.3. Ott Slack-Line Cableway

The Ott slack-line cableway is a variant of the conventional manual winch slack-line design. Its main point of difference is that it incorporates a double drum winch, with one drum for traversing and the other drum for raising and lowering the gauging line. Both drums are operated manually.

The main advantage of the Ott design is an increase in span. Use of a dedicated winch drum for the gauging line, instead of an extended range reel, allows the span to be increased to around 100 metres.

Note: There are other commercially available unpowered slack-line designs that have similar capabilities.

3.4. Motorised Slack-Line Systems

Several proprietary motorised slack-line cableway systems are now available.

These systems provide motorised control of the traveller and incorporate a remote controlled winch, powered by batteries incorporated in the traveller.

Motorised slack-line systems are not restricted in span by the length of the gauging cable because the gauging winch and drum is on the traveller. Typically, these systems can be used with spans up to 250 to 400 metres.

Furthermore, since they can be fitted to run on a larger static cable, they can be retrofitted to manned cableways, thereby converting these to an unmanned slack-line system.

Figure 4 shows an example of such a system.

Figure 4 – Flow gauging using a 'Hornet' motorised slack-line system retrofitted to a manned cableway

Photo: Courtesy of Neil Blair, NIWA.

Retrofitting a motorised slack-line to a manned cableway eliminates the need to have one or more field staff suspended over a river during a flood to gauge the flow. It provides a safer environment for field staff during gauging operations. There are also cost savings in reduced certification and maintenance requirements. However, there are some compromises involved.

Feedback from field staff who have used these systems indicates that:

- water depth is difficult to determine
  Note: This is because it is difficult to sense when the counterweight hits the bottom.
  Note: Some systems, e.g. Hornet Plus, incorporate a ground feeler device that alerts the operator when contact is made with the bed, which eliminates this problem.
- angular flow may be difficult to assess
  Note: Because flow is oblique to the cross-section, the angle of the flow is not measured directly.
- visibility, when operating close to the bank, may be an issue
  For example, where the site is in a gorge, or the line of sight is obstructed by trees or other obstacles.
- undertaking depth-integrated sediment gaugings may be problematic because of:
  - the time required to traverse back to the bank after each sample to change the sampling bottle, or
  - inadequate control of the vertical traversing rate in some systems, and
- maintenance of the cable, far bank backstay, anchor block and traveller pulley may be expensive or have to cease.
  Note: This can occur where the cableway was the only access to the far bank.

There are some advantages, therefore, in retaining manned cableways, particularly for sites with very long spans and where visibility to the water is an issue.

3.5. Design Considerations

All components of a slack-line system should be determined by specific design and approved by a chartered professional engineer with competency in structural engineering.

The design should be based on the design loads specified below.

3.5.1. Cable

The static cable should be designed for a 3.5 kN snag load acting at minimum operating temperature.

Note: The 3.5 kN snag load can be regarded as the maximum possible load that can be applied to the instrument cable. It assumes a load-limiting device rated at 3.5 kN has been installed at the connection between the instrument cable socket and the gauging equipment hanger bar.

Note: Minimum operating temperature is generally taken as –10 °C, but could be higher. Each site must be considered on its own merits.

The cable tension under load at minimum operating temperature (maximum cable tension) should not exceed the allowable working load of the cable, T, given as:

$$T = U/F_s$$

where: T is the allowable working load of the cable in kilonewtons (kN)

U is the ultimate tensile strength of the cable in kilonewtons (kN), and

F_s is the factor of safety, which is taken as 4.5

3.5.2. Anchor Ends

For a conventional slack-line, the static cable is generally anchored to a steel cross-beam that is mounted on timber posts and tied back to suitable anchors via wire ropes attached to each end of the cross-beam.

The cross-beams should be:

- mounted on firm ground
  This is to ensure the foundations are stable.
- at about 1.5 metres height above ground, and
  This is governed by the need to provide a comfortable height for manual operation of the winch and gauging reel.
- mounted at the same or near-same elevation on each side of the span.
  This is particularly important for long spans, in which case a vertical height difference between the supports may make operation of the manual winch against the gradient very difficult.

The design of the cross-beams, timber posts, tie-backs and suitable anchors should be of sufficient strength as determined by detailed design.

Likewise, forces acting on the suitable anchors should be considered. If these are conventional gravity anchor systems, then stability against sliding and overturning should also be considered.

Navigational Clearance

The cable should have a safe working clearance of at least 3 metres from design maximum flood level to the bottom of the traveller at maximum working temperature, when under load.

Note: This is to provide clearance to pass small trees and floating debris. The 3-m clearance may be insufficient if the river in full flood usually carries large floating debris.

Note: Design maximum flood level is generally taken as the 0.05 annual exceedance probability level (i.e. 200-year flood level).

Note: Maximum working temperature is generally taken as 50 degrees above minimum operating temperature.

Where the cable is a potential hazard to large craft using the reach, higher clearance from high flood level to the cable may be required. In this case, details of the site and clearances should be forwarded to the appropriate authorities for approval prior to commencement of construction.

4. Meteorological Masts

4.1. Background

Meteorological masts come in many different types, and there are many different variations of the same type. Even on flat lowland areas, constraints on the building footprint and differences in design wind speed can lead to many variations on the same type.

4.1.1. Common Types of Mast

Common types of meteorological masts include:

- 10-m tilting mast (NIWA)
- 6-m tilting mast (NIWA)
- 3-m, 6-m and 10-m lattice masts (NIWA).

This is not intended to be a complete list.

4.1.2. Disclaimer

The masts described in this section are given as examples of commonly used types. Their representation in this document is not intended as a recommendation for use, nor of compliance with the New Zealand Building Code.

4.2. 10-metre Tilting Mast

The 10-m tilting mast is a NIWA design. Figure 5 shows an example of this type of mast.

Figure 5 – Example of a 10-m tilting mast

Photo: Courtesy of Andrew Harper, NIWA.

This type of mast comprises a vertical mast, a horizontally mounted tilting arm, three guy wires, a concrete foundation pad, and concrete anchor pads or ground anchors.

4.2.1. Components

The lower mast and tilting arm are made up of 80-mm nominal bore steel tube. Above the point of attachment of the three guy wires, smaller 50-mm nominal bore tube is used.

4.2.2. Advantage

An important advantage of this type of mast is the ability to tilt the mast to ground using the tilting arm, which avoids the need to climb the mast.

4.2.3. Disadvantage

A disadvantage of this type of mast is its large footprint: a 6.5-m radius is required for the guys and, in addition, 10 metres of working space is required to lower the mast.

4.3. 6-metre Tilting Mast

A 6-m tilting mast is sometimes used for sites where:

- wind data is needed, but not necessarily at 10 metres, or
- the footprint available at the site is less than that required for a 10-m tilting mast.

A further requirement is that the wind loading on the mast is low; that is, the mast only has a wind sensor, so wind drag is minimal, and the design wind speed at the site is low.

Figure 6 shows an example of this type of mast.

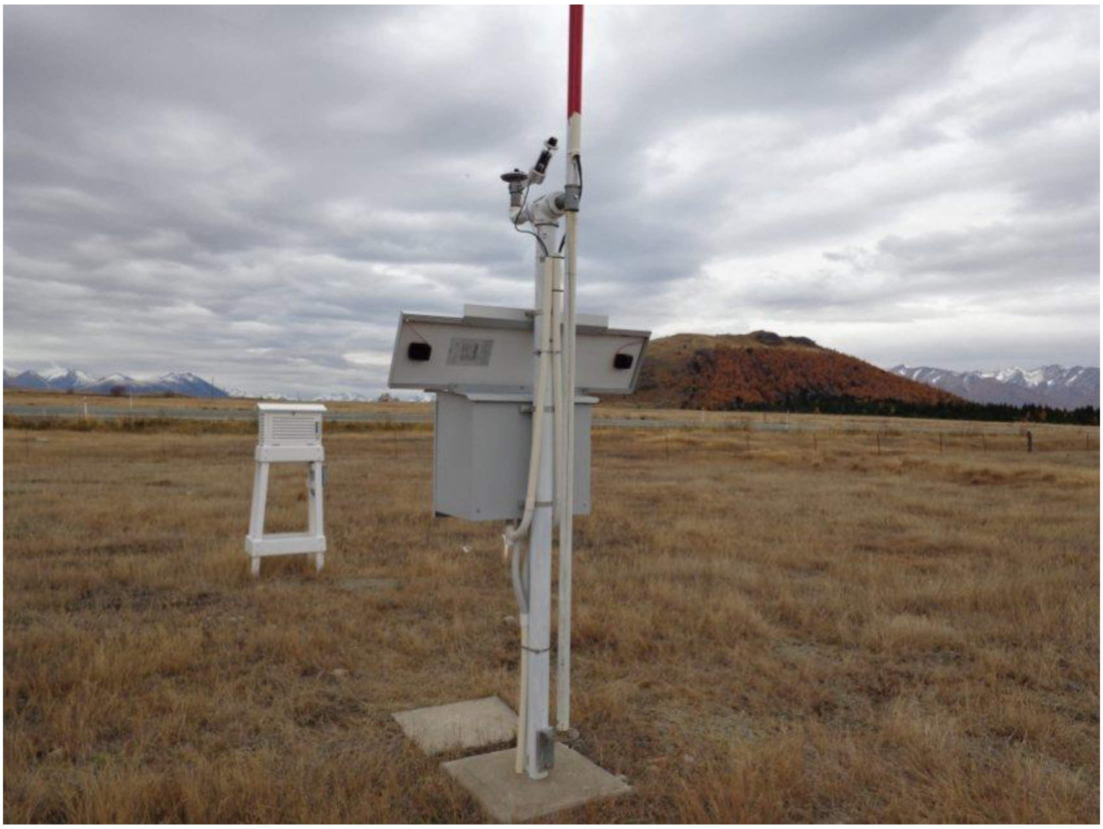


Figure 6 – Example of a 6-m tilting mast
Photo: Courtesy of Andrew Harper, NIWA.

The mast is essentially a 3.25-m long, 80-mm nominal bore galvanised pipe that is concreted into the ground to a depth of 750 mm with standard off-the-shelf pipe fittings to pivot a 6.5-m length of 40-mm pipe, to allow work on instrumentation at ground level. The mast is unguyed.

4.4. 3-metre, 6-metre and 10-metre Lattice Masts (NIWA)

The lattice mast is a fixed mast; it cannot be pivoted.

This type of mast is going out of favour because it must be climbed to service instruments, and this introduces a working-at-heights hazard.

However, lattice masts still have application at alpine sites, where strength and a minimal footprint is usually necessary because of:

- high wind speeds
- snow and ice loading
- consenting issues, and
- the amount of equipment needed to be hung on the mast.

Figures 7 and 8 show examples of this type of mast.

Figure 7– Example of a 3-m lattice mast
Photo: Courtesy of Andrew Harper, NIWA.

Figure 8 – Example of a 6-m lattice mast

Photo: Courtesy of Andrew Harper, NIWA.

Typically, 3-m lattice masts are guyed at the top, and 6-m lattice masts are guyed either only at the top or at both top and mid-level. The base is either a 1-m section concreted into the ground or bolted to threaded studs that are epoxied into rock.

4.5. Design Considerations

4.5.1. General

Load-bearing components should be determined by specific design and should comply with New Zealand Building Code Requirements.

4.5.2. Guys

Guy wires are typically of galvanised steel wire or Parafil.

Note: Parafil is a synthetic rope consisting of a core of closely packed, high-strength aramid, PBO or high-tenacity polyester fibres, encased in a protective polymeric sheath. Properties of Parafil include high tensile strength, high strength-to-weight ratio, good tension fatigue resistance, and good resistance to degradation under UV light.

Use of Parafil is preferable at sites where high rates of corrosion is likely; for example, in the tropics. Parafil has lower stiffness than galvanised steel wire so is less likely to snap because of over-tightening. However, Parafil is more expensive than galvanised steel wire, mainly because of the high cost of fittings required. Because of this, galvanised steel wire is more commonly used.

4.5.3. Footing

All masts require a concrete footing.

If the mast is not guyed, the footing will require detailed design.

4.5.4. Anchors

Anchors for guys are generally concrete gravity blocks that are embedded 600 mm into earth.

Anchors should be adequately sized to prevent uplift and horizontal forces.

In rock, rock anchors should be used.

4.5.5. Lightning Protection

In known high-risk areas, lightening protection is recommended; for example, copper earthing straps. Typically, other sites have earthing rods or nothing.

Note: According to NIWA, lightning has not been a major issue, except at mountain sites (personal communication, Andrew Harper, NIWA).

5. Access Platforms and Catwalks

5.1. Background

Platforms may be required at water level recorder sites for access to a recorder housing. At other sites, catwalks may be required. Catwalks are simple bridged walkways that generally run as a single span from the river bank to the recorder housing. Multi-span catwalks may be required at some sites.

5.2. Design Considerations

5.2.1. General

A new platform or catwalk, to comply with the New Zealand Building Act (2004), will typically need a building consent.

Guidance: A building consent is not required where it is not possible for a person to fall more than 1.5 metres (under Exemption (g) of Schedule 1 of the New Zealand Building Act 2004).

All structural components should be determined by specific design.

Prior to site work or construction, the design should be approved by a chartered professional engineer with competence in structural engineering.

5.2.2. Loading

Design loading should, unless otherwise stated, be consistent with AS/NZS 1180:1:2002.

In designing catwalks and access platforms, the design live load should be taken as:

- 3.0 kPa at rural sites, and
- 4.0 kPa at sites close to populated areas.

Barriers design should consider a design live load acting on the top edge acting as either:

- a 0.35 kN/m uniformly distributed load, acting horizontally or vertically, or
- a concentrated load of 0.6 kN acting down, inwards or outwards.

Note: The lower distributed live loading at rural sites reflects the low likelihood of crowd loading on platforms and catwalks located at rural locations.

5.2.3. Use as a Stilling Well Bracing Element

Where the platform or catwalk is to be used as a bracing element, it should be designed as such.

Note: The platform or catwalk that is supported at one end by a standard steel stilling well may form part of the bracing system.

To ensure longitudinal forces are transmitted to the abutment and then to the ground, the platform or catwalk structure should be adequately anchored to:

- the stilling well, and
- a concrete abutment that is keyed into ground.

5.3. Catwalk – MWD Design

Many existing catwalks are built to a Ministry of Works and Development (MWD) design.

5.3.1. New Catwalks

The MWD design, as documented in the Ministry's *Standard specifications for automatic water level recorder installations and current meter gauging stations* (Hanson & Turner, 1958), should not be used for new catwalks.

5.3.2. Existing Catwalks

Existing catwalks that use MWD design should display 'load limit' signage.

Note: The MWD design, although commonly used, does not comply with current Building Code requirements.

- *The design live load adopted was 45 lb/ft2 which equates to 2.1 kPa. This is less than the current design live load requirements for a new catwalk (see sub*section 5.2.2: '*Design Loading*'*).*
- *The barrier handrail does not meet current requirements, in that it doesn't have a centre rail or kick plate.*

Figure 9– Catwalk (MWD design)

Note: Figure 9 shows a typical example of this design, although it differs in having an expanded mesh floor (the floor in the MWD design is made of timber planks).

Photo: Courtesy of Jeremy Walsh, NIWA.

5.4. Catwalk – NIWA Design

The NIWA catwalk uses an underslung u-shaped steel component to form the handrail stanchions. These are diagonally braced to provide longitudinal stiffness, and support horizontal pipes at top, middle and bottom to form the handrail on each side.

The NIWA catwalk can be retrofitted to existing steel or timber stringer beams where the existing beams are adequate in strength and condition. Alternatively, new steel or timber stringers can be fitted.

Generally, a timber plank floor is used.

Figure 10 shows the NIWA design fitted to an existing water level recorder site with concrete stilling well. An underside view showing the u-shape component connection details is shown in Figure 11.

Figure 10 – Catwalk (NIWA design)

Photo: Jon Marks, GWRC.

Figure 11 – Underside view of NIWA-design catwalk

Photo: Courtesy of Colin Grace, NIWA.

An important consideration when fitting a catwalk to a 600-mm steel stilling tower is the support provided at the stilling tower end.

Figure 12 shows a steel bracket design that extends to the flange below the catwalk, so that vertical loading from the catwalk is transmitted to the flange in bearing.

Note: The MWD design uses an angle seat that is bolted through the stilling tower cylinder. Improper packing of the angle seat has resulted in bending of the cylinder walls and the angle seat at some sites, with consequent loss of strength. The NIWA design eliminates this problem.

Figure 12 – Attachment to 600-mm stilling well with the new seat design (NIWA)

Photo: Courtesy of Colin Grace, NIWA.

5.5. Stairways, Ramps and Ladders

The following shall comply with the most recent New Zealand Building Code (NZBC).

5.5.1. General Requirements

Check the latest NZBC for general requirements for fixed ladders.

When choosing a fixed ladder design, the following factors should be considered:

- the reason for access, the intended frequency of use, and the need to carry tools or materials by hand

  Rung-type ladders should not be used where frequent access and the carriage of tools, equipment or materials are required.
- protection from falling

  People should be protected from falling from all fixed ladders that rise more than 6.0 metres above the ground level or rise from a landing or platform.

  See the most recent NZ Building Code for acceptable solutions for safety hoops and longitudinal straps.
- the landing width and length, and
- rung or tread spacing uniformity.

5.5.2. Slope

Slopes in the direction of travel for different types of access route shall comply with the most recent NZBC.

5.5.3. Structural Stability

The access route including handrails should comply with the strength and stiffness requirements in the most recent NZBC.

5.5.4. Barriers

Barriers to prevent falling from the access route shall comply with the most recent NZBC.

5.5.5. Slip Resistance

Wet and dry slip resistance for difference walking surfaces, i.e. for both a level surface and for a sloping surface or stairs, shall comply with the most recent NZBC.

5.5.6. Fixed Ladders types

Consider additional requirements for other ladder types including:

Step-Type Ladders

- slope
- tread width and spacing
- width between stiles
- height between landings
- toe and hand clearances
- horizontal openings at landings, and
- handrails

Rung-Type Ladders

- slope

  The slope must be between 70 degrees and 90 degrees to the horizontal.
- width between stiles
- height between landings
- toe, hand, side and back clearances, and
- access to landings

Individual Rung-Type Ladders

For example, a ladder with individual climbing rungs cast into a vertical concrete surface.

- rung size and spacing
- tread width limitations , and
- height and clearance limitations.

Annex A – List of Referenced Documents

Building Act 2004. Available from http://www.legislation.govt.nz/act/public/2004/0072/latest/DLM306036.html?search=qs_act%40bill%40regulation%40deemedreg_New+Zealand+Building+Act+2004_resel_25_h&p=1&sr=1

Building Regulations 1992, Schedule 1 (The Building Code). Available from http://www.legislation.govt.nz/regulation/public/1992/0150/latest/whole.html#DLM162576

Hanson, F. M. & Turner, C. W. O. (1958). *Standard specifications for automatic water level recorder installations and current meter gauging stations.* Wellington, New Zealand: Ministry of Works.

Health and Safety at Work Act 2015. Available from http://www.legislation.govt.nz/act/public/2015/0070/latest/whole.html

National Environmental Monitoring Standards (NEMS). (2013). *Glossary* (A National Environmental Monitoring Standard). Wellington, New Zealand: Ministry for the Environment. Available from https://www.lawa.org.nz/media/2982084/NEMS-Glossary.pdf

National Environmental Monitoring Standards (NEMS). (2013). *Open channel flow measurement – Measurement, processing and archiving of open channel flow data* (A National Environmental Monitoring Standard). Wellington, New Zealand: Ministry for the Environment. Available from http://www.lawa.org.nz/media/16578/nems-open-channel-flow-measurement-2013-06.pdf

National Environmental Monitoring Standards (NEMS). (2013). *Water level – Measurement, processing and archiving of water level data*. (A National Environmental Monitoring Standard). Wellington, New Zealand: Ministry for the Environment. Available from http://www.lawa.org.nz/media/16590/nems-water-level-recording-2013-06-1-.pdf

Standards® New Zealand. (1993). *Timber structures Standard* (New Zealand Standard 3603:1993). Wellington, New Zealand: Ministry Business, Innovation and Employment. Available from https://shop.standards.govt.nz

Standards® New Zealand. (1997). *Aluminium structures – Limit state design* (Australian/New Zealand Standard 1664.1:1997). Wellington, New Zealand: Ministry Business, Innovation and Employment. Available from https://shop.standards.govt.nz

Standards® New Zealand. (1997). *Concrete construction* (New Zealand Standard 3109:1997). Wellington, New Zealand: Ministry Business, Innovation and Employment. Available from https://shop.standards.govt.nz

Standards® New Zealand. (1997). *Steel structures Standard* (New Zealand Standard 3404, Part1: 1997). Wellington, New Zealand: Ministry Business, Innovation and Employment. Available from https://shop.standards.govt.nz

Standards® New Zealand. (1997). *Structural design actions Standard* (Australian/New Zealand Standard 1170:2002). Wellington, New Zealand: Ministry Business, Innovation and Employment. Available from https://shop.standards.govt.nz

Resource Management Act 1991. Available from http://www.legislation.govt.nz/act/public/1991/0069/latest/DLM230265.html?search=qs_act%40bill%40regulation%40deemedreg_Resource+Management+Act_resel_25_h&p=1&sr=1

Seelig, W. N. (1977). *Stilling well design for accurate water level measurement* (Technical Paper No. 77-2). Fort Belvoir, VA: Coastal Engineering Research Center (US).

Annex B – Relevant Statutes and Codes of Practice

The most recent New Zealand statutes:

- Building Act
  Available from http://www.legislation.govt.nz/act/public/2004/0072/latest/DLM306036.html
- Building Regulations
  Available from http://www.legislation.govt.nz/regulation/public/1992/0150/latest/DLM162570.html
- Health and Safety in Employment Act, and
  Available from http://www.legislation.govt.nz/act/public/1992/0096/latest/DLM278829.html
- Resource Management Act
  Available from http://www.legislation.govt.nz/act/public/1991/0069/latest/DLM230265.html

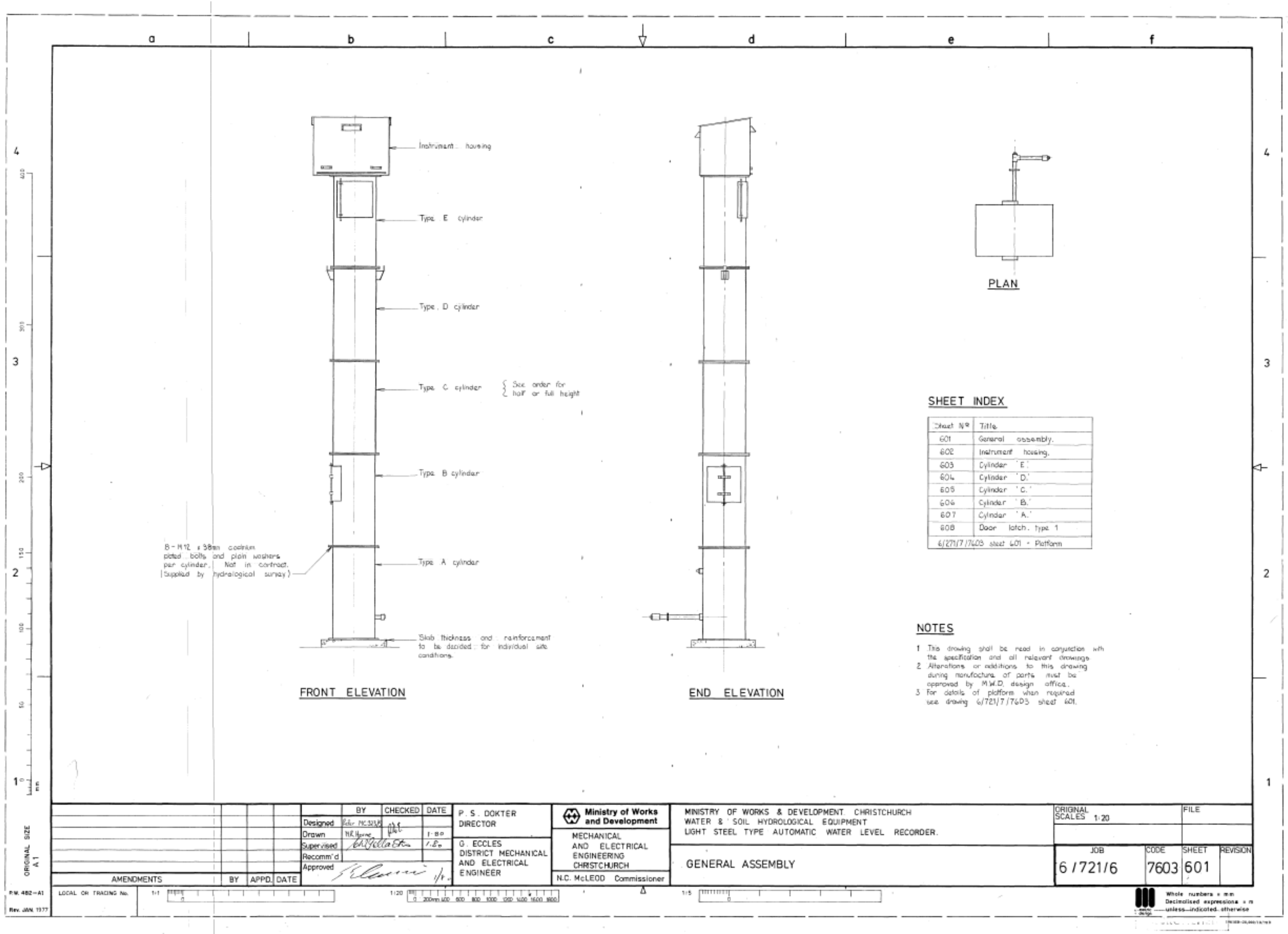
The most recent New Zealand Building Codes for:

- concrete construction
- steel structures
- timber structures, and
- design loading.

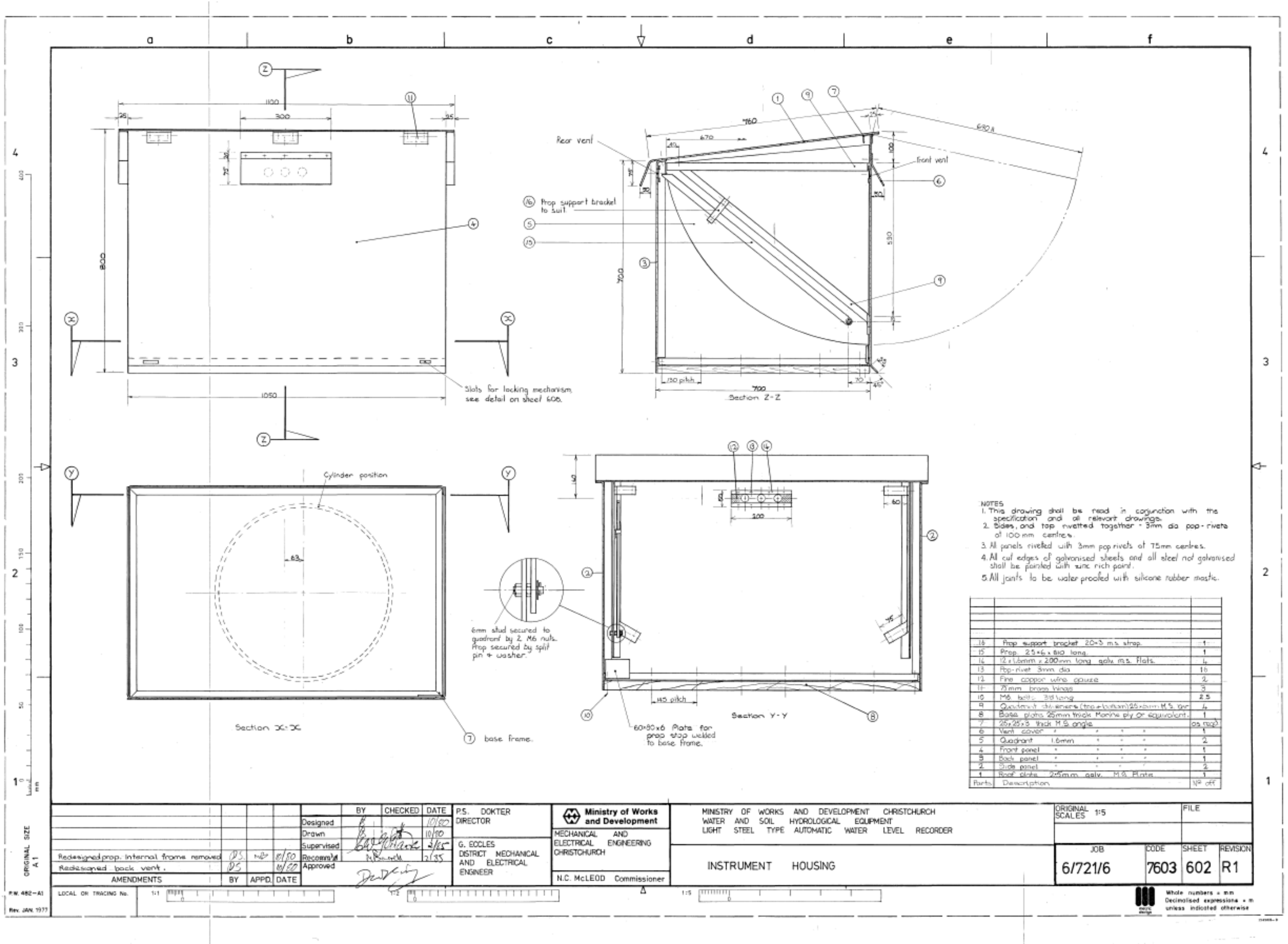
Annex C – Steel Stilling Well Design Drawings

This Annex contains the following Ministry of Works and Development design drawings:

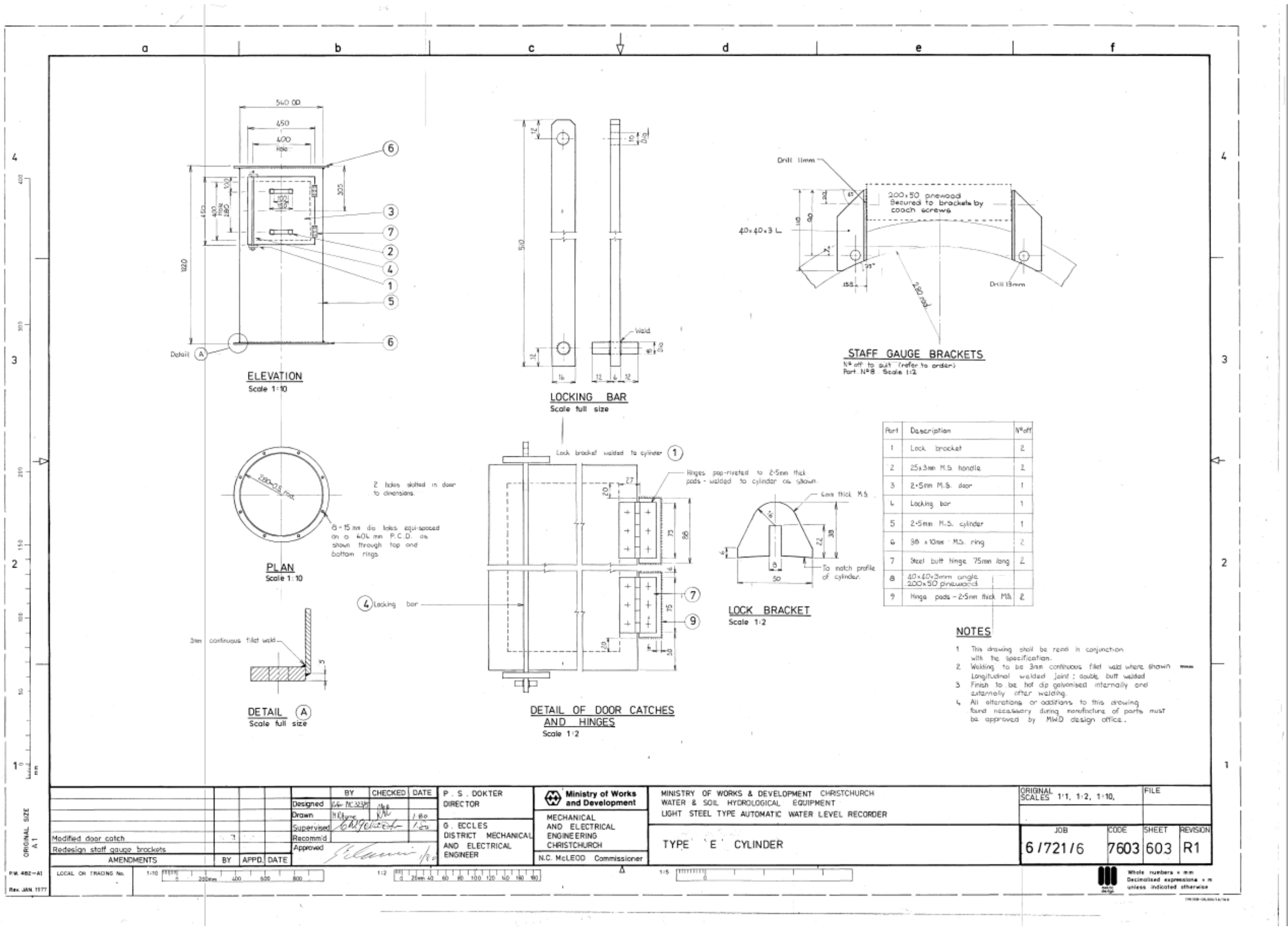
• **General Assembly**	MWD Drawing **6/721/6/7603/601**
• Instrument Housing	MWD Drawing 6/721/6/7603/602/R1
• Type 'E' Cylinder	MWD Drawing 6/721/6/7603/603/R1
• Type 'D' Cylinder	MWD Drawing 6/721/6/7603/604/R1
• Type 'C' Cylinder	MWD Drawing 6/721/6/7603/605
• Type 'B' Cylinder	MWD Drawing 6/721/6/7603/606
• Type 'A' Cylinder	MWD Drawing 6/721/6/7603/607
• Door Latch Type 1	MWD Drawing 6/721/6/7603/608/R1
• Platform	MWD Drawing 6/721/7/7603/601



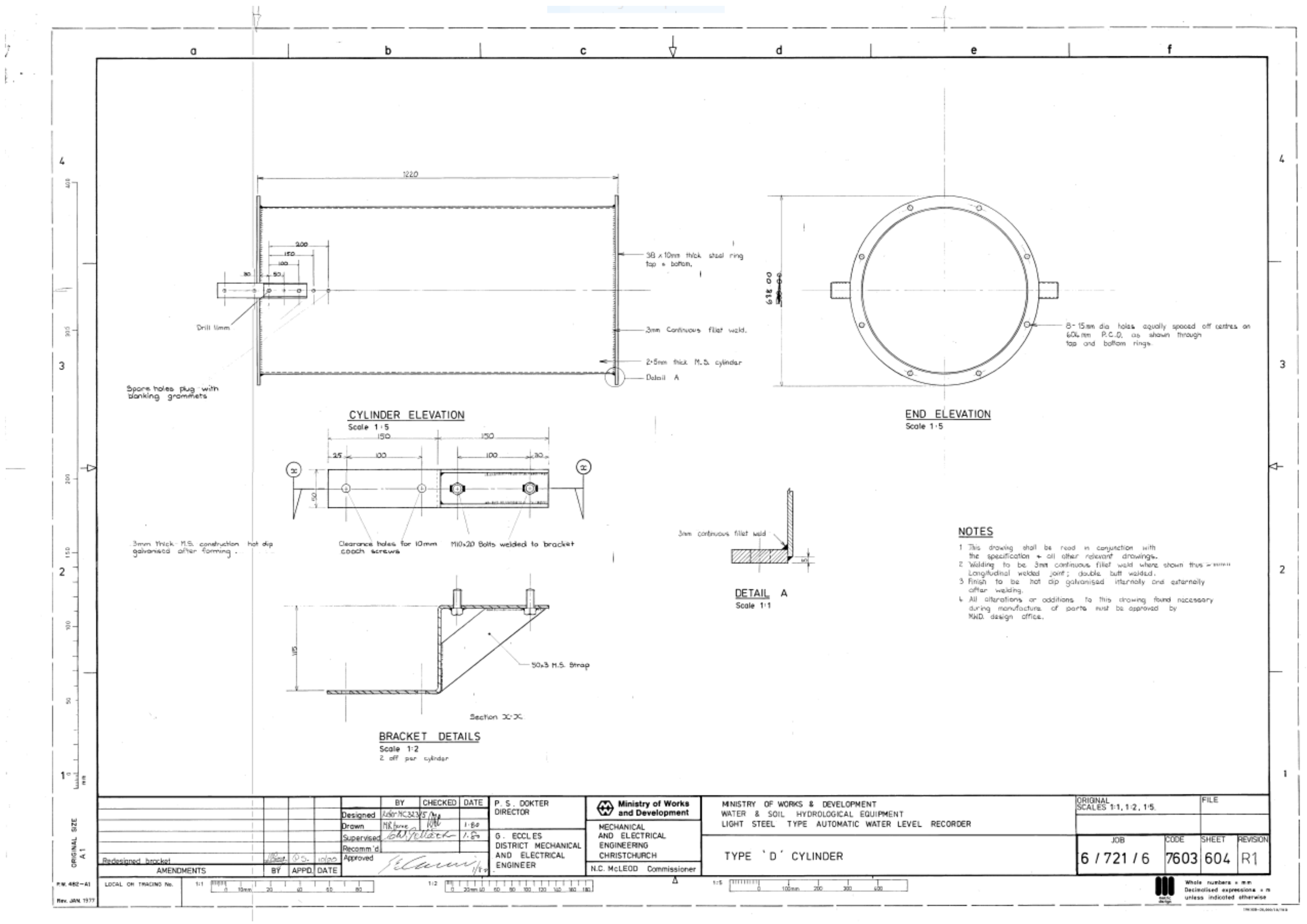
General assembly
(MWD Drawing 6/721/6/7603/601)



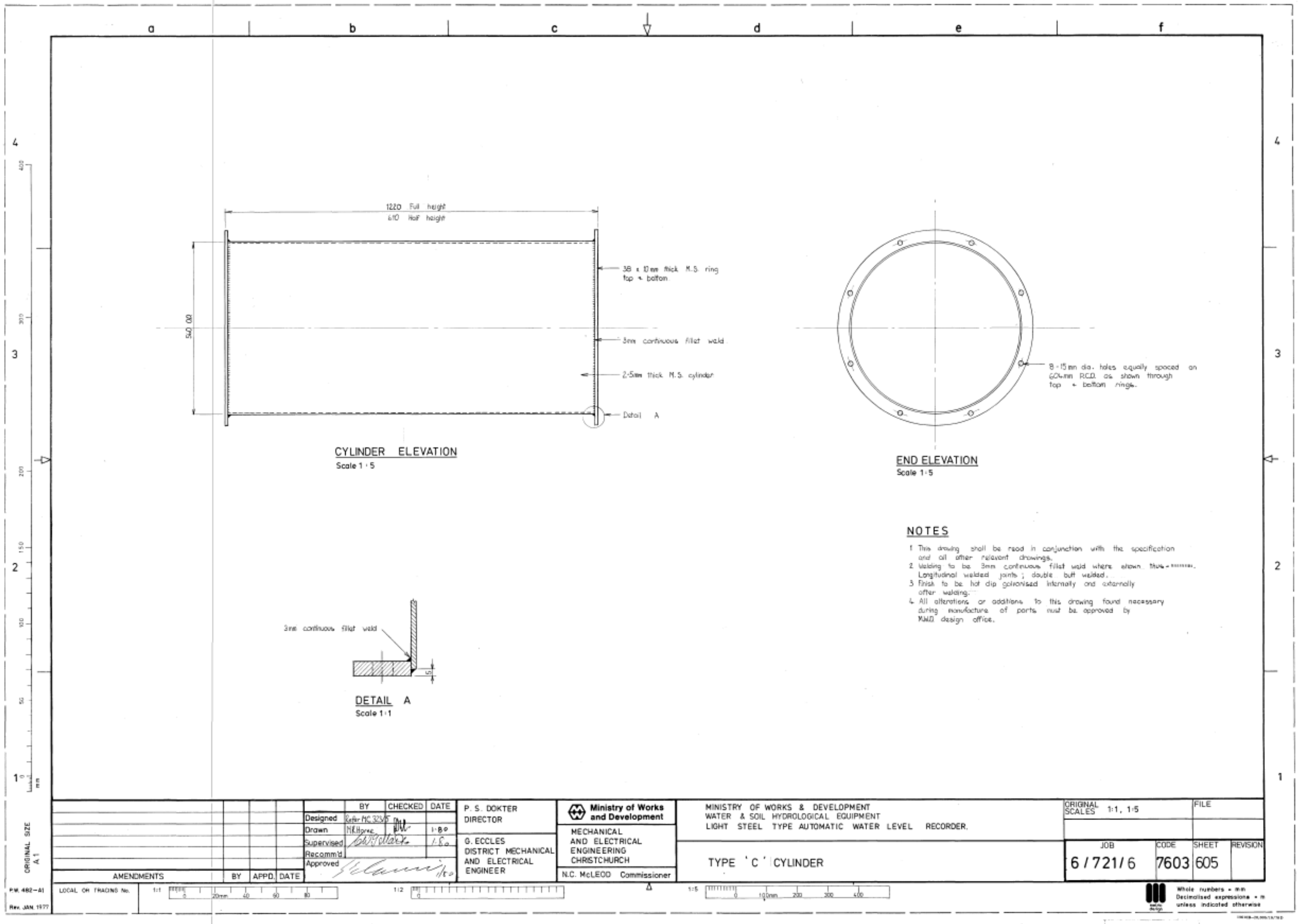
Instrument housing
(MWD Drawing 6/721/6/7603/602/R1)



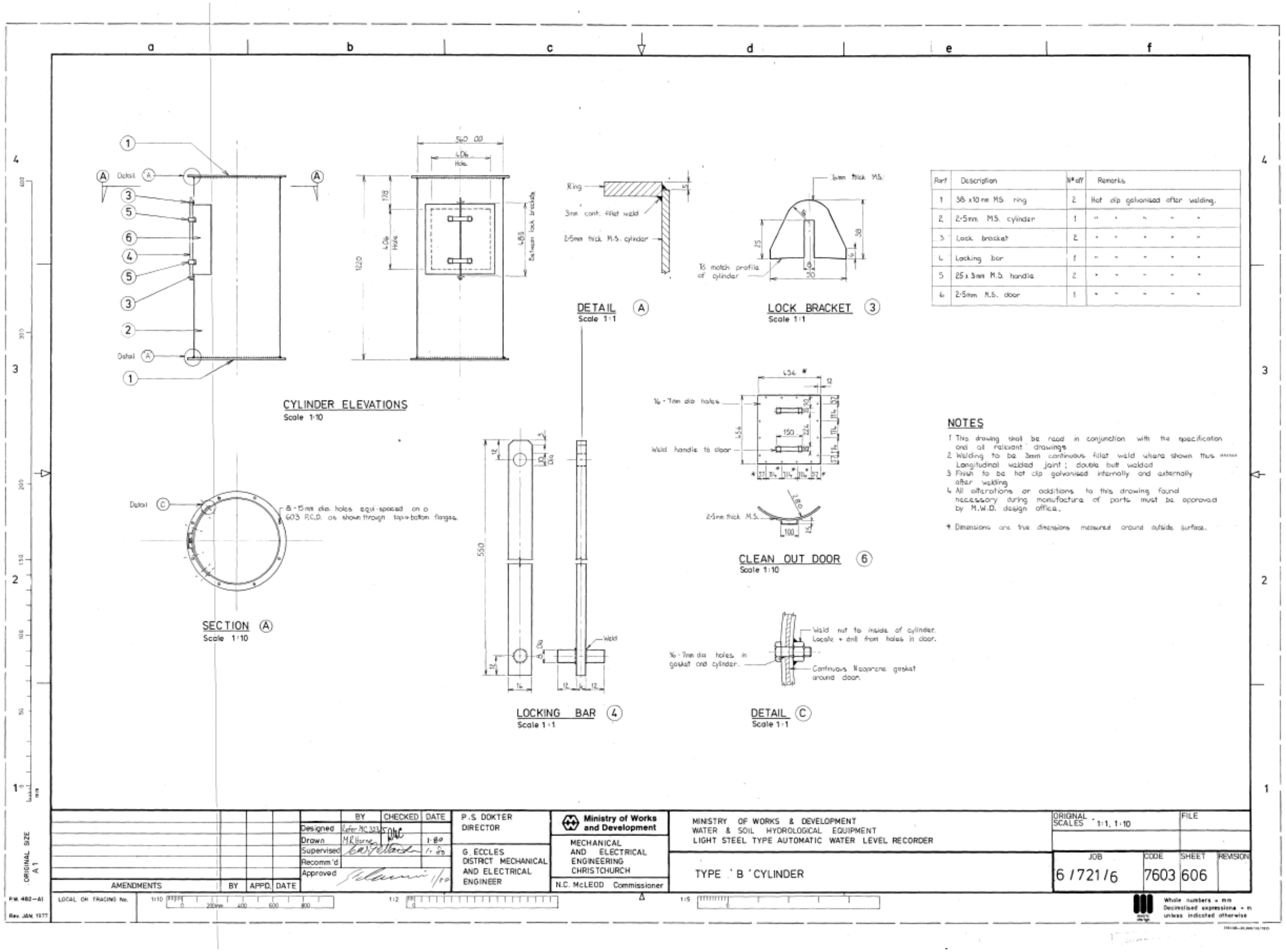
Type 'E' cylinder
(MWD Drawing 6/721/6/7603/603/R1)



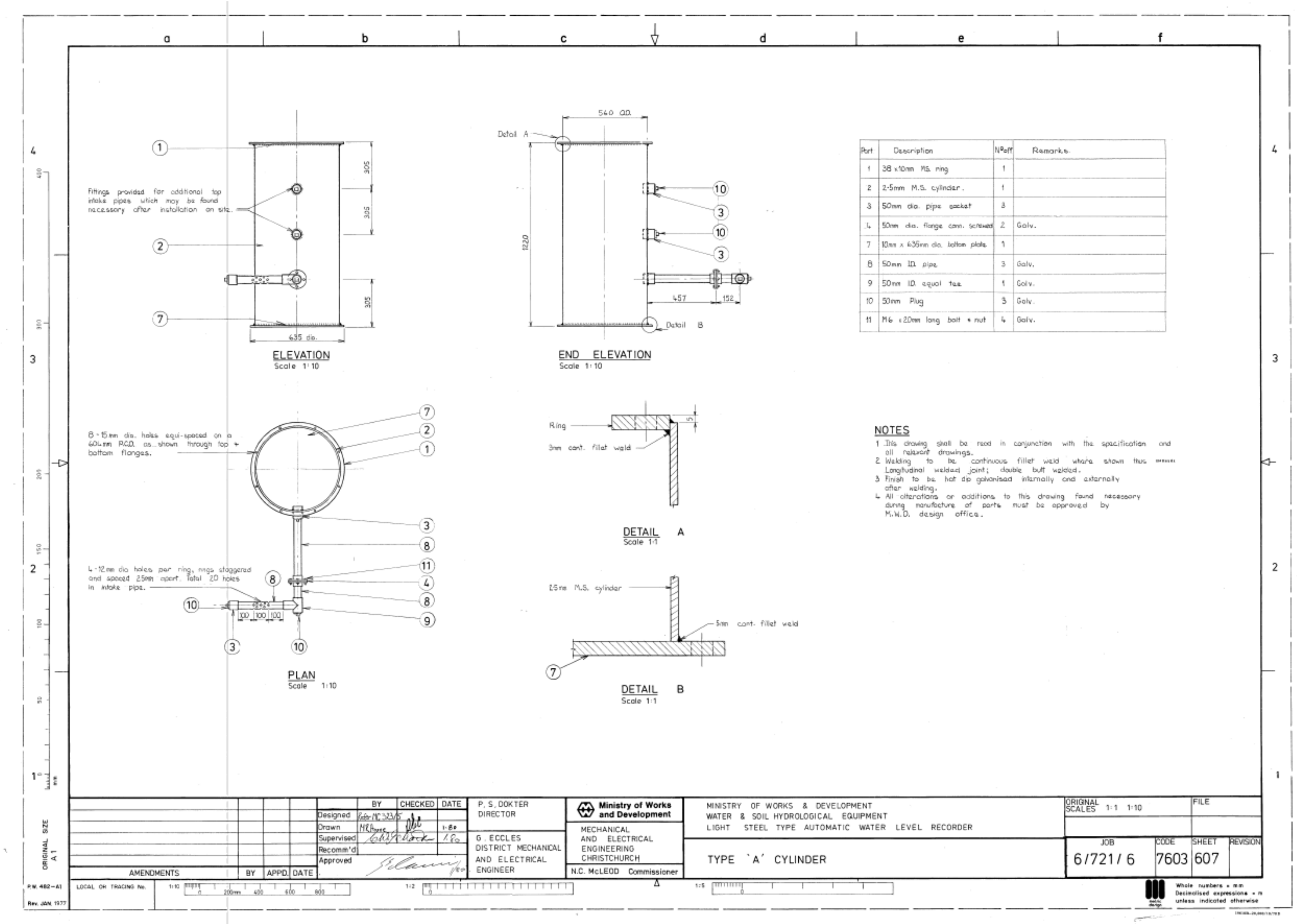
Type 'D' cylinder
(MWD Drawing 6/721/6/7603/604/R1)



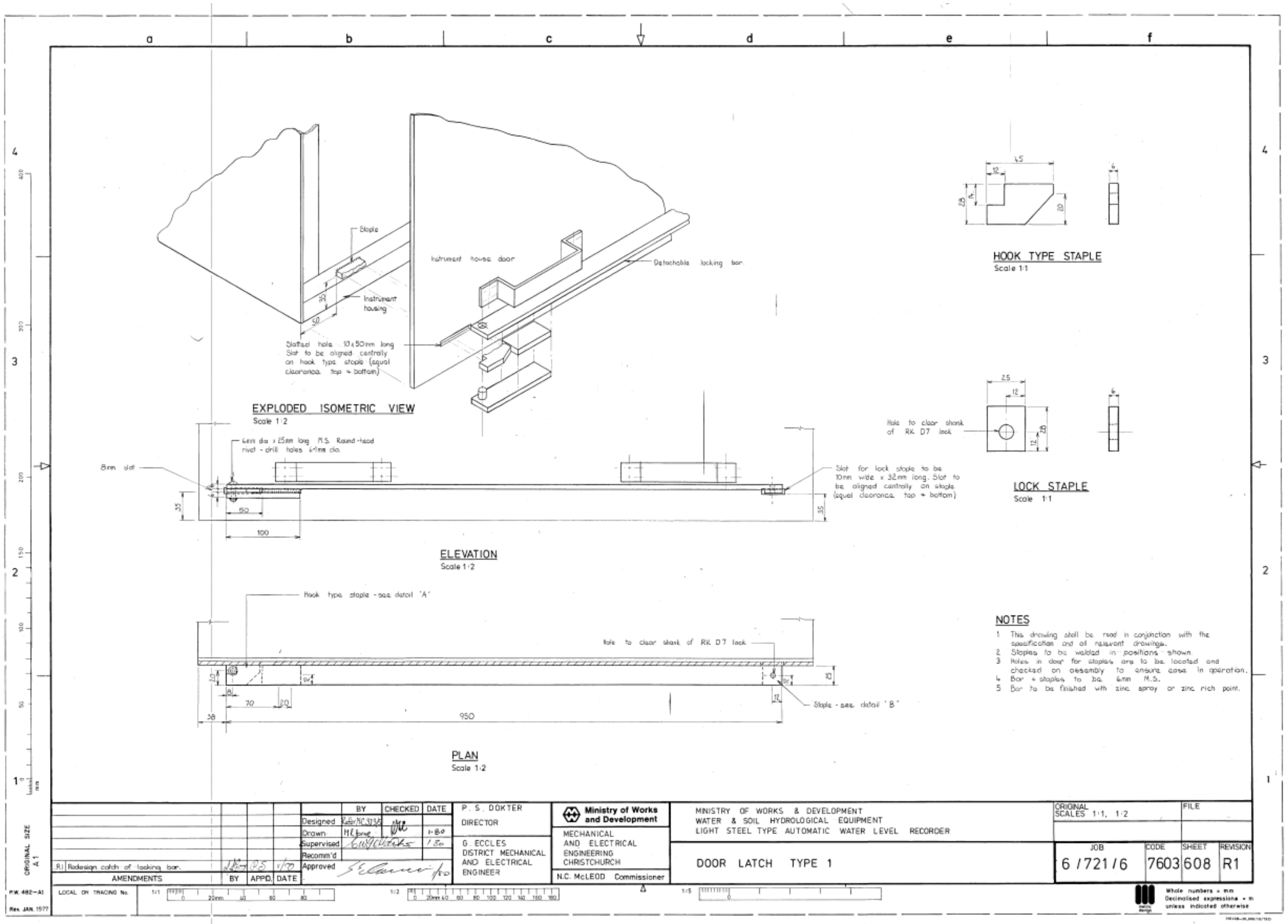
Type 'C' cylinder
(MWD Drawing 6/721/6/7603/605)



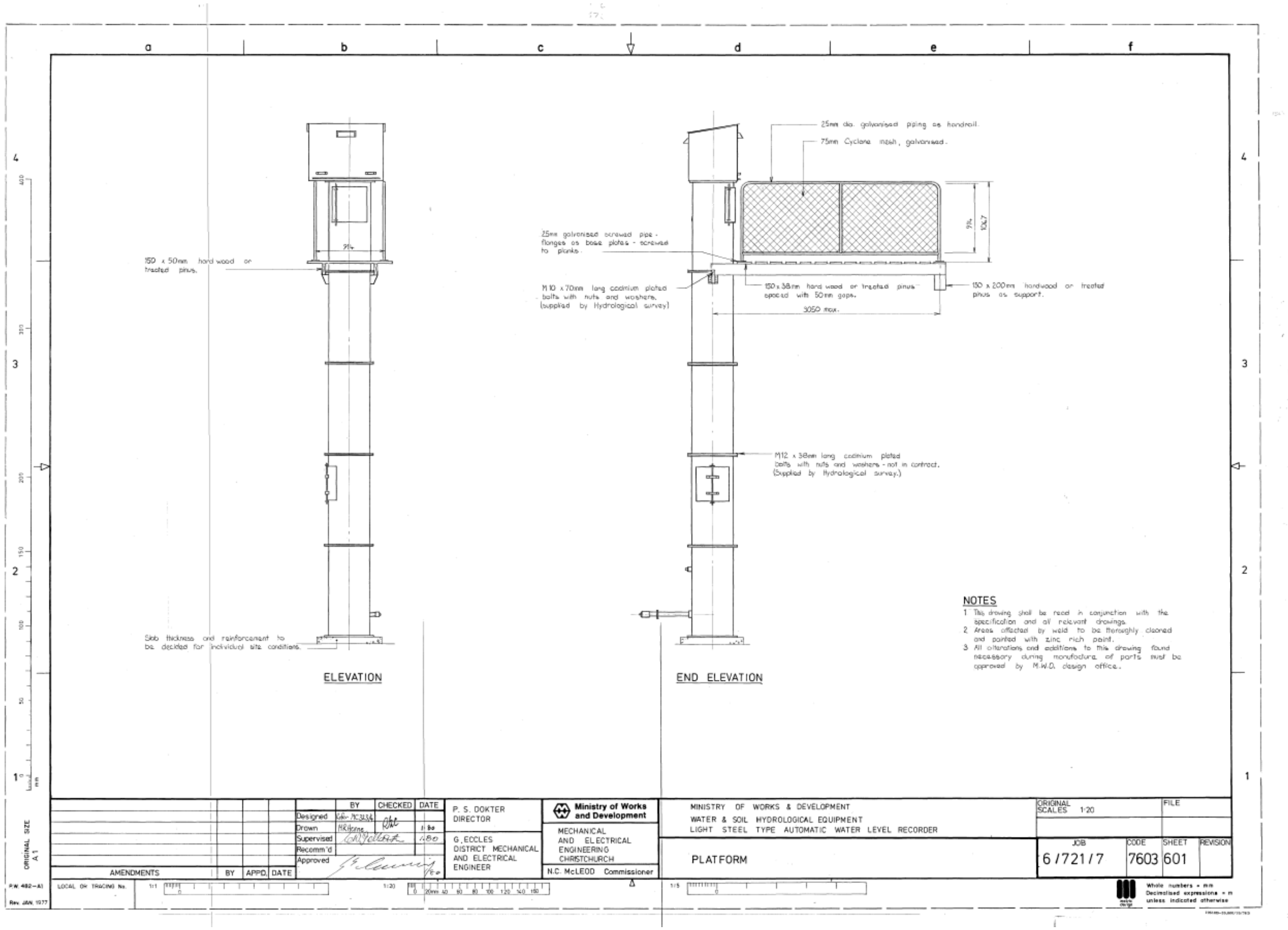
Type 'B' cylinder
(MWD Drawing 6/721/6/7603/606)



Type 'A' cylinder
(MWD Drawing 6/721/6/7603/607)



Door latch Type 1
(MWD Drawing 6/721/6/7603/608/R1)



Platform
(MWD Drawing 6/721/7/7603/601)


NEMS