

State of California  
California Natural Resources Agency  
DEPARTMENT OF WATER RESOURCES

# Methodology for Flow and Salinity Estimates in the Sacramento-San Joaquin Delta and Suisun Marsh



33<sup>rd</sup> Annual Progress Report to the  
State Water Resources Control Board in  
Accordance with Water Right Decisions 1485 and 1641

**June 2012**

**Edmund G. Brown Jr.**  
Governor  
State of California

**John Laird**  
Secretary for Natural Resources  
Natural Resources Agency

**Mark W. Cowin**  
Director  
Department of Water Resources

If you need this publication in an alternate form, contact the Public Affairs Office,  
1-800-272-8869.

## Foreword

This is the 33rd annual progress report of the California Department of Water Resources' San Francisco Bay-Delta Evaluation Program, which is carried out by the Delta Modeling Section. This report is submitted annually by the section to the California State Water Resources Control Board pursuant to its Water Right Decision 1485, Term 9, which is still active pursuant to its Water Right Decision 1641, Term 8.

This report documents progress in the development and enhancement of the Bay-Delta Office's Delta Modeling Section's computer models and reports the latest findings of studies conducted as part of the program. This report was compiled under the direction of Tara Smith, program manager for the Bay-Delta Evaluation Program.

Online versions of previous annual progress reports are available at:

<http://baydeltaoffice.water.ca.gov/modeling/deltamodeling/annualreports.cfm>.

For more information contact:

Tara Smith

[tara@water.ca.gov](mailto:tara@water.ca.gov)

(916) 653-9885

Page left blank for two-sided printing

State of California  
**Edmund G. Brown Jr., Governor**  
California Natural Resources Agency  
**John Laird, Secretary for Natural Resources**  
Department of Water Resources  
**Mark W. Cowin, Director**  
**Dale Hoffman-Floerke, Chief Deputy Director**

Office of the Chief Counsel  
Cathy Crothers

Public Affairs Office  
Nancy Vogel, , Ass't Dir.

Security Operations  
Sonny Fong

Gov't & Community Liaison  
Kimberly Johnston-Dodds

Policy Advisor  
Waiman Yip

Legislative Affairs Office  
Kasey Schimke, Ass't Dir.

*Deputy Directors*

**Russell Stein, acting**

Assistant to Deputy Director: B Harrell

**Delta and Statewide Water Management**

**Gary Bardini**

Assistant to Deputy Director: D Uding and J Marr; Assistant Deputy Director J Andrew, Climate Change

**Integrated Water Management**

**Carl Torgersen, acting**

Assistant to Deputy Director: D Adachi, P Lecocq, and G Scholl; Assistant Deputy Director M Anderson

**State Water Project**

**John Pacheco, acting**

Assistant to Deputy Director R Grix

**California Energy Resources Scheduling**

**Kathie Kishaba**

Assistant to Deputy Director J Cole

**Business Operations**

Bay Delta Office

**Katherine Kelly, Chief**

Modeling Support Branch

**Francis Chung, Chief**

Delta Modeling Section

**Tara Smith, Chief**

Edited by

**Ralph Finch, Bay Delta Office**

See individual chapters for author names

**Editorial review, graphics, and report production**

Supervisor of Technical Publications Patricia Cornelius

Marilee Talley, research writer

## Report Contents

<b>Foreword</b> .....	<b>iii</b>
<b>Preface</b> .....	<b>xiii</b>
<b>Acronyms and Abbreviations</b> .....	<b>xv</b>
<b>Metric Conversion Table</b> .....	<b>xvi</b>
<b>1 Monitoring Station Locations</b> .....	<b>1-1</b>
1.1 Introduction .....	1-1
1.2 Procedure.....	1-1
1.3 Conclusion .....	1-6
Appendix ArcPy Script.....	1-7
<b>Figure</b>	
Figure 1-1 Sacramento-San Joaquin Legal Delta, DSM2 Channels, and CDEC Stations.....	1-3
<b>Tables</b>	
Table 1-1 Partial List of Stations and Station-Lists near Measured Stations .....	1-2
Table 1-2 Station-Lists and Counts.....	1-4
Table 1-3 Partial List of Stations and Station-Lists near Measured Stations, Sorted by Station-List.....	1-4
Table 1-4 Proportion of Stations near Measured Stations .....	1-5
Table 1-5 Partial Water Quality List and nearby Stations in Surface Water List.....	1-5
<b>2 Improved Geometry Interpolation in DSM2-Hydro</b> .....	<b>2-1</b>
2.1 Introduction .....	2-1
2.2 Hydro Geometry Setup and Channel Cross Section Interpolation Methods.....	2-1
2.3 Improvement in Spatial Integration .....	2-5
2.4 Model State at the Midpoint of a Computational Reach .....	2-6
2.5 Summary of Modifications.....	2-7
2.6 References .....	2-7
<b>Figures</b>	
Figure 2-1 Computational Grid for a Fictional Channel Connecting Nodes ‘1’ and ‘2’ .....	2-1
Figure 2-2 A Map of User Input Cross Sections of Channel 445 in Suisun Marsh.....	2-3
Figure 2-3 Virtual Cross Section Locations at Computational Points and Midpoint.....	2-4
Figure 2-4 Illustration of Height-based Cross Section Interpolation .....	2-4
Figure 2-5 Illustration of Elevation-based Cross Section Interpolation .....	2-5
Figure 2-6 Illustration of a Poor Area Calculation .....	2-6

<b>3 DSM2 Version 8.1 Recalibration.....</b>	<b>3-1</b>
3.1 Introduction .....	3-1
3.2 Hydro Recalibration Results.....	3-1
3.3 EC Recalibration Results .....	3-16
3.4 Summary .....	3-24
3.5 References .....	3-24

### Figures

Figure 3-1 Stations for Hydro Calibration .....	3-3
Figure 3-2 Hydro Calibration, Sacramento River at Freeport .....	3-4
Figure 3-3 Hydro Calibration, Sacramento River above Delta Cross Channel .....	3-5
Figure 3-4 Hydro Calibration, Sacramento River downstream of Georgiana Slough .....	3-6
Figure 3-5 Hydro Calibration, Sacramento River at Rio Vista .....	3-7
Figure 3-6 Hydro Calibration, San Joaquin River at Jersey Point .....	3-8
Figure 3-7 Hydro Calibration, San Joaquin River at Stockton .....	3-9
Figure 3-8 Hydro Calibration, Old River at Bacon Island.....	3-10
Figure 3-9 Hydro Calibration, Old River near Byron .....	3-11
Figure 3-10 Hydro Calibration, Three Mile Slough at SJR .....	3-12
Figure 3-11 Hydro Calibration, Georgiana Slough.....	3-13
Figure 3-12 Hydro Calibration, Delta Cross Channel.....	3-14
Figure 3-13 Hydro Calibration, Grant Line Canal at Tracy Boulevard Bridge .....	3-15
Figure 3-14 Key EC Comparison Stations .....	3-17
Figure 3-15 Qual Model Performance of EC, Sacramento River at Emmaton .....	3-18
Figure 3-16 Qual Model Performance of EC, Sacramento River at Collinsville.....	3-19
Figure 3-17 Qual Model Performance of EC, San Joaquin River at Jersey Point.....	3-20
Figure 3-18 Qual Model Performance of EC, Old River at Bacon Island .....	3-21
Figure 3-19 Qual Model Performance of EC, Clifton Court Forebay.....	3-22
Figure 3-20 Qual Model Performance of EC, Montezuma Slough at Beldons Landing .....	3-23

### Table

Table 3-1 Recalibrated Manning's Coefficient.....	3-2
---	-----

<b>4 South Delta Null Zone Study .....</b>	<b>4-1</b>
4.1 Background .....	4-1
4.2 Purpose .....	4-1
4.3 Modeling Analysis Approach .....	4-2
4.3.1 Modeling Scenarios .....	4-2
4.3.2 Modeling Assumptions and Considerations .....	4-3
4.3.3 Simulation Periods .....	4-4
4.3.4 Model Results Interpretation.....	4-4
4.4 Results and Findings.....	4-5
4.4.1 Flow .....	4-5
4.4.2 Stage .....	4-10
4.5 Conclusions .....	4-18
4.6 References .....	4-18

## Figures

Figure 4-1 South Delta .....	4-1
Figure 4-2 Process of DSM2 Modeling Analysis.....	4-2
Figure 4-3 Condition 1 of Assumed Null Zone Definition.....	4-3
Figure 4-4 Condition 2 of Assumed Null Zone Definition.....	4-3
Figure 4-5 South Delta Channels included in Null Zone Assessment (Highlighted Area) .....	4-4
Figure 4-6 Model Results of Null Zone Occurrence for NO_CVP_SWP_BARRIERS and NO_BARRIERS Scenario (January 1990 to December 2010).....	4-6
Figure 4-7 Model Results of Null Zone Occurrence for NO_CVP_SWP_BARRIERS and HISTORICAL Scenario (January 1990 to December 2010).....	4-7
Figure 4-8 Model Results of Null Zone Occurrence for NO_CVP_SWP_BARRIERS and NO_BARRIERS Scenario for July Only (1990 to 2010).....	4-8
Figure 4-9 Model Results of Null Zone Occurrence for NO_CVP_SWP_BARRIERS and HISTORICAL Scenario for July Only (1990 to 2010).....	4-9
Figure 4-10 Locations of Stage Assessment in South Delta .....	4-10
Figure 4-11 Daily Minimum Stage Results for the Entire 21 Years (1990 to 2010).....	4-11
Figure 4-12 Daily Minimum Stage Results for July Only (1990 to 2010).....	4-15

## Table

Table 4-1 Summary of Modeling Scenarios.....	4-3
--	-----



<b>5</b>	<b>Estimating Delta-wide Bromide Using DSM2-Simulated EC Fingerprints .....</b>	<b>5-1</b>
5.1	Introduction .....	5-1
5.2	Background .....	5-2
5.3	Directly Simulating Delta Bromide.....	5-3
5.4	Estimating Historical Bromide Based on Simulated EC .....	5-5
5.5	Comparison of Direct Bromide Simulation and Delta-wide Regression.....	5-9
5.6	Comparison of Performance of Different Methods in Estimating Bromide.....	5-22
5.7	Conclusions .....	5-24
5.8	References .....	5-24

### Figures

Figure 5-1	Martinez Regression Used for Converting from EC to Bromide .....	5-3
Figure 5-2	Sacramento River Boundary Regression Used for Converting from EC to Bromide.....	5-4
Figure 5-3	San Joaquin River Boundary Regression Used for Converting from EC to Bromide.....	5-4
Figure 5-4	Bromide Assumed for Agricultural Drainage by Region .....	5-5
Figure 5-5	Illustration of Change of Bromide Concentration with Change of Water Sources.....	5-6
Figure 5-6	Grab Sample Locations and Groupings for Derivation of Regressions .....	5-8
Figure 5-7	Comparison of Grab Sample Data and Calculated Bromide Concentration at Sacramento River at Mallard Island (four figures total).....	5-10
Figure 5-8	Comparison of Grab Sample Data and Calculated Bromide Concentration at Banks Pumping Plant (four figures total).....	5-12
Figure 5-9	Comparison of Grab Sample Data and Calculated Bromide Concentration at Jones Pumping Plant (four figures total).....	5-14
Figure 5-10	Comparison of Grab Sample Data and Calculated Bromide Concentration in Old River at Bacon Island (four figures total) .....	5-16
Figure 5-11	Comparison of Grab Sample Data and Calculated Bromide Concentration in Old River near Highway 4 Bridge (four figures total).....	5-18
Figure 5-12	Comparison of Grab Sample Data and Calculated Bromide Concentration at Contra Costa Pumping Plant 1 (four figures total) .....	5-20

### Tables

Table 5-1	Methods to Determine Bromide Concentrations .....	5-1
Table 5-2	Comparison of Performance of Different Methods in Estimating Bromide .....	5-23

<b>6</b>	<b>A Continuous Surface Elevation Map for Modeling .....</b>	<b>6-1</b>
6.1	Introduction .....	6-1
6.2	Data Sources .....	6-2
6.3	Methodology Overview .....	6-5
6.4	10 m Base Map .....	6-5
	6.4.1 <i>Prioritization of Core Data and Supplemental Data Sets</i> .....	6-5
	6.4.2 <i>Filling at 10 m and Missing Values</i> .....	6-6
	6.4.3 <i>Transitions between Data Sources</i> .....	6-6
	6.4.4 <i>Orthogonal Levee Reinforcement</i> .....	6-6
6.5	High Resolution Model .....	6-7
	6.5.1 <i>Gaps</i> .....	6-8
6.6	Fine-coarse Transitions .....	6-15
6.7	Time and Spatial Sampling .....	6-17
6.8	Summary and Conclusions.....	6-21
6.9	References .....	6-22

## Figures

Figure 6-1	Cross Section Profile near BNSF Railway Bridge .....	6-1
Figure 6-2	Data Sources for Version 1.0 of the 10 m DEM .....	6-3
Figure 6-3	Data Sources Being Added for Version 2.0 of Elevation Model.....	6-4
Figure 6-4	Preparation of 10 m DEM .....	6-5
Figure 6-5	Examples of False Numerical ‘Leaks’ in Levee Elevation Models .....	6-7
Figure 6-6	Example of Simple Gaps.....	6-9
Figure 6-7	Comparison of Interpolation Techniques on Simple Gap.....	6-10
Figure 6-8	Delineation of an Inhabited Island Using Bounds of a Polygon as a Hard Constraint .....	6-11
Figure 6-9	Cross Section Profiles with and without Island Enforcement.....	6-12
Figure 6-10	Complex Shallows near BNSF Railroad Bridge Crossing Middle River near Bullfrog Marina .....	6-13
Figure 6-11	Shallow Horseshoe Bend on Middle River North of Bullfrog Marina (top) and Close-up of Southern Part of Bend where Interpolation was Compared (bottom).....	6-14
Figure 6-12	Example of Vertical Cross Sections with Supporting Data.....	6-15
Figure 6-13	Example of Fine-coarse Transitions .....	6-16
Figure 6-14	Result of Stitching and Smoothing Discontinuity at 10 m .....	6-16
Figure 6-15	Evolution of Channel Bedforms over 3 Data Collections in 2010 and 2011 .....	6-17
Figure 6-16	Longitudinal Profile (top) and Lateral Profile for 2 m DEM Derived from Terrain Using Different Window Sizes.....	6-19
Figure 6-17	Longitudinal Profile (top) and Lateral Profile Generated from Different Resolution DEMs Using Same Proportional Window Size.....	6-20

<b>7 DSM2-PTM Simulations of Particle Movement .....</b>	<b>7-1</b>
7.1 Summary .....	7-1
7.2 Study Scenario Determination and Modeling Configuration .....	7-1
7.2.1 Hydrodynamic Boundary and Source Flows Configuration .....	7-1
7.2.2 Operable Barrier and Gate Configuration .....	7-3
7.2.3 Hydrodynamic Scenario Configuration .....	7-4
7.2.4 DSM2-PTM Configuration .....	7-5
7.3 Sacramento River Flow Sensitivity Test .....	7-9
7.3.1 Simulation Configuration .....	7-9
7.3.2 Result Summary .....	7-10
7.4 Hydrodynamic Scenario Results and Analysis .....	7-11
7.4.1 Old and Middle River (OMR) .....	7-11
7.4.2 Flow Splits at San Joaquin River Junctions to South Delta .....	7-14
7.5 PTM Scenarios Results and Analysis .....	7-19
7.5.1 Particle Fate Comparison for PTM Standard Boundary Outputs .....	7-19
7.5.2 HORB IN-OUT Difference of Particle Flux at Martinez .....	7-20
7.5.3 Particle Flux Split at San Joaquin River Junctions to Southward Branch .....	7-24
7.6 Conclusions .....	7-29
7.7 Acknowledgments .....	7-29
7.8 References .....	7-29
Appendixes A-1 through D-6 .....	7-30

## Figures

Figure 7-1 Delta Boundaries Showing Flows (blue circles) and Temporary Barriers and Gates (purple circles) .....	7-2
Figure 7-2 Priority 3 Operation Rule .....	7-4
Figure 7-3 PTM Particle Insertion Locations (purple circles) .....	7-7
Figure 7-4 Stage at Martinez at Station RSAC054 .....	7-9
Figure 7-5 San Joaquin River Flow at Station RSAN112 .....	7-9
Figure 7-6 OMR and its HORB IN-OUT Difference for sjr_ie Scenarios .....	7-12
Figure 7-7 Export and IE Ratios and Their HORB IN-OUT Difference for sjr_omr Scenarios .....	7-14
Figure 7-8 Flow Directions (red arrows) of Channels around ROLD for sjr1500_ie11 Scenario .....	7-16
Figure 7-9 HORB IN-OUT Difference of Martinez Particle Flux Fate at 45-day's End for sjr_ie Scenarios .....	7-22
Figure 7-10 HORB IN-OUT Difference of Martinez Particle Flux Fate at 45-day's End for sjr_omr Scenarios .....	7-23

## Tables

Table 7-1 Monthly Average of San Joaquin and Sacramento River Flows in May, 1990 to 2010.....	7-1
Table 7-2 DSM2-HYDRO Configuration for the Delta Boundaries and Source Flows .....	7-3
Table 7-3 Facilities Configuration for the Delta Temporary Barriers and Important Gates .....	7-4
Table 7-4 Simulation Hydro Combinations of sjr_ie Scenarios and sjr_omr Scenarios .....	7-5
Table 7-5 PTM Particle Insertion Location Scenarios.....	7-5
Table 7-6 PTM Flux Output Groups and Specification .....	7-8
Table 7-7 HYDRO Configuration for SAC R. Sensitivity Analysis.....	7-10
Table 7-8 Locations Required for OMR Calculation in DSM2 Grid.....	7-11
Table 7-9 Hydro Conditions for sjr_ie Scenarios.....	7-12
Table 7-10 Hydro Conditions for sjr_omr Scenario.....	7-13
Table 7-11 Average Flow (cfs) Range (min, max) for SJR Junctions in sje_omr Scenarios.....	7-17
Table 7-12 Average Flow Variation Pattern with SJR Flow Increasing for SJR Junctions in sjr_omr Scenarios.....	7-17
Table 7-13 Average Flow Variation Pattern with OMR Increasing for SJR Junctions in sjr_omr Scenarios.....	7-18
Table 7-14 Particle Fates' Ranges (min, max) of PTM Standard Outputs at 45-days' End for sjr_omr Scenarios, Unit %.....	7-21
Table 7-15 Particle Fates' Variation Patterns of PTM Standard Outputs with OMR and SJR Flow for sjr_omr Scenario .....	7-21
Table 7-16 HORB IN-OUT Difference of Martinez Particle Flux Fate at 45-day's End for sjr_ie Scenarios .....	7-22
Table 7-17 HORB IN-OUT Difference of Martinez Particle Flux Fate at 45-day's End for sjr_omr Scenarios.....	7-23
Table 7-18 Particle Fate Ranges (min, max) at 45-day's End at SJR Junctions for sjr_omr Scenarios, Unit %.....	7-26
Table 7-19 Variation Pattern of Particle Fate (45-days' end) with SJR Flow Increasing at SJR Junctions for sjr_omr Scenarios .....	7-27
Table 7-20 Variation Pattern of Particle Fate (45-days' end) with OMR Increasing at SJR Junctions for sjr_omr Scenarios.....	7-28

## **Preface**

### **Chapter 1 Monitoring Station Locations**

The authors compared several lists of purported accurate measurement station locations and conducted field measurements of some sites. The lists were analyzed using ESRI products and a script in ArcPython. This chapter describes and summarizes the analysis.

### **Chapter 2 Improved Geometry Interpolation in DSM2-Hydro**

This chapter documents modifications to the DSM2 Delta modeling program that improve the model's internal representation of bathymetry under conditions typical of the Sacramento-San Joaquin River Delta. The authors implemented a more accurate channel cross-sectional calculation scheme based on absolute elevation and also increased the density of geometry samples (number of quadrature points) used when calculating integral quantities such as volume.

### **Chapter 3 DSM2 Version 8.1 Recalibration**

Modifications to the DSM2 program source code that improve channel geometry representation described in Chapter 2 of this report affects results both in DSM2-Hydro and DSM2-Qual. The model has been recalibrated by adjusting Manning's coefficient values in DSM2-Hydro. The recalibrated Hydro results (flow and stage) are very close to the Bay Delta Conservation Plan (BDCP) 2009 Calibration results, although there are significant changes in Manning's coefficient values. Qual was recalibrated in 2011 after changes to improve DSM2-Qual model convergence. Using the recently recalibrated Hydro, we reran the Qual module to check the impacts of the Hydro source code changes and the Hydro recalibration on EC results. The electrical conductivity results are compared with field data and also the 2009 BDCP Calibration results.

### **Chapter 4 South Delta Null Zone Study**

The State Water Resources Control Board (SWRCB) is in the process of reviewing and updating the 2006 Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary (Bay-Delta Plan). The review may result in the potential amendments to the South Delta salinity objectives in the Bay-Delta Plan. Under the review process, SWRCB states that poor water circulation (null zones) contributes to bad water quality in the South Delta, and that the Central Valley Project (CVP) and State Water Project (SWP) are responsible for improving the water circulation conditions while raising water stage so that the farmers are able to divert water.

The purpose of this study is to analyze through hydrodynamic modeling whether and to what extent CVP and SWP exports and the agricultural temporary barrier actually influence the water levels (stage) and water circulation in South Delta.

### **Chapter 5 Estimating Delta-wide Bromide Using DSM2-Simulated EC Fingerprints**

This chapter compares 6 methods to determine bromide concentrations at select locations in the Sacramento-San Joaquin River Delta (the Delta). The results of the methods are compared to observed grab sample bromide data at those Delta locations. The analysis confirms MWH's conclusion that direct simulation of bromide with DSM2 and the current version of dispersion coefficients is equivalent to estimating bromide based on DSM2-simulated electrical conductivity (EC) and applying multiple linear regressions based on simulated EC fingerprints. However, using observed EC and multiple linear regressions provides significantly better estimates of bromide. Multiple linear regressions based on

Delta regions perform nearly as well as site-specific regressions and allow for converting from EC to bromide at nearly any location in the Delta.

### **Chapter 6 A Continuous Surface Elevation Map for Modeling**

This chapter documents the development of an elevation data set for multidimensional modeling developed under the REALM project, synthesizing LiDAR, single- and multibeam sonar soundings and surveys and integrating them with existing integrated maps that themselves were collated from multiple sources. The result is a continuous surface—terrestrial and water—in meters using the NAVD88 vertical datum. The initial release of this map was in the form of a 10 m Digital Elevation Map (DEM) for the entire Bay-Delta and parts of the coast to the Farallones, supplemented by a 2 m model of the South Delta in a region where the channel features are poorly resolved at 10 m.

### **Chapter 7 DSM2-PTM Simulations of Particle Movement**

The National Marine Fisheries Service requested the California Department of Water Resources Modeling Support Branch perform a DSM2-PTM modeling study to investigate the impact of various factors on salmon/steelhead migration behaviors in the Sacramento-San Joaquin River Delta. Those factors include San Joaquin River flows, exports from the State Water Project and Central Valley Project, and the Head of Old River Barrier (HORB). The report documents the assumptions, model setups, and simulation results and could be used to help studies on HORB installation/operation and export adaptive management for salmonid outmigration protections.

## Acronyms and Abbreviations

Bay-Delta Plan	2006 Water Quality Control Plan for the San Francisco Bay/San Joaquin Delta Estuary
BDCP	Bay Delta Conservation Plan
BNSF	Burlington Northern Santa Fe Railway
Br	bromide
CDEC	California Data Exchange Center
cfs	cubic feet per second
CLFCT	Clifton Court Forebay Gates
CVP	Central Valley Project
DC	dispersion coefficient
DCC	Delta Cross Channel
Delta	Sacramento-San Joaquin River Delta
DEM	Digital Elevation Map
DSM2	Delta Simulation Model 2
DWR	California Department of Water Resources
EC	electrical conductivity
GIS	Geographical Information System
GLCB	Grant Line Canal Barrier
HORB	Head of Old River Barrier
IE ratio	inflow/export ratio
Marsh	Suisun Marsh
MIDB	Middle River Barrier
MTZSL	Montezuma Salinity Control Structure
NED	National Elevation Dataset
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
N-S	Nash-Sutcliffe
OMR	Old and Middle River
ORTB	Old River Barrier at Tracy
PTM	Particle Tracking Model
RPA	Reasonable Prudent Alternative
SAC R.	Sacramento River
SJR	San Joaquin River
SWP	State Water Project
SWRCB	State Water Resources Control Board
TDS	total dissolved solids
USBR	US Bureau of Reclamation
USGS	US Geological Survey
WDL	Water Data Library

## Metric Conversion Table

<i>Quantity</i>	<i>To Convert from Metric Unit</i>	<i>To Customary Unit</i>	<i>Multiply Metric Unit By</i>	<i>To Convert to Metric Unit Multiply Customary Unit By</i>
Length	millimeters (mm)	inches (in)	0.03937	25.4
	centimeters (cm) for snow depth	inches (in)	0.3937	2.54
	meters (m)	feet (ft)	3.2808	0.3048
	kilometers (km)	miles (mi)	0.62139	1.6093
Area	square millimeters (mm <sup>2</sup> )	square inches (in <sup>2</sup> )	0.00155	645.16
	square meters (m <sup>2</sup> )	square feet (ft <sup>2</sup> )	10.764	0.092903
	hectares (ha)	acres (ac)	2.4710	0.40469
	square kilometers (km <sup>2</sup> )	square miles (mi <sup>2</sup> )	0.3861	2.590
Volume	liters (L)	gallons (gal)	0.26417	3.7854
	megaliters (ML)	million gallons (10*)	0.26417	3.7854
	cubic meters (m <sup>3</sup> )	cubic feet (ft <sup>3</sup> )	35.315	0.028317
	cubic meters (m <sup>3</sup> )	cubic yards (yd <sup>3</sup> )	1.308	0.76455
	cubic dekameters (dam <sup>3</sup> )	acre-feet (ac-ft)	0.8107	1.2335
Flow	cubic meters per second (m <sup>3</sup> /s)	cubic feet per second (ft <sup>3</sup> /s)	35.315	0.028317
	liters per minute (L/mn)	gallons per minute (gal/mn)	0.26417	3.7854
	liters per day (L/day)	gallons per day (gal/day)	0.26417	3.7854
	megaliters per day (ML/day)	million gallons per day (mgd)	0.26417	3.7854
	cubic dekameters per day (dam <sup>3</sup> /day)	acre-feet per day (ac-ft/day)	0.8107	1.2335
Mass	kilograms (kg)	pounds (lbs)	2.2046	0.45359
	megagrams (Mg)	tons (short, 2,000 lb.)	1.1023	0.90718
Velocity	meters per second (m/s)	feet per second (ft/s)	3.2808	0.3048
Power	kilowatts (kW)	horsepower (hp)	1.3405	0.746
Pressure	kilopascals (kPa)	pounds per square inch (psi)	0.14505	6.8948
	kilopascals (kPa)	feet head of water	0.32456	2.989
Specific capacity	liters per minute per meter drawdown	gallons per minute per foot drawdown	0.08052	12.419
Concentration	milligrams per liter (mg/L)	parts per million (ppm)	1.0	1.0
Electrical conductivity	microsiemens per centimeter (μS/cm)	micromhos per centimeter (μmhos/cm)	1.0	1.0
Temperature	degrees Celsius (°C)	degrees Fahrenheit (°F)	(1.8X°C)+32	0.56(°F-32)