



# WaterReuse Foundation Style Guide for Research Reports



**WaterReuse  
Foundation**



# **WaterReuse Foundation Style Guide for Research Reports**

*November 2006*



## How to Use this Guide

The results of most WaterReuse Foundation research projects are published in a final report. This style guide is divided into two sections to help researchers with proper report preparation. The first section outlines the Foundation's editorial preferences. The second section describes how to properly format the report. Before preparing the draft report, read the guidelines carefully. If multiple members of the research team are writing sections of the report, each should familiarize himself or herself with the style guide. It can also be helpful to create a list of terms specific to the report to share with all members of the research team to ensure consistency.

## Checklist for Final Report Submission

Before submitting a final report, use this checklist to ensure that the document is complete and ready to be delivered to the WaterReuse Foundation.

- Include one hard copy output of the final report along with the corresponding files on disk in Microsoft Word.
- Include Frontmatter (see Appendix for sample pages):
  - *Title page.* Include the title of the report, the name(s) of the principal investigator(s), and the names of cosponsoring organizations.
  - *Table of Contents.* The table of contents should include the title and beginning page number of each major section of the report. Do *not* use the Word automatic table of contents page numbering.
  - *List of Figures.* List the titles and page numbers of figures. If captions are long, use a shortened titled in this list. If there a very few figures, this list may be omitted. Do *not* use the Word automatic table of contents page numbering.
  - *List of Tables.* List the titles and page numbers of tables. Do *not* use the Word automatic table of contents page numbering.
  - *Acknowledgements.* List project team, project advisory committee members, and others who participated in the project.
  - *Executive Summary.* Summarize the research results.
- Include all chapters and backmatter (references, list of acronyms, etc.) in complete form.
- All text has been thoroughly proofread, spell-checked, and adheres to WRF guidelines.
- All text has been formatted according to WRF guidelines.
- All references cited in the text have been fully documented in the Reference list.
- Figures and tables have been formatted to fit on an 8 ½ x 11 inch page and incorporated into the final document. (If figures or tables were originally created in another program, also include the original source files in a separate folder.)
- Figures and tables have been prepared for reproduction in black and white. Use patterns (not colors) to differentiate elements in illustrations. Type captions in the Microsoft Word document beneath the figure; do not include captions as part of the figure.
- Include Project Profile.



## **Overview of Publishing Process**

Once the project is near completion, researchers are asked to submit a draft report to the Foundation. The draft report is reviewed by Foundation staff and the Project Advisory Committee and comments on the content are returned to the research team. The research team should address these comments in the final report.

An editor will review the final report for style, grammar, consistency, and completeness. The editor will typically generate a list of queries if there are missing references, conflicting information, or other issues that need to be resolved. The list of queries will be sent to the Principal Investigator for response. The research team is usually asked to supply missing information or clarify issues, *not* to revise the report. However, the Foundation may request that new figures be supplied if there are typos or if the figures are not legible. Once the editorial review is complete, the Foundation prepares the report for final publication.

## **Publishing Timeline**

Once the final report is accepted by the Foundation, the publishing process begins. Most reports will be published about 10 to 15 weeks after the final report is accepted.

## **Style and Formatting Questions**

For questions about preparing a report for publication, please contact:

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## EDITORIAL STYLE

The WaterReuse Foundation follows *The ACS Style Guide*, published by the American Chemical Society, for most style issues. For issues not covered in *The ACS Style Guide*, the Foundation defers to *The Chicago Manual of Style*. The Foundation follows Webster's Collegiate Dictionary for spelling. Some of the Foundation's key style preferences are highlighted below, but authors should also consult *The ACS Style Guide* for issues not covered here.

### Numbers

In nontechnical text, use words for cardinal numbers less than 10; use numerals for 10 and above. Spell out ordinals "first" through "ninth"; use numerals for 10th or greater.

In technical discussions, use numerals with units of time or measure, and use a space between the numeral and the unit, except %, \$, and ° (angular degrees), ´ (angular minutes), and ´´ (angular seconds).

6 min  
4%  
40 °C

Use all numerals in a series or range containing numbers 10 or greater, even in a nontechnical sense.

4, 9, and 14 experiments

For very large numbers used in a nontechnical sense, use a combination of numerals and words.

1 billion tons  
155 million people

Spell out numbers at the beginning of a sentence or recast the sentence.

Arabic numerals in parentheses may be used to enumerate a list of phrases or sentences within a paragraph. Always use an opening and a closing parenthesis, not one alone.

Arabic numerals followed by periods or enclosed in parentheses may be used to enumerate a displayed list of sentences or to number paragraphs.

In four digit numbers, use no commas or spaces.

1000 *but* 10,000



## Capitalization

Generally, in text keep all words lowercase, including chemical names and terms, except proper nouns and adjectives.

Capitalize the words “figure,” “table,” “chart,” and “scheme” when they refer to a specific numbered item.

Capitalize the first word after a colon if the colon introduces more than one complete sentence, a quotation, or a formal statement.

In general, capitalize formal proper names but do not capitalize the general terms for them.

32nd Western Regional Meeting, *but* the regional meeting  
Governor Smith, *but* the governor

In text, capitalize the names of specific titles when they appear with a person’s name, but not the general term for them.

Professor Mary Smith, the professor  
Bob Jones, Chair of the Department of Chemistry; the chair of the department

## Abbreviations and Acronyms

Define acronyms on first use, followed by the acronym in parentheses. Thereafter, use only the acronym. For clarity, it may be necessary to define the acronym again if it is used infrequently and many pages have passed since it was last used. Include a complete list of acronyms with the final report.

Use the abbreviations U.S. and U.K. as adjectives only; spell out United States and United Kingdom as the noun forms.

Use two-letter abbreviations for U.S. state and territory names and Canadian provinces and territories.

Abbreviate units of measure when they accompany numerals. Do not use a period after an abbreviated unit of measure (exception: in. for inch). Do not define units of measure.

Always use the symbol “%” with numerals. Spell out the word “percent” when it does not follow a numeral.

Please refer to *The ACS Style Guide* for a list of standard abbreviations.



## Dashes

The shortest dash is the hyphen (-); the en dash (–) is longer; and the em dash (—) is the longest.

Consult *Webster's Collegiate Dictionary* to resolve hyphenation questions. The Foundation prefers not to hyphenate most *prefixes* such as anti-, co-, extra-, micro-, non-, pre-, re-, etc.

antibacterial  
cooperation  
nonpolar  
precooled

Hyphens may be used with *prefixes* if more than one prefix is present (post-reorganization) or when the unhyphenated word does not convey the intended meaning (reform vs. re-form).

*Unit Modifiers.* Unit modifiers are two words that together describe a noun. They are often hyphenated.

time-dependent reaction  
high-frequency transition

The Foundation allows the hyphen to be omitted in cases where there is little or no risk of ambiguity, but the use must be consistent throughout the report. An example of a unit modifier that could be clarified with the use of a hyphen is “fast sailing ship.” Does the phrase refer to a ship that is now sailing fast or a sailing ship that is capable of rapid navigation? If the second construction is intended, a hyphen should be included: “fast-sailing ship”

Use the *en* dash to mean the equivalent of “and”, “to”, or “versus” in two word concepts where both words are of equal weight.

carbon–oxygen bond  
cost–benefit analysis  
Beer–Lambert law

Use an *en* dash between ranges.

12–20 months  
parts C–E

Use an *em* dash to set off words that would be misunderstood without them.

All three experimental parameters—temperature, time, and concentration—were strictly followed



## Punctuation

Use serial commas. A serial comma is the final comma before a conjunction

cats, dogs, and horses *not* cats, dogs and horses

Quoted words, phrases, and sentences run into the text are enclosed in double quotation marks. Single quotation marks enclose quotations within quotations. Place periods and commas inside quotation marks. Exclamation marks and question marks should be placed inside the quotation marks when they are part of the quoted material; otherwise they should be placed outside.

## Vertical Lists

Each entry in a vertical list begins with a bullet or a number. Omit periods after items in a vertical list unless one or more of the items are complete sentences. If the vertical list completes a sentence begun in an introductory element, the final period is also omitted unless the items in the lists are separated by commas or semicolons.

If the vertically listed items are phrases, especially long phrases, that grammatically complete the sentence containing them, commas may, but need not, be used after each item. If commas are used, the last item is followed by a period.

## References

Indicate references in text by author name and year of publication in parentheses inside the punctuation. If a reference has more than two authors, give only the first name listed followed by “et al.”

(Smith, 1999)  
(Johnson and Johnson, 2006)  
(Perez et al., 2003)

Use an en dash (–) rather than a hyphen (-) between page ranges.

The following are examples of ACS Books standard forms for various types of literature citations. (For more examples and a thorough discussion of reference style, consult *The ACS Style Guide*.)

### ***Journal***

Author, A. B.; Author, C. D. *J. Abbrev.* **19XX**, *vol.* xx-yy.

NOTE: No punctuation in journal abbreviations except periods. No conjunctions, articles, or prepositions in journal abbreviations. No comma or semicolon before or after journal titles.

### ***Magazine with dates instead of volume numbers***

Author, A. B.; Author, C. D. *Magazine Abbrev.* October 26, 1995, p. 20.



***Book without editors***

Author, A. B.; Author, C. D. *Book Title*; Series Name and number; Publisher: City, STATE (2 letters), year; Vol. 1, pp xx–yy.

***Book with editors, no authors named***

*Book Title*; Editor, A. B.; Editor, C. D., Eds.; Series Name and number; Publisher: City, STATE (2 letters), year; Vol. 2, pp xx–yy.

***Book with editors and authors named***

Author, A. B. In *Book Title*; Editor, C. D.; Ed.; Series Name and number; Publisher: City, STATE (2 letters), year; Vol. 3, pp xx–yy.

***Patent***

Author, A. B. U.S. Patent 3,123,456, year.

***Thesis***

Author, A. B. Ph.D. thesis, Institution Name, City, STATE, year.

NOTE: Do not include the title of the thesis.

An example of an electronic reference is: *About the Commercial Internet eXchange*, URL <http://www.acs.org>. Use Chemical Abstracts abbreviations for journal names. For books, edition follows title: *Book Title*, 2nd ed.;

The punctuation retains the style (e.g., roman, bold, or italic) of the character to which it is attached. Include the state name for all U.S. cities except New York. Include the country name for all non-U.S. cities except London and Paris.

For unpublished results, give author names and affiliations. Describe submitted material as *unpublished*. Unless an article has been published, it is either *unpublished* or accepted, in which case it is *in press*. Include the journal name and year.

When citing M.S. or Ph.D. theses, include the name of the school, city, and state (or city and country). Certain journals that have duplicate titles should be cited along with the city of publication. For example:

*Science* (Washington, D.C.)

*Nature* (London)

*Nature* (London) *New Biol.*

*Nature* (London) *Phys. Sci.*

Certain journals do not have volume numbers:

*Chem. Ind. (London)*

*Chem Lett.*

*J. Chem. Soc.*

*J. Chem. Soc. Chem. Commun.*

*J. Chem. Soc. Faraday Trans. 1 or 2*

*J. Chem. Soc. Perkin Trans. 1 or 2*

*Proc. Chem. Soc. London*

*Tetrahedron Lett.*

## FORMATTING GUIDELINES

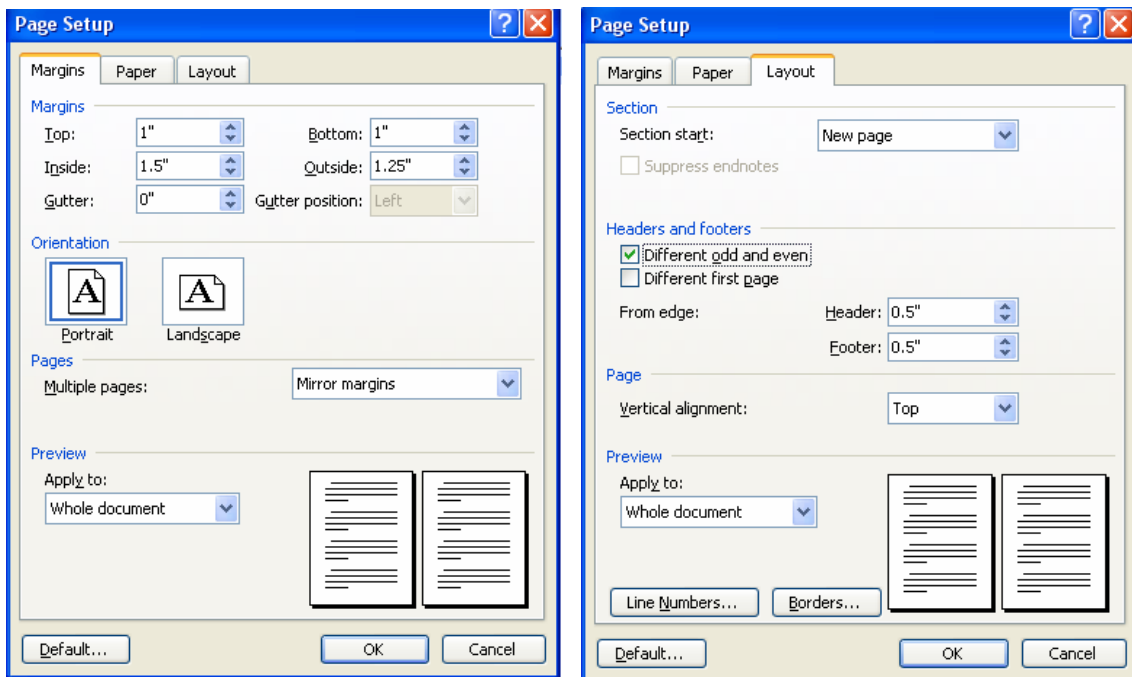
The final report must be prepared using Microsoft® Word. A template document is available from the Foundation to assist you in following the specifications for preparing the report.

### Page Setup

In the Page Setup dialog box, choose *Mirror Margins*. This allows the margins to be set to account for the binding of the report. Set the margins as follows:

Top: 1 inch  
Inside: 1.5 inch  
Bottom: 1 inch  
Outside: 1.25 inch

Under Headers and Footers, select *Different Odd and Even* and set footers at 0.5 inch from the edge. See the screen captures below.



### Pagination

All pages should be counted in the pagination. Use roman numerals in the frontmatter. The Table of Contents is the first page that should include a page number (roman numeral). The first page of the first chapter should be numbered as Arabic page 1.



## Footers

Footers are set in 9 point Arial. The odd page footer includes the words “WateReuse Foundation” set flush left and the page number flush right (right tab set at 5.75 inches). The even page footer includes the page number set flush left and the words “WateReuse Foundation” set flush right (right tab set at 5.75 inches).

## Chapter Openers

All new chapters start on odd (recto) pages. If necessary, insert a page break at the end of a chapter to force the next chapter to begin on an odd page. Blank pages are counted as part of the pagination, but page numbers are omitted on blanks.

## Chapter Number

The word “CHAPTER” followed by an Arabic numeral (1, 2, 3, etc.) is set on the first line of a chapter opening page. The text is set in 14 point Times New Roman Bold, all caps, single spaced, left aligned, with 9 points of spacing after this line. If using the Foundation template, you may highlight the text and select *Chapter Number* from the Styles and Formatting menu to apply the appropriate style to text.

## Chapter Title

The chapter title is set in 14 point Times New Roman Bold, all caps, single spaced, left aligned, with 9 points of spacing after this line. Insert a paragraph return after the chapter title and set a .5 point rule (border) above the blank line. If using the Foundation template, you may highlight the text and select *Chapter Title* from the Styles and Formatting menu to apply the appropriate style to the chapter title. Highlight the blank line and select *Chapter Rule* from the Style and Formatting menu to add the rule after the chapter title.

## Body Text

Text is set in 11 point Times New Roman, single spaced, and left aligned. There is a 12 point space (or 1 line) following each paragraph. Paragraphs are not indented. If using the Foundation template, you may highlight the text and select *Body Text* from the Styles and Formatting menu to apply the appropriate style to text.

## Heading 1

The first level subhead is set in 12 point Times New Roman Bold, all caps, single spaced, and left aligned. Insert 18 points before the heading and 6 points after the heading. Do not use paragraph returns before and after the heading. If heads are numbered, use double numbering separated by a period with the first number indicating the chapter number and second number indicating the heading number (1.1, 1.2, etc.). There is no period following second number. Insert a tab of .35 inches between the number and the heading text in a numbered head. If using the Foundation template, you may highlight the text and select *Heading 1* from the Styles and Formatting menu to apply the appropriate style to the heading.



## **Heading 2**

The second level subhead is set in 12 point Times New Roman Bold, initial caps, single spaced, and left aligned. Insert 18 points before the heading and 6 points after the heading. (If Heading 2 immediately follows Heading 1 with no text in between, reduce to 12 points above Heading 2.) Do not use paragraph returns before and after the heading. If heads are numbered, use triple numbering separated periods (1.1.1, 1.1.2, etc.). There is no period following the last number. Insert a tab of .5 inches between the number and the heading text in a numbered head. If using the Foundation template, you may highlight the text and select *Heading 2* from the Styles and Formatting menu to apply the appropriate style to the heading.

## **Heading 3**

The third level subhead is set in 11 point Times New Roman Bold Italic, initial caps, single spaced, and left aligned. Insert 12 points before the heading and 3 points after the heading. Do not use paragraph returns before and after the heading. If heads are numbered, use quadruple numbering separated periods (1.1.1.1, 1.1.1.2, etc.). There is no period following the last number. Insert a tab of .65 inches between the number and the heading text in a numbered head. If using the Foundation template, you may highlight the text and select *Heading 3* from the Styles and Formatting menu to apply the appropriate style to the heading.

## **Figures**

All figures should be black and white. WateReuse Foundation products are printed in black and white only. Color figures will be reproduced in black and white. Do not use shaded, tinted, or screened backgrounds in graphics or in text. Use patterns (not colors) to differentiate elements in illustrations making sure to allow for reduction. All figures should be formatted to fit on an 8 ½ x 11” page and be embedded in the Microsoft Word document and placed as close as possible after they are cited in the text. If figures are very wide, they can be presented in landscape on the 8 ½ x 11” page.

Figures should be centered on the page. Insert a paragraph return between the text and the top of the figure.

## **Figure Captions**

Every figure should be given a number and cited in the text by that number. The figure number and caption are set on the same line. Each caption should be double numbered (1.1., 1.2., 1.3., etc.) A period and a single space separate the figure number and the figure caption. The text is set in 10 point Times New Roman Bold, single spaced, and indented .5” from the left and the right sides. Center the caption if it is one line long or less. Left align the caption if it is more than one line. Capitalize only the first word of the caption and insert a period at the end of the caption. Add 36 points of spacing below the caption. Do not include captions as part of the figure file. If using the Foundation template, you may highlight the text and select *Caption* from the Styles and Formatting menu to apply the appropriate style to the caption.

## **Tables**

All tables should be black and white and formatted to fit on an 8 ½ x 11” page. If tables are very wide, they can be presented in landscape on the 8 ½ x 11” page. If tables are very long, they can continue to another page. Tables should be placed as close as possible after they are cited in the text; however, tables should be placed so that they begin and end on the same page if the table can fit on a single page. Tables are most aesthetically pleasing when placed at the tops and bottoms of pages. The formatting for the table title inserts the correct amount of space between text and the top of the table. Two paragraph returns should be entered to separate the bottom of a table from the text that follows. A minimum of six lines of text should appear on the page with the table. If six lines do not fit, insert a page break so that no text appears on the page.

### **Table Number and Title**

Every table should be given a number and cited in the text by that number. The table number and table title are set on the same line. Each table should be double numbered (1.1., 1.2., 1.3., etc.) A period and a single space separate the table number and table title. The text is set in 11 point Times New Roman Bold, initial caps, single spaced, and left aligned. The text is indented .5” from the left and the right with 36 points of spacing above and 6 points of spacing below. If using the Foundation template, you may highlight the text and select *Table Title* from the Styles and Formatting menu to apply the appropriate style to the heading.

### **Table Column Heads**

The table column heads and table body are best set using the MS Word table editor. The table column heads are set in 10 point Times New Roman Bold, initial caps, single spaced, left aligned or centered, with 3 points space above and below. There is .5 pt border (rule) above and below the column heads. (While the standard size type for table text is 10 point, the text may be reduced to as small as 8 point to make a very large table fit.) If using the Foundation template, you may highlight the text and select *Table Col Heads* from the Styles and Formatting menu to apply the appropriate style to the heading. Use the *Borders and Shading* menu to add the borders.

### **Table Body**

The table column heads and table body are best set using the MS Word table editor. The table body is set in 10 point Times New Roman, first word only in caps, and single spaced. The first column is always left aligned; the other columns can be left aligned or centered. When numbers are totaled in a column, align on the decimal point. Add 3 points space above the first line in the table and 3 points below the last line in the table. Add a .5 pt border (rule) below the last entry in the table. Two paragraph returns should be entered to separate the bottom of a table from the text that follows. If using the Foundation template, you may highlight the text and select *Table Body* from the Styles and Formatting menu to apply the appropriate style to the table text. Use the *Borders and Shading* menu to add the border.



### **Table Footnotes**

The footnotes are set in 9 point Times New Roman, single spaced, left aligned, with 3 points space above each note. Two paragraph returns should be entered to separate the bottom of a table from the text that follows. If using the Foundation template, you may highlight the text and select *Table Notes* from the Styles and Formatting menu to apply the appropriate style to text.

### **Table Borders**

The table body and borders best set using the MS Word table editor. Use the *Borders and Shading* menu to add .5 point borders above and below the column heads and below the last entry in the table. Do *not* use outside borders or vertical borders. Additional horizontal borders are permitted for clarity, but it is best to add horizontal or vertical spacing to further separate items.

### **References**

References are set in 11 point Times New Roman, single spaced, and left aligned. There is a 6 point space following each entry. There is also a .25" hanging indent for each entry. If using the Foundation template, you may highlight the text and select *References* from the Styles and Formatting menu to apply the appropriate style to text.

### **Table of Contents**

Text is set in 10 point Times New Roman, single spaced, and left aligned. There is a 3 point space above each entry. Page numbers are tabbed flush right (5.75") with leader dots. Chapter titles in the TOC are set in bold with a paragraph return before each entry. First level subheads are indented .2" from the left. Second level subheads are indented .5" from the left.

### **List of Figures and List of Tables**

Text is set in 11 point Times New Roman, single spaced, and left aligned. There is a 3 point space following each entry. Page numbers are tabbed flush right (5.75") with leader dots.

# APPENDIX

## SAMPLE PAGES

The following sample pages show how the final formatted report should look. There are two Microsoft® Word documents available from the Foundation that will help you format the report.

**WRF\_Reports\_Template.dot** – This template document has built in styles to help you format the report properly. Select *Styles and Formatting* from the *Format* menu. Highlight the text and pick a formatting style to apply.

**WRF\_Reports\_Front\_Template.doc** – This document includes sample frontmatter pages.

# **An Economic Framework for Evaluating the Benefits and Costs of Water Reuse**

*Final Project Report and User Guidance*

## **Principal Investigator**

Robert S. Raucher, Ph.D.  
*Stratus Consulting Inc.*

## **Cosponsors**

Southwest Florida Water Management District  
California State Water Resources Control Board  
United States Bureau of Reclamation  
Inland Empire Utilities Agency (CA)  
Las Vegas Valley Water District (NV)  
Santa Clara Valley Water District (CA)

## **Participating Agencies**

Dublin San Ramon Services District (CA)  
El Paso Water Utilities (TX)  
Inland Empire Utilities Agency (CA)  
Las Vegas Valley Water District (NV)  
Orange County Water District (CA)  
Phoenix Water Services Department (AZ)  
Pinellas County Utilities (FL)  
San Diego County Water Authority (CA)  
Santa Clara Valley Water District (CA)  
West and Central Basin Municipal Water Districts (CA)



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This study would not have been possible without the insights, efforts, and dedication of many individuals and organizations. These include the members of the research team and PAC members (as identified below); the WaterReuse Foundation's project manager, Josh Dickinson; many key individuals at the participating utilities and related organizations; and the outstanding editorial and production staff at Stratus Consulting (including Diane Callow, Laura Cross, and Erin Miles).

The research team would like to thank the WaterReuse Foundation for funding this applied research project, as well as the following organizations for their in-kind contributions: Dublin San Ramon Services District (CA), El Paso Water Utilities (TX), Inland Empire Utilities Agency (CA), Las Vegas Valley Water District (NV), Orange County Water District (CA), Phoenix Water Services Department (AZ), Pinellas County Utilities (FL), San Diego County Water Authority (CA), Santa Clara Valley Water District (CA), and West and Central Basin Municipal Water Districts (CA).

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Rich Mills, *State Water Resources Control Board*

Steve Piper, *United States Bureau of Reclamation*

Eric Rosenblum, *City of San Jose Environmental Services Department*

## **EXECUTIVE SUMMARY**

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### **PROJECT BACKGROUND AND OBJECTIVES**

This research report develops an economic framework that is a tool to help water agencies and other water sector professionals conduct a benefit–cost analysis (BCA) of reuse or desalination investments. The economic framework is designed to help water managers (1) identify, (2) estimate (to the degree feasible and meaningful), and (3) effectively communicate the full range of benefits associated with water reuse projects or related activities.

Having a reasonably complete recognition and accounting of the full range of benefits of a reuse or desalination project is extremely important. This is because the financial costs of building and operating a reuse or desalination facility are often relatively high (compared to the cost of using more traditional sources of water). Given the high relative costs, water agencies and water resource planning bodies may wonder whether the expense is justified—i.e., whether the benefits may outweigh the costs. They may also face difficulties obtaining support from local governing officials or customers, or need economic justification for seeking funding support (e.g., cost sharing with neighboring entities in the region, or state and federal grants or loans).

One of the key challenges in assessing whether or where the benefits of reuse outweigh the costs is that the benefits are often hard to estimate in full. Among the key reasons that benefits are hard to identify or estimate are:

1. Benefits often are very diverse in type (i.e., many types of benefits may be generated, and several may not be immediately obvious to some parties);
2. Many of the benefit types are hard to explain, and/or difficult to estimate in monetary terms (e.g., many benefits involve “nonmarket” values for ecological or recreational services); and
3. Those who receive or enjoy the benefits (i.e., the beneficiaries) often are dispersed across water agency and political jurisdictional boundaries (meaning that there often are large externalities, and these are often positive externalities rather than negative ones).

These factors can make it very difficult to justify or build public/political support for reuse or desalination projects that, in reality, often have many important net social benefits to offer. This report is intended to help agencies overcome these challenges.

### **DIFFERENCES BETWEEN FINANCIAL AND ECONOMIC ANALYSIS**

While technological advances and increased demands for water have combined to make water reuse increasingly feasible and more cost-effective, there are still several economic roadblocks to broader implementation of water reuse. One of the key challenges for reuse applications is that the financial assessment of such projects may often appear unfavorable,

## CHAPTER 2

### STATE OF KNOWLEDGE ON NDMA

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#### 2.1 BACKGROUND

Although NDMA has been a concern to the public health community for over 30 years (Mirvish, 1975; NTP, 2005), it has not been a major issue for water utilities until recently. Since the state of knowledge on NDMA in water and wastewater systems was rapidly evolving at the time of the proposal submission, the original research plan included a task to summarize recent research findings on NDMA prior to the start of the project (Task 1: Conduct a workshop to assess the state of the art on NDMA sources, fate, and control).

##### 2.1.1 Overview of NDMA

NDMA is a small, polar molecule ( $\log K_{ow} = 0.57$ ) that is highly water soluble (100 g/L at 20 °C). In the 1960s, the compound was classified as a potent class B2 (animal) carcinogen. It belongs to a family of nitrosamines with similar carcinogenic potencies (ATSDR, 1989). The chemical structure of NDMA is shown in Figure 2-1.

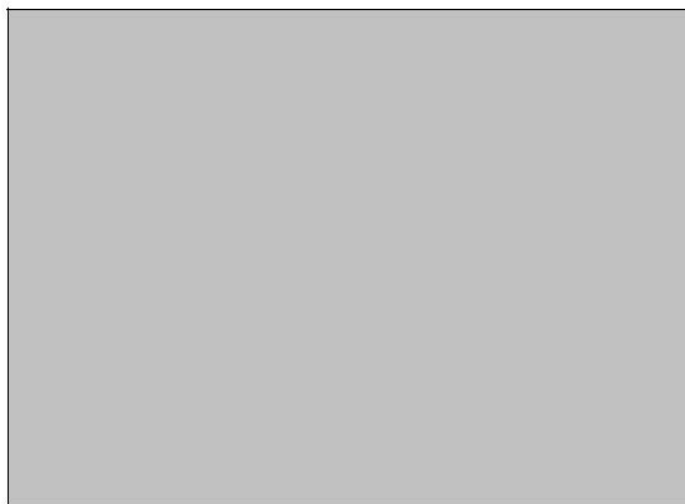
CalDHS currently (2005) has a notification level of 10 ng/L of NDMA. The notification level was referred to as an action level prior to 2005. The Ontario Ministry of the Environment and Energy in Canada has set an interim standard of 9 ng/L of NDMA in drinking water. While the United States Environmental Protection Agency (U.S. EPA) has not yet developed a maximum contaminant level (MCL) and has not listed NDMA as a candidate for MCL development, U.S. EPA risk assessment results estimate that the  $10^{-6}$  cancer risk to humans corresponds to 0.7 ng/L of NDMA in drinking water (U.S. EPA, 1991). U.S. EPA has set low clean-up levels for NDMA at hazardous waste sites such as Aerojet, Rancho Cordova, CA (2 ng/L) (U.S. EPA, 2001). U.S. EPA has also designated NDMA as a priority toxic pollutant for inland surface waters and enclosed bays and estuaries in California with implications for utility monitoring programs (CFR, 2000).

##### 2.1.1.1 Impacts of NDMA on Water Recycling

Controlling NDMA concentrations in wastewater effluent is a significant concern for utilities practicing indirect potable water reuse, especially in California. In May 2000, two wells operated by the Orange County Water District (OCWD) were shut down due to the detection of 30 to 40 ng/L of NDMA associated with nearby reinjection of water produced by OCWD's advanced treatment plant. Also in 2000, the Sanitation Districts of Los Angeles County (LACSD) detected 30 to 90 ng/L of NDMA in wastewater effluent prior to blending and discharge to an infiltration basin used to recharge groundwater. In the city of San Jose, CA, plans to construct a nonpotable water reuse pipeline to deliver water to a proposed power plant were temporarily stopped by a lawsuit alleging that NDMA in the irrigation water had the potential to percolate into groundwater and contaminate the aquifer (Rosenbaum, 2001). The presence of NDMA in wastewater effluent has increased the level of uncertainty among utilities with ongoing water reuse projects.



**Figure 2-2. Typical NDMA concentrations in surface water sources and waste waters as shown in repeated tests.**



**Figure 2-2. Typical NDMA concentrations in surface water.**

In contrast, secondary wastewater effluent typically contains 10 to 1000 ng/L of NDMA, up to two orders of magnitude higher than surface water. Even after advanced treatment, such as microfiltration (MF) followed by reverse osmosis (RO) and/or UV disinfection, treated and chlorinated wastewater commonly contains between 10 and 100 ng/L of NDMA, well above California's notification level (West Basin, unpublished data).

**Table 3.4. Summary of NDMA and NDMA Precursors Measured in Residential and Industrial Sources**

<b>Location</b>	<b>Location Description</b>	<b>NDMA, ng/L</b>	<b>NDMA Precursors, ng/L</b>	<b>DMA, µg/L</b>
Domestic Wastewater	Trunkline	40	8150	77
Cirtech Industry (Non-DTC Process)	Industrial wastewater	29	1570	7
Pioneer Circuit (DTC Process)	Industrial wastewater	4230	82,500	1242

<sup>a</sup>The Whittier Narrows and San Jose Creek West WWTPs were operated by the LACSD.

<sup>b</sup>Value represents the design flow for secondary treatment. The OCSD's Plant 1 WWTP has a design flow of 4.7 m<sup>3</sup>/s for primary treatment, and the OCSD's Plant 2 WWTP has a design flow of 7.3 m<sup>3</sup>/s for primary treatment. Primary effluent from both WWTPs was discharged through an ocean outfall.

High NDMA concentrations in wastewater effluent are of concern due to the potential for NDMA to enter drinking water supplies during intentional or unintentional potable water reuse. Indirect potable water reuse has become the leading source of new water resources in many regions with fully allocated freshwater supplies (Recycled Water Task Force, 2003). Currently, California has one of the most extensive water reuse programs in the world. California reuses 19.5 m<sup>3</sup>/s (0.5 million acre ft/year) through planned water reuse projects (Recycled Water Task Force, 2003). This is equivalent to approximately 10% of the total annual volume of municipal wastewater effluent in California (Recycled Water Task Force, 2003). Primary uses of this water include agricultural irrigation (48%), landscape irrigation (20%), groundwater replenishment (12%), industrial supply (5%), seawater intrusion barriers (3%), and other uses (12%). California has the potential to increase water recycling to a total of 1.5 million acre ft/year by 2030 at an estimated cost of \$11 billion (2000 \$) (Recycled Water Task Force, 2003).

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