# SMALL WATER SYSTEM OPERATION AND MAINTENANCE COURSE OUTLINE

<table>
<thead>
<tr>
<th>Chapter</th>
<th>Topic</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>THE SMALL WATER SYSTEM OPERATOR</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>WATER SOURCES AND TREATMENT</td>
<td>13</td>
</tr>
<tr>
<td>3</td>
<td>WELLS</td>
<td>39</td>
</tr>
<tr>
<td>4</td>
<td>SMALL WATER TREATMENT PLANTS</td>
<td>183</td>
</tr>
<tr>
<td>5</td>
<td>DISINFECTION</td>
<td>279</td>
</tr>
<tr>
<td>6</td>
<td>SAFETY</td>
<td>353</td>
</tr>
<tr>
<td>7</td>
<td>LABORATORY PROCEDURES</td>
<td>433</td>
</tr>
<tr>
<td>8</td>
<td>SETTING WATER RATES AND SYSTEM SECURITY FOR SMALL WATER UTILITIES</td>
<td>519</td>
</tr>
</tbody>
</table>

**Appendix**

- COMPREHENSIVE REVIEW QUESTIONS AND SUGGESTED ANSWERS .......... 565
- HOW TO SOLVE SMALL WATER SYSTEM ARITHMETIC PROBLEMS .............. 589
- WATER ABBREVIATIONS .................................................. 633
- WATER WORDS ...................................................................... 635
- SUBJECT INDEX .................................................................... 711
SUBJECT INDEX

A

ADA (Americans with Disabilities Act), traffic control, 412
ADT (average daily traffic), 388
Abandoning wells, 69, 180, 181, 378
Absorption, 233
Accidents, 363, 366, 367, 416, 461, 462
Acid rain, 23
Acid treatment of wells, 97–100
Acids, safety, 366, 376, 459, 460
Administration
  contaminated water supply, 552
  contingency planning, 549
  emergency response, 549–558
  operator’s duties, 8
  planning for emergencies, 549
Administrative expenses, 529, 533, 534, 537, 543
Adsorption, 211
Aeration, 264
Agents, disinfection, 295
Agricultural drainage systems, 23, 26, 29
Air blow test method, wells, 169
Air chargers, wells, 88–91
Air gap, 86
Air lines, wells, 77, 79
Air pressure pump, 452
Air release valve, wells, 77, 79, 80, 87
Air rotary drilling, wells, 153
Air-lift pumps, 104
Algae counts, 514
Algal blooms, 26, 30
Algae, 494
Alkalinity, 197, 473
Alluvial, 119, 149
Alum, 197
Americans with Disabilities Act (ADA), traffic control, 412
Ammonia, 294, 297, 304
Ammonia solution, 331
Amperometric titration, 335, 476
Analytical balance, 453
Annual report, 546
Annular grout seal, wells, 162
Annular space, 182, 153
Anthracite, 213
Appropriative rights, 24
Aquifers, 63, 64, 65
Arithmetic assignment, 35, 136, 273, 348, 514
Also see Calculations:
  Arrow panels, traffic control, 408
  Artesian wells, 25, 27
  As-built plans (record drawings), 7
  Assessment of system vulnerability, 549
  Automatic sampling, 467
  Auxiliary power, 127, 129
  Available chlorine, 100
  Average daily traffic (ADT), 388
  Awareness, safety, 363
  Backflow prevention, 86, 270
  Backwash, 214–219
  filtration, 214–219
  softening, 267
  Bacteria, 220, 291
  disinfection, 220, 291
  heterotrophic, 304
  Bacteriological analysis, 334
  Bailing test method, wells, 169
  Balance, analytical, 453
  Barricades, traffic control, 404, 406
  Base costs, 536
  Base-extra capacity method, 536
  Bases, 296
  disinfection, 296
  laboratory, safety, 460
  Battery, charging, 365
  Beakers, 447, 456
  Bicycle safety, traffic control, 412
  Bill-frequency analysis, 540
  Biofouling, wells, 94
  Blowoff, wells, 77, 80
  Boats, safety, 365
  Boils, 217
  Bonds, 530, 532
  Bored wells, 149, 150
  Bottles, lab, 448
  Bowls, pump, wells, 104, 156
  Brake horsepower, 105
  Breakpoint chlorination, 224, 225, 300–303, 480, 482
  Breakthrough, 214, 216
  Brine disposal, 268
  Brine stage, 267
  Bromine, disinfection, 296
Bruises, injury, 459
Budget preparation, 527, 545
Budgets, operator responsibility, 8
Buffer, 485
Buffer capacity, 299
Bulb, pipet, 452
Bunsen burner, 451
Burets, 448, 455
Burns, laboratory, 459, 462

C

Calibration of feeders, 200
Capital costs, 530, 534, 536, 538
Capital improvement program, 531
Carbon monoxide, safety, 367
Carelessness, 364
Cash basis, 534
Cash flow, 530
Cash reserve, 530
Casing, wells, 77, 156, 157
Cathodic protection, 238
Caustics, 460
Cave-ins, 416
Centrifugal pumps, uses, 104
Certification
examinations, 11
operator, 8, 269
responsible, 8
Channelizing devices, traffic control, 404
Check valves, 82, 83, 84
Chemical
disinfection, 296
feeders, 199–202
names, 446
safety, 576
solution preparation, 457
solutions, 457
storage, 461
treatment, corrosion, 232
use and handling, 459
CHEMTREC [(800) 424-9300], 341, 550
Chloramination, 304, 305
Chloramines, 222, 223, 225, 299, 300, 304
Chloride, 514
Chlorinated hydrocarbons, 31
Chlorination
Also see Chlorinators, Disinfection, and Hypochlorinators
amperometric titration, 335, 476
bacteriological analysis, 334
CT values, 223, 335
Also see WATER TREATMENT PLANT OPERATION,
Volume II, Appendix, "How to Solve Water Treatment
Plant Arithmetic Problems"
Cable-tool drilling, wells, 149, 152, 156
Caisson, wells, 153
Calcium carbonate equivalent, 196, 473, 505
Calcium hypochlorite, 220
Calcium test, 514
Calculations
chlorinators, 333
coupling, 200
filtration, 217
hypochlorinators, 329, 344
pump efficiency, 172
sedimentation, 206
wells, 115, 172
Calibration of feeders, 200
Capital costs, 530, 534, 536, 538
Capital improvement program, 531
Carbon monoxide, safety, 367
Carelessness, 364
Cash basis, 534
Cash flow, 530
Cash reserve, 530
Casing, wells, 77, 156, 157
Cathodic protection, 238
Caustics, 460
Cave-ins, 416
Centrifugal pumps, uses, 104
Certification
examinations, 11
operator, 8, 269
responsible, 8
Channelizing devices, traffic control, 404
Check valves, 82, 83, 84
Chemical
disinfection, 296
feeders, 199–202
names, 446
safety, 576
solution preparation, 457
solutions, 457
storage, 461
treatment, corrosion, 232
use and handling, 459
CHEMTREC [(800) 424-9300], 341, 550
Chloramination, 304, 305
Chloramines, 222, 223, 225, 299, 300, 304
Chloride, 514
Chlorinated hydrocarbons, 31
Chlorination
Also see Chlorinators, Disinfection, and Hypochlorinators
amperometric titration, 335, 476
bacteriological analysis, 334
CT values, 223, 335
Also see WATER TREATMENT PLANT OPERATION,
Volume II, Appendix, "How to Solve Water Treatment
Plant Arithmetic Problems"
chlorinators, 316, 321–324, 330–333
calcine residual tests, 302, 334, 335, 475
coliform tests, 334
containers, 317, 318, 325, 327
cylinders, 321, 322, 323, 325, 326, 327
dPD method, 222, 223, 354, 355, 476
demand, 297, 479
diaphragm-type pump, 319
equipment, 224, 316, 321, 350
freezing, chlorine, 321
fuible plug, 321, 326
hypochlorinators, 316–318, 327–330
injection, 316, 329
laboratory tests, 307, 334
maintenance, hypochlorinators, 228, 327–330
operation, 328, 330–333
performance, 327
poppet valves, 228, 328
removal from cylinder, 321
residual chlorine tests, 334, 335, 475
rotameter, 316, 324
safety, 321, 330, 338–342
valves, 326
withdrawal from cylinder, 225, 321
CHLORINATION AND ALTERNATIVE DISINFECTANTS,
HANDBOOK OF, 223
Chlorinators
Also see Chlorination
ammonia solution, 331
calculations, 333
containers, 317, 318, 325, 327
cylinders, 321, 322, 323, 325, 326, 327
description, 316
decay of systems, 334
developing, chlorine, 321
installation, 321–324
leak detection, 331
maintenance, 324, 333
operation, 332
rotameter, 316, 324
Chlorinators (continued)
safety, 330, 338
scale, 325
self-contained breathing apparatus, 330, 339
shut down, 332
start up, 331
training, operators, 341
troubleshooting, 225, 332, 334
uses, 220

Chlorine
ammonia, 294, 297, 304
CHEMTREC [800] 424-9300, 341
chloramines, 222, 223, 225, 299, 300, 304
demand, 297, 479
disinfection, 220, 296, 297
disinfection action, 297
dose, 228, 229, 297, 302
first aid, 341
freezing, 321
HTH (high test hypochlorite), 299, 311
handling, 327, 339
hazards, 330, 339–342
hydrogen sulfide, 297
hypochlorite, 220, 223, 228, 298, 299, 341, 342, 475
physiological response, 339
properties, 296
reaction with water, 297
residual, 223–229, 297, 302, 303, 334, 335, 475
safety, 327, 330, 338–342, 376
uses, 220
Chlorine available, 100
Chlorine demand test, 479
Chlorine detention rate curve, 302, 303
Chlorine dioxide, 299, 304
CHLORINE MANUAL, 338
Chlorine residual test kit, 454
Chlorine residual tests, 302, 334, 335, 475
Chlorine treatment, 100, 113–116, 221, 263, 307, 342
Chloroform, 475
Chlorophenol, 302
Chlororganic, 300
Cistern, 24
Clamps laboratory, 450, 451
Clarifiers, 233, 234, 235
Clarity of water, 221, 294
Clear wells
description, 7
small plants, 195
Clogged well screen, 92–102
Closures, street, 389
Clothing, safety, 371, 372
Coagulation
alkalinity, 197
alum, 197
calculations, 200
calibration of feeders, 200
chemical feeders, 199–202
dosage, 197
floc, 197
flocculation, 199, 202
gang stirrer, 197, 198
jar test, 197, 198
mixing, 197, 198
pathogen removal, 295
pH, 197
polymer, 200
process, 195, 197
streaming current meter, 199
temperature, 197

Coatings, tanks, 87, 375, 421
Coliform
bacteria, 31, 291, 307, 483
disinfection, 31, 291, 307, 334
laboratory procedures, 483–504
maximum contaminant levels, 291, 292
microbiological standards, 292
regulations, 291
sampling requirements, 292, 293
tests
Colilert, 499
Colisure, 502
fermentation tubes, 483, 486, 487
membrane filter, 484, 493
presence/absence, 499
Coliform Rule, Total, 483
Also see the poster included with this manual and WATER TREATMENT PLANT OPERATION, Volume II, Chapter 22, “Drinking Water Regulations”
Colilert method, 499
Colisure method, 502
collapsed well, 95
collapsed well screen, 94
color comparison tubes, 449
colortimeter, 453
column pipe, wells, 108, 110
Combined chlorine, 223, 475
Combustible gases, 468
Commodity costs, 536, 537
Commodity–demand method, 536
Community water system, 33
Competent person, 415, 422
Complaint handling, operator’s duties, 8
Composite sample, 467
Concentration, chlorine, 221
Condenser, laboratory, 449
Conductor casing, wells, 78, 156, 157
Cone of depression, 67, 144
Cone of influence, 168
Cones, traffic control, 404, 407
Confined space, 367, 370, 422
Confined space entry permit, 422, 423
Connection fees, 531
Conservation, 23
Consolidated formation, 153
Disinfection (continued)
chlorinator, 220, 225, 316, 321, 330
Also see Chlorinators
chlorine, 220, 296, 297
carbon dioxide, 220, 300, 341
clear of water, 221, 294
coliforms, 31, 291, 307, 334
combined chlorine, 223, 475
centration, 221
contact time, 221, 302
critical factors, 221, 294, 302
Cryptosporidium, 239, 253, 291
DPD method, 222, 223, 334, 335, 476
definition, 220, 291
diseases, 220, 291
doage, 228, 229, 297, 302
emergency, 313, 334
feal coliforms, 503
free chlorine, 223
giardiasis, 220, 253, 291
HANDBOOK OF CHLORINATION AND ALTERNATIVE
DISINFECTANTS, 223
heat, 296
hypochlorinator, 228, 316–318, 327–329
hypochlorite, 220, 223, 228, 298, 299, 342
influencing factors, 221, 294, 302
inorganic matter, 294
iodine, 296
laws, 291
main, 309
maintenance, 313
methods, 295, 309
microbiological standards, 291, 292
microorganisms, 220, 295
mixing, 221, 302
operation, 223–230
organic matter, 294
ozone, 220, 296
pH, 221, 223, 294, 298, 302
physical means, 295
points of application, 222, 307
population served, 293
preventive measures, 309
problems, 313
procedures, 309, 314
processes, 195, 220, 295
province, 220
purpose, 220, 291, 295
recordkeeping, 226, 227
reducing agents, 294, 297
residual chlorine, 223–229, 297, 302, 303, 334, 335
resistance of organisms, 220, 295
safe drinking water laws, 291
safety, 339, 377
sampling, 293, 315

small plants, 195
sodium hypochlorite, 220, 223
specifications, 315
sterilization, 291
storage facilities, 314
tanks, 314
temperature, 221, 294, 302
time of contact, 221, 302
total chlorine, 223
trihalomethanes, 195, 294
troubleshooting, 225, 330, 332
turbidity, 221, 294
ultrasonic waves, 296
ultraviolet radiation, 220, 295
virus, 220, 291
water treatment plants, 195
wells, 113–116, 307, 342
withdrawal rate of chlorine, 225, 321
Displacement well pumps, 104, 106
Disposal of
brine, 268
records, 549
sludge, 206
Dissolved oxygen
meter, 451
test, 514
Distances to wells, 144–146
Distribution system O & M
DPD method, 476
flushing, 125
sampling, 466, 468
Distribution systems, description, 7
Also see Distribution system O & M
Diversion works, 195
Dosage, coagulation, 197
Dose, chlorine, 228, 229, 297, 302
DPD method, 222, 223, 334, 335, 476
drawdown, wells, 29, 78, 135, 171
Drilled wells, 149–153
Driller’s log, wells, 69
Driller’s report, wells, 119, 120
Driven wells, 149, 151
Driving, safety, 364
Drums, traffic control, 404, 407
Dual media filter, 213
Dug wells, 147, 148
Duties of operators, 5, 8, 269
Dysentery, 26

E
ESWTR (Enhanced Surface Water Treatment Rule), 291
E. coli (Escherichia coli), 503
Edulators, 516
Effective use, 158, 242
Electric shock, 459, 462
Electrical, safety, 374, 377
Electrical supply, pumps, 127
Electrochemical reaction, 232
Emergency administration, 549–558
contaminated water supply, 552–558
disinfection, 313, 334
preparation for, 549–558
procedures, 556
situations, traffic, 389
toxicity, 552
treatment, 556, 557
vulnerability assessment, 549
Employee “Right-To-Know” laws, 366
End point titration, 457
ENGINEERING NEWS RECORD, 531
Enhanced Surface Water Treatment Rule (ESWTR), 291
Enzymes, 297
Epidemiology, 28
Equipment
chlorination, 224, 316, 321, 330
laboratory, 447–456
maintenance, 271
safety, 367–371
sampling, 467
Equity, 535
Errors, sampling, 465
Escherichia coli (E. coli), 503
Evaluation of wells, 168
Evaporating dish, 452
Evaporation, 24, 25, 63, 64
Evapotranspiration, 25
Excavations in streets
  cave-ins, 416
  ladders, 416
  safety rules, 415
  shoring, 415, 416
  spoil, 389, 416
  trench, 416
  underground utilities, 416–419
Expenses, 530, 532, 533
Explosions, 459, 460
Explosive charges, wells, 100
Explosive conditions, safety, 368
Explosive limits, 368, 370
Extra capacity costs, 556
Filter aids, 210, 213, 217
Filtration
  anthracite, 213
  backwashing, 214–219
  boils, 217
  breakthrough, 214, 216
  calculations, 217
  controller, 213
cutaway view, 210
diatomaceous earth, 210, 211, 212
dual media filter, 213
  filter aids, 210, 213, 217
gravity, 209, 210
  head loss, 214, 217
iron and manganese control, 263, 264
media, 212, 213
  mixed media filter, 213
mudballs, 215, 217
  operation, 213
  polymers, 210, 213, 217
  precut filters, 212
  pressure, 209, 211, 212, 215, 216, 218
  process, 195, 209, 210
  purpose, 195, 209, 210
  rapid sand filters, 213
  rate, 213, 216
  rate-of-flow controller, 213
  rinsing pressure filters, 216
  sand, 209, 212
  slow sand filters, 209, 211, 239–262
  Also see Slow sand filter
  softening, 264, 265
  surface wash, 213, 215
troubleshooting, 216
turbidity, 215
types, 209
  underdrain, 210, 211, 213, 214, 241
  waste backwash water, 215
Financial stability, 544
Fire extinguishers, 463
Fire, laboratory, 459, 463
Fire protection costs, 536, 541, 542
First aid, 341, 462
First-draw samples, 470
Fixed costs, 530
Flag tree warning devices, high-level, traffic control, 408, 409
Flagging, traffic control, 410, 411
Flame polished, 462
Flammable conditions, 368
Flammable materials, 462
Flashing yellow vehicle lights, 408
Flasks, laboratory, 448, 456
Floc, 197
Flocculation
  mixing, 202
  operation, 202, 203
  process, 195, 202
Flocculation (continued)
short-circuiting, 203
troubleshooting, 203
Flow measurement, 195
Flowmeters, wells, 85
Fluoride, 514
Flushing, mains, sand, 125
Foot valve, wells, 80, 82, 85
Forecasting expenditures, 530
Formation
consolidated, 153
unconsolidated, 157
Formulas
laboratory, 446, 492
sampling, 466
Free chloride, 223, 475
Freezing, chlorine, 321
Friction loss table, 174, 614
Fuel, safety, 385
Fume hood, 451
Funnels, laboratory, 449
Furnace, laboratory, 450
Fusible plug, 321, 326

G

Gang stirrer, 197, 198
Garnet, 213
Gases, safety, 369
Geologic data, 69
Geological log, 28
Geometric mean, 492
Giardia lamblia, 224, 239, 253, 256, 292, 335
Giardiasis, 26, 220, 253, 291
Glasses, safety, 461
Glassware, laboratory, 447–456
Gooch crucible, 452
Grab sample, 467
Graduated cylinders, 447, 455
Gravel-envelope wells, 78, 156, 163, 164
Gravel-packed wells, 156, 157, 163, 164
Gravity filters, 209, 210
Greensand, 264
Ground Water Disinfection Rule (GWDR), 291
Grounds, maintenance, 271
Groundwater
advantages, 68
aquifers, 63
hydrologic cycle, 63, 64
importance, 63
movement, 66
origin, 63, 65
overdraft, 66
perched aquifer, 65
pollution, 63, 68, 69
porosity, 66
protection, 74–77
recharge, 27
recordkeeping, 69
sampling, 465
soil moisture, 63
source, 24, 25, 27, 28, 34
specific yield, 66
transmissivity, 66
treatment, 196
wells, 63, 65
yield, 66, 101
zone of saturation, 64, 65
Grout seal, wells, 162, 164
Guards, safety, 380–382

H
HRR (high resolution redox), 338
HTH (high test hypochlorite), 299, 311
Halliburton grout method, 164
HANDBOOK OF CHLORINATION AND ALTERNATIVE
DISINFECTANTS, 223
Handling and lifting, 371
Handling chlorine, 327, 339
Hardness test, 505
Hardness treatment, 196
Hard-rock wells, 156, 157
Hazardous materials, 459
Hazardous wastes, 23
Hazardous chemicals, 330, 339–342
safety, 273, 338, 339, 363, 459
Head, 104, 108
Head loss, filtration, 214, 217
Health hazards
disease, 26
groundwater recharge, 27
laboratory, 459
Hearing protection, 425
Heat, disinfection, 296
Hepatitis, 26
Heterotrophic bacteria, 304
High resolution redox (HRR), 338
High service pumps, 195
High test hypochlorite (HTH), 299, 311
High-level flag tree warning devices, traffic control, 408, 409
High-rate settlers, 206, 207, 208
High-velocity jetting, wells, 95, 97, 98
Holding time, sampling, 471
Homeland defense, 551–555
Hood, fume, 451
Hot plate, laboratory, 450
Hydraulic gradient, 144
Hydraulic rotary drilling, wells, 149, 153, 154
Hydrogen sulfide, 297, 367
Hydrogeologic, 66
Hydrologic cycle, wells, 24, 25, 63–65
Hydrologic data, 69
Hydropneumatic tanks, wells, 82, 85, 87, 90, 164–168
Hydrostatic pressure, 153
Hygiene, laboratory, 461
Hypochlorinators
Also see Chlorination
calculations, 329, 344
containers, 317, 318
description, 316
diaphragm-type pump, 319
failure of system, 334
installation, 316, 317, 318
maintenance, 228, 327–330
operation, 228, 327–330
safety, 341
shutdown, 328
start-up, 327
testing, operator, 341
troubleshooting, 228, 330
uses, 220
Hypochlorite, 220, 223, 228, 298, 299, 341, 342, 475
Hypochlorous acid, 223, 475

I
ICR (Information Collection Rule)
See WATER TREATMENT PLANT OPERATION, Volume II,
Chapter 22, “Water Quality Standards”
IESWTR (Interim Enhanced Surface Water Treatment Rule), 291
Impermeable, 24
Importance of water, 23
Incrustation, well screens, 92–100
Industrial facilities, wells, 145
Inflation, 531
Information Collection Rule (ICR)
See WATER TREATMENT PLANT OPERATION, Volume II,
Chapter 22, “Water Quality Standards”
Injection, chlorine, 316, 320
Injuries, safety, 363
Intake, 203, 204, 205
Inorganic matter, 294
In-plant sampling, 466
Inspection
ladders, 421
maintenance, 271
safety, 378, 425–427
safety report form, 425–427
Installation
chlorinators, 321–324
hypochlorinators, 316, 317, 318
pipe, 415
Intake structures, 26
Intake, wells, 158–164
Interim Enhanced Surface Water Treatment Rule (IESWTR), 291
Internal parasites, 291
Inventory records, 547
Investor-owned utilities, 535
Iodine, 220, 296
Ion exchange, 267–270
Iron and manganese
aeration, 264
damages, 263
dehchlorination, 264
damages, 263
dehlorination, 264
damages, 263
dehlorination, 264
damages, 263
dehlorination, 264
damages, 263
dehlorination, 264
damages, 263
K
Kelly, rotary drilling, wells, 155
Kemmerer depth sampler, 469
Kinetic energy, 87

L
LEL (lower explosive limit), 368, 370
Labeling sample containers, 470
Laboratory equipment
air pressure pump, 452
amperometric titrator, 454
analytical balance, 453
autoclave, 452
balance, analytical, 453
bulb, pipet, 452
Bunsen burner, 451
calorimeter, 453
crucibles, 452
calorimeter, 453
crucibles, 452
calorimeter, 453
crucibles, 452
calorimeter, 453
crucibles, 452
calorimeter, 453
crucibles, 452
Laboratory equipment (continued)
glassware, 447–456
Also see Laboratory glassware
Gooch crucible, 452
hood, fume, 450
incubator, 453
magnetic stirrer, 453
muffle furnace, 450
oven, 450
pH meter, 451
pH test paper, 452
pipet bulb, 452
pump, air pressure and vacuum, 452
safety tongs, 450
spectrophotometer, 453
stirrer, magnetic, 453
test paper, pH, 452
titration, amperometric, 454
tongs, 450, 462
tripod, 451
turbidimeter, 452
vacuum pump, 452

Laboratory glassware
beakers, 447, 456
bottles, 448
burets, 448, 455
color comparison tubes, 449
condenser, 449
culture tube, 449
desiccator, 450
flasks, 448, 456
funnels, 449
graduated cylinders, 447, 455
meniscus, 455
Nessler tubes, 449
petri dish, 449
pipets, 448, 456
test tubes, 449
thermometer, 450
vials, test, 449

Laboratory procedures
additional reading, 447, 464, 514
alkalinity, 473
arithmetic assignment, 514
chemical names, 446
chemical solutions, 457
chlorine demand, 479
chlorine residual, 475
coliform bacteria, 483–504
Colilert method, 499
Colisure method, 502
color, 514
data recording, 457
dilutions, 457

end point, 457

equipment, 447–456
Also see Laboratory equipment
Escherichia coli (E. coli), 503
formulas, 446, 492
glassware, 447–456
Also see Laboratory glassware
hardness, 505
importance, 445
jar test, 506
MPN (most probable number) procedure, 483, 490–492
membrane filter, 484, 493
meniscus, 455
metric system, 445
multiple tube fermentation method, 483, 486, 487
normal solution, 457
notebooks, 457
pH, 509
presence/absence method, 499
quality control, 445, 458
recordkeeping, 457
references, 447
safety, 459–464
Also see Laboratory, safety
sampling, 465
solutions, 457
standard solution, 457
temperature, 445, 510
titrations, 457, 458
turbidity, 511
use of glassware, 455
worksheets, laboratory, 459, 460

Laboratory, safety
accidents, 461, 462
acids, 459, 460
bases, 460
burns, 459, 462
cautions, 460
chemical storage, 461
corrosive materials, 459, 460
cuts, 459, 462
electric shock, 459, 462
explosions, 459, 460
fires, 459, 463
first aid, 462
flammable materials, 460, 462
glasses, safety, 461
hazardous materials, 459
hazards, 459
hygiene, 461
mercury, 462
movement of chemicals, 462
OSHA (Occupational Safety and Health Act), 459
personal safety, 461
prevention of accidents, 461
Laboratory, safety (continued)
proper techniques, 462
protective clothing, 461
shock, 459, 462
toxic materials, 460, 463
waste disposal, 463
Lakes
sampling, 465
sources of water, 26
Land subsidence, 27
Langelier Index, 232
Lay out, small plants, 194
Le Système International d'Unités (SI), 602
Leak detection, chlorine, 331
Lifting, safety, 269, 371, 373
Lighting devices, traffic control, 408
Lights, flashing yellow vehicle, 408
Lime
corrosion control, 252
soda ash softening, 264
Location, wells, 143
Lockout/tagout procedure, 382
Log removals, 253, 632
Lower explosive limit (LEL), 368, 370
Lubricants, safety, 385
Lubricating oils, 112
MAC (maximum allowable concentration), 556
MCL (maximum contaminant level), 35, 291
MPN
See Most probable number (MPN)
MSDS (Material Safety Data Sheet), 348, 367
Maintenance
chlorinators, 224, 333
equipment, 271
grounds, 271
hypochlorinators, 228, 327–330
inspections, 271
plant grounds, 271
program, 271
safety, 380
slow sand filters, 251
small plants, 271
solids-contact clarification units, 238
tools, 271
wells, 92–102
Management, safety, 363
Manganese, 514
Also see Iron and manganese
Manifold, 168
Manual sampling, 467
Mable test, 265, 514
Material Safety Data Sheet (MSDS), 348, 367
Maximum allowable concentration (MAC), 556
Maximum contaminant level (MCL), 33, 291
Mean, arithmetic and geometric, 492
Mechanical joints, 147
Media, filtration, 212, 213
Median, 492
Meg, 134
Membrane filter test, 484, 493
Mensicus, 455
Mercury, 462
Mesh, 85
Meter equivalents, 541
Metric system, 445, 602
Microbiological standards, 291, 292
Microorganisms, 220, 295
Mixed media filter, 213
Mixing
coagulation, 197, 198
disinfection, 221, 302
flocculation, 202
Monitoring equipment, safety, 367, 370
Monitoring, water quality changes, 102
control systems, 445
slow sand filters, 245
wells, 95, 101
Monochloramine, 475
Most probable number (MPN)
formula, 492
procedure, 483, 490–492
Motor starters, pumps, 127, 128
Motors, pumps, 113
Movement, groundwater, 66
Moving parts, safety, 380–382
Mudballs, 215, 217
Muffle furnace, 450
Multiple tube fermentation method, 483, 486, 487
Multiple-block rate structure, 541
Multistage pumps, 105
Nameplate, 135
Need for operators, 5
Negligence, safety, 364
Nephelometer, 511
Nessler tubes, 449
Nitrate test, 514
Nitrification, 304, 306
Noise, 425
Noncommunity water system, 33
Non-permit-required confined space, 422
Nontransient noncommunity water system, 33
Normal solution, laboratory, 457
Notebooks, laboratory, 457
O

O & M
See Operation and Maintenance (O & M)

ORP (oxidation-reduction potential) probe, 338

OSHA (Occupational Safety and Health Act), 370, 459

Oil-lubricated pumps, 105, 107, 110, 112

Operating expenses, 530, 532, 533

Operating pressure differential, 166

Operating ratio, 545

Operation and maintenance (O & M)
chlorinators, 332

disinfection, 223–230, 328, 330, 332

expenses, 530, 532, 533

filters, 213, 246

flocculation, 202, 203

hypochlorinators, 228, 327–330

need for O & M, 193

operator’s duties, 7, 8

sedimentation, 203–206

small plants
See Operation, small plants

softening, 265, 267

sols–contact clarification, 237–239

Operation, small plants

backflow prevention, 270

certification, operator, 269

daily log or diary, 270

daily tasks, 270

duties, operator, 269

laboratory tests, 270

maintenance, 271

periodic tasks, 270

plant operation, 269

procedures, 270

recordkeeping, 270

responsibilities, operator, 269

safety, 273

system records, 270

training operators, 269

Operators

certification, 8, 269

complaint handling, 8

duties, 5, 8, 269

need, 5

operation and maintenance, 7, 8

pay, 9

preparation for jobs, 10

public relations, 8

qualifications, 10

recordkeeping, 8

requirements, 9

responsibility, 5, 67, 68, 77, 117, 170, 269

safety, 8, 273

supervision and administration, 8

training courses, 10, 269

water supply systems, 5

Organic matter, 294

Ovifite, 86

Origin, groundwater, 63, 65

Outlet chamber, 243, 244

Outlets, tank, 204, 205

Oven, laboratory, 450

Overdraft, wells, 66

Overflow rates, 205, 206, 236

Overpumping, wells, 92

Oxidation, 196

Oxidation-reduction potential (ORP) probe, 338

Oxidizing agent, 300

Oxygen deficiency/enrichment, 367, 422

Ozone, 220, 226

PCMs (portable changeable message sign), traffic control, 410

Package plants, 193

Paper, pH test, 452

Parasites, 291

Parshall flume, 199

Pathogenic organisms, 242, 253, 291, 483

Pay for operators, 9

Payback time calculation, 546

Pedestal, pump, wells, 77, 78, 79

Pedestrian safety, traffic control, 412, 413, 416

Perched aquifer, 65

Percussion drilling, wells, 149, 152

Performance testing, wells, 168

Permeability, 149

Permit-required confined space, 422, 423

Personal safety, 367, 461

Personnel records, 548

Persons with disabilities, safety, traffic control, 412

Pesticides, 31

Pet cock, 80

Petri dish, 449

pH

coaugulation, 197

disinfection, 221, 223, 294, 298, 302

meters, 451

test, 509

test paper, 452

Phenol, 302

Physical disinfection, means of, 295

Physiological response, chlorine, 339

Piezometer, 246

Piping, 448, 456

Piston pump, 106, 109

Planning

emergency, 549

expenses, 530

Plant operations records, 547

Plugging, wells, 69, 180, 378

Pumping, wells, 95, 96

Policy, safety, 363
Pollution
groundwater, 63, 68, 69
sources, 69
wells, 63

Polymers
coaulation, 200
filtration, 210, 213, 217

Polyphosphates
corrosion control, 100, 232
iron and manganese, 263
safety, 577
wells, 100

Poppet valves, 228, 328

Population served, sampling, 293

Pore, 66
Porosity, 66

Portable, changeable message sign (PCMS), traffic control, 410

Positive displacement pumps, 104, 106

Postammoniation, 304
Prechlorination/postammoniation, 304

Precipitate, 196
Precoat filters, 212
Preparation for emergencies, 549–558
Prescriptive rights, 24
Presence/absence method, coliform test, 499

Present worth, 531
Preservation, samples, 470, 471
Pressure
differential, operating, 166
filters, 209, 211, 212, 215, 216, 218
hydrotatic, 155

relief valves, wells, 88, 89
tanks, wells, 82, 85, 87, 90, 92, 164–168
tests, 164–168

Prevention of accidents, 363, 461, 462
Preventive maintenance
See Maintenance
Prime, pumps, 85
Processes, treatment
coaulation, 195, 197
disinfection, 195, 220, 295
filtration, 195, 209, 210
flocculation, 195, 202

sedimentation, 203
solids-contact clarification, 233

Procurement records, 547
Program
maintenance, 271

safety, 8, 273, 363
Properties, chlorine, 296
Protective clothing, 371, 372, 461
Protective measures, water supply, 556

Protozoa, 220
Public health, 26–34
Public relations, operator’s duties, 8
Public safety, 377, 416
Pump
air pressure and vacuum, 452
bowl, wells, 104, 156
calculations, pump efficiency, 172
pedestal, wells, 77, 78, 79
station, wells, 82, 83
Pumping, tests, wells, 169
Pumps, wells
air-lift, 104
auxiliary power, 127, 129
centrifugal, 104
column pipe, 108, 110
controls, 127–133
deep well, 104, 105, 106, 112
disinfection, 113–116, 307, 342
displacement, 104, 106
electrical supply, 127
hydropneumatic tanks, 82, 85, 87, 90, 164–168
jet, 106, 108, 148
lubricating oils, 112
motor starters, 127, 128
motors, 113
multistage, 105
oil lubricated, 105, 107, 110, 112
operating pressure differential, 166
operator responsibility, 170
piston, 106, 109
positive displacement, 104, 106
pressure tanks, 82, 85, 87, 90, 164–168
prime, 85
pump station, 82, 83
reciprocating, 104
recordkeeping, 117–124
rotary, 106, 109
safety, 380–385
sand, 119, 126–127
selection, 112
service guidelines, 112, 114, 117–124
shallow, 104, 150
small plants, 195
submersible deep well, 105, 108
terminology, 171
testing, 170–176
troubleshooting, 133–135
turbine-type, 104–107, 114
variable displacement, 104
volute-type, 104, 105
water lubricated, 105, 107, 110, 114
water treatment plants, 195
Purchase order, 545, 547, 548

Q
Quality control, laboratory, 445, 458
Quality monitoring, wells, 102
Index 723

R

Ranney well, 153, 155
Rapid sand filters, 213
Rate
administration, 544
components, 541
design, 540–543
of return, 535
setting, 527
structure, 542
studies, 527
Rate-of-flow controller, 213
Rates of filtration, 213, 216
Rates, water, 23, 527
Recarbonation, 265
Recharge of groundwater, 27
Reciprocating pump, 104
Recirculation, 237–239
Reclaimed water, 27
Record drawings (as-built plans), 7
Recordkeeping
computer, 546
disinfection, 226, 227
disposal of, 549
equipment and maintenance, 548
groundwater, 69
inventory, 547
laboratory, 457
operation, 270
operator’s responsibility, 8
personnel, 548
plant operations, 547
procurement, 547
pumps, 117–124
purpose, 546
slow sand filters, 256
small plants, 270
solids-contact clarification, 237
types, 547
wells, 69, 95, 117–124
Records
See Recordkeeping
Recreation lakes, 26, 29
Redox, 338
Reducing agents, 294, 297
Reducing chemicals, 294, 297
Regeneration, 267
Regulations
street work, 389
wells, 143
Regulatory negotiation, 693
Rehabilitation costs, 528, 533
Rehabilitation, wells, 92
Reliquefaction, 225
Removal of chlorine, 225, 321
Repair/replacement fund, 535
Repairs
safety, 380
wells, 95
Replacement costs, 528, 533
Reporting, 470
Representative sample, 465
Requisition, 545, 548
Reserve funds, 530
Reservoirs, sampling, 465
Residual chlorine, 223–229, 297, 302, 303, 334, 335, 475
Resistance of organisms, 220, 295
Responsibility of operators
operation, 5, 269
safety, 8, 363
small plants, 193, 196, 269
wells, 67, 68, 77, 117, 170
Revenue requirements, 527, 529–535
Reverse circulation, well drilling, 153, 155
Rights to use water
appropriative, 24
prescriptive, 24
riparian, 24
Right-To-Know laws, 366
Rinsing pressure filters, 216
Riparian rights, 24
Rivers, 26, 465
Rossum sand sampler, 126
Rotameter, 316, 324
Rotary drilling, wells, 149–153
Rotary pumps, 106, 109
Roughing filter, 254, 255
Routing traffic, 385–415

S

SCBA (self-contained breathing apparatus), 330, 339
SDWA (Safe Drinking Water Act), 8, 32, 239, 291
SI (Le Système International d’Unités), 602
SWTR (Surface Water Treatment Rule), 31, 239, 253
Safe distances to wells, 144–146
Safe Drinking Water Act (SDWA), 8, 32, 239, 291
Safe yield, 27, 29
Safety
ADA (Americans with Disabilities Act), 412
ADT (average daily traffic), 388
accidents, 363, 366, 367, 416
acids, 366, 376, 459, 460
additional reading, 425
arrow panels, traffic control, 408
awarness, 363
barricades, traffic control, 404, 406
battery, 365
bicycle, traffic control, 412
boats, 365
carbon monoxide, 367
carelessness, 364
Safety (continued)
cave-ins, 416
channelizing devices, traffic control, 404
chemicals, 376
CHEMTREC [(800) 424-9300], 341
chlorinators, 330, 338
chlorine, 327, 330, 338–342, 376
chlorine dioxide, 341
communications, 389
clothing, 371, 372
coatings, 375, 421
combustible gases, 368
competent person, 415, 422
cones, traffic control, 404, 407
confined space, 367, 370, 422
congruent space entry permit, 423
control devices, traffic control, 386, 397–409
closure zones, traffic control, 390–403
corrosive chemicals, 366
dangerous air contamination, 367, 369, 422
definition, 363
disabled persons, traffic control, 412
disinfection, 338, 377
driver, 364
drums, traffic control, 404, 407
electrical, 374, 377
emergency situations, traffic, 389
equipment, 367–371
explosive conditions, 368
explosive limits, 368, 370
falls, 371, 418
flagging, traffic control, 410, 411
flammable conditions, 368
flashing yellow vehicle lights, 408
fuel, 385
guards, 380–382
handling and lifting, 371
hazards, 273, 338, 339, 363, 459
hearing protection, 425
high-level flag tree warning devices, traffic control, 408, 409
homeland defense, 551–555
hydrogen sulfide, 367
hypochlorinators, 341
injuries, 363
inspection, 378, 425–427
ladders, 416, 419, 420–421
lifting, 269, 371, 373
lighting devices, traffic control, 408
lockout/tagout procedure, 382
lower explosive limit (LEL), 368, 370
lubricants, 385
maintenance, 380
management, 363
Material Safety Data Sheet (MSDS), 348, 367
monitoring equipment, 367, 370
moving parts, 380–382
negligence, 364
noise, 425
non-permit-required confined space, 422
OSHA (Occupational Safety and Health Act), 370, 459
operator’s responsibility, 8, 273
oxygen deficiency/enrichment, 367, 422
PCMS (portable changeable message sign), traffic control, 410
pedestrians, traffic control, 412, 413, 416
permit-required confined space, 422, 423
personal, 367, 461
persons with disabilities, traffic control, 412
policy, 363
polyphosphate, 377
portable changeable message sign (PCMS), traffic control, 410
prevention of accidents, 363, 461, 462
program, 8, 273, 363
protective clothing, 371, 372, 461
public, 377, 416
pumps, 380–385
regulations, street work, 389
repair, 380
responsibilities, 8, 363
Right-To-Know laws, 366
routing traffic, 385–415
shoring, 415, 416
signs, traffic control, 386, 387, 397, 409
sling, 382
slips, 371, 418
small plant hazards, 273
speed limits, traffic control, 414
storage facilities, water, 418
storage of fuel, 385
street work, 385–418
Also see Traffic control, safety
tailgate safety sessions, 366
tanks, 375, 421
tapers, traffic control, 391, 393, 395, 396, 397
think safety, 363
threat levels, homeland defense, 552–555
tongs, 450, 462
toxic gases, 368, 463
traffic, 385–418
Also see Traffic control, safety
tailgate training, 364
tarnings, 341, 363, 422
trenches, 416
tubular markers, traffic control, 404, 407
underground utilities, 416–419
uniform traffic control devices, 386
unsafe acts, 363, 364, 371
upper explosive limit (UEL), 368, 370
ventilation, 368, 377, 422
vertical panels, traffic control, 407, 408
visibility, worker, 412
Index 725

Safety (continued)
water storage facilities, 418
wells, 374, 376, 377
work zones, 414
worker considerations, traffic control, 414
worker viability, 412
working in streets, 385–418
Also see Traffic control, safety zones, work, 414
Safety program
operator’s duties, 8
small plants, 273, 363

Sampling
automatic, 467
composite samples, 467
containers, 470, 471
depth, 468–470
device, 467, 468, 469, 470
disinfection, 293, 315
distribution system, 466, 468
equipment, 467
erros, 465
first-draw, 470
formulas, 466
grab samples, 467
groundwater, 465
holding time, 471
importance, 465
in-plant, 466
Kemmerer depth sampler, 469
labeling container, 470
lakes, 465
manual, 467
population served, 293
preservation, 470, 471
procedures, 465
representative sample, 465
reservoirs, 465
rivers, 465
source water, 465
station, 468
surface, 468, 469
tap water, 469
volume, 471
Sampling tap, wells, 77, 79, 80
Sand media, 212, 242, 247–251
Sand separator, wells, 85, 86, 126
Sand trap, wells, 85, 86
Sand, wells, 119, 126–127
Sanitary landfill, 23
Sanitary seal, wells, 78, 163, 164
Sanitary survey
groundwater, 28
surface water, 29
treatment of water, 28
Scale, chlorine, 325
Schmutzdecke, 240

Screens, wells, 92–102, 158–164
Seal, wells, 78, 162, 163, 164
Seawater intrusion, 23, 25, 27, 67
Sedimentation (settling)
calculations, 206
currents in tank, 205
detention time, 205, 206
disposal of sludge, 206
high-rate settlers, 206, 207, 208
inlets, 203, 204, 205
operation, 203–206
outlets, 204, 205
overflow rate, 205, 206
process, 203
settling zone, 203, 204, 205
short-circuiting, 205
sludge zone, 204, 205
sludges, 203, 204, 206
surface loading (overflow rate), 205, 206
temperature, 205
troubleshooting, 205
tube settlers, 206, 207, 208
wind, 205
zones, 203, 204, 205
Selection of well site, 143
Self-contained breathing apparatus (SCBA), 330, 339
Service area statistics, 529
Service charge, 541
Service guidelines, well pumps, 112, 114, 117–124
Set point, 129, 131
Setting rates, 527
Settling
See Sedimentation (settling)
Settling zone, 203, 204, 205
Sewers, location from well, 145
Shallow collector wells, 150, 153, 155
Shallow well pumps, 104, 150
Shock, electric, 459, 462
Shoring
cave-ins, 416
safety, 415, 416
Short-circuiting, 29, 203, 205
Shutdown
chlorinators, 332
hypochlorinators, 328
slow sand filters, 262
Signs, traffic control, 386, 387, 397, 409
Slit, 26
Site selection, 143
Sling, safety, 382
Slips, safety, 371, 418
Slow sand filter
cleaning media, 247–251, 260
components, 240
control, flow, 243–246
daily operation, 246
development of process, 239
Slow sand filter (continued)
diagram, 240, 242, 244, 260, 262
effective size, 242
filter tank, 241
finished water, 245, 252
flow control, 243–246
hydraulic controls, 243, 245
hydraulic loading, 256
maintenance, 251
media, 242, 247–251
modifications, 257
monitoring, 245, 258
operation, 246–251, 259
outlet chamber, 243, 244
pathogens, 242, 253
performance, 253–256
preventive maintenance, 251
procedures, 239
process modifications, 257
recordkeeping, 256
sand media, 242, 247–251
shutdown, 262
start-up, 246, 257
Summit Lake, 257–262
troubleshooting, 252
underdrain system, 241
uniformity coefficient, 242
Sludge
clear well, 195
corrosion control, 195
custom designed plant, 196
disinfection, 195
diversion works, 195
filtration, 195
flocculation, 195
flow measurement, 195
groundwater, 196
hardness, 196
hazards, 273
high service pumps, 195
importance, 193
iron and manganese control, 196
layout, 194
maintenance, 271
O & M, 193
operator responsibility, 193, 196, 269
package plants, 195
pumps, 195
raw water storage, 193
settling, 195
softening, 196, 264, 267
storage, 195
surface waters, 193
Soda ash, corrosion control, 232
Sodium hypochlorite, 220, 223
Softening
backwash, 267
brine disposal, 268
brine stage, 267
calculations, ion exchange, 268
chemical doses, 264
disposal of brine, 268
filtration, 264, 265
ion exchange softening, 267
jar tests, 264
lime–soda ash softening, 264
maintenance, brine system, 268
Marble test, 265
operation, 265, 267
raw water quality, 265
regeneration, 267
zeolite, 267
Soil moisture, 63
Solid waste disposal sites, wells, 145
Solutions, chemical, 457
Sources of water
description, 5
direct runoff, 24
groundwater, 24, 25, 27, 28, 34
hydrologic cycle, 24, 25
Sources of water (continued)
lakes, 26
ocean, 24
precipitation, 30
reclaimed water, 27
reservoirs, 26
rivers, 26
select, 28
springs, 25, 27
streams, 26
surface water, 24, 34
wells, 27
Space, annular, 102, 153
Specific capacity, 101
Specific yield, wells, 66
Specifications, 313
Spectrophotometer, 453
Speed limits, traffic control, 414
Sprad, 389, 416
Staffing needs, 9
Standard solutions, 457
Start-up
chlorinators, 331
hypochlorinators, 327
slow sand filters, 246, 257
Station, sampling, 468
Statistics, service area, 529
Stirrer, magnetic, 453
Storage facilities (water)
description, 5
safety, 418
small plants, 195
Storage of
chemicals, 461
chlorine, 317
fuel, 385
Stratification, 26
Streaming current meter, 199
Street work, safety, 385–418
Traffic control, safety
Structure, wells, 156
Submersible deep-well pump, 105, 108
Subsidence, land, 27, 66
Subsurface features, wells, 156
Suction lift, 104
Sulfate, test, 514
Summit Lake, slow sand filter, 257–262
Superchlorination, 264
Superintendant, 507
Supervision and administration, operator’s duties, 8
Surface features, wells, 77–80
Surface loading (overflow rate), 205, 206, 236
Surface wash, 213, 215
Surface water, 24, 468, 469

Surface Water Treatment Rule (SWTR), 31, 239, 253
Surge suppressors, wells, 87
Surging, wells, 95
Sustained yield, 27
System records, 270
Système International d'Unités (SI), 602

T
TCE (trichloroethylene), 23
THMs (trihalomethanes), 31, 195, 294, 475, 514
Tailgate safety meeting, 366
Tanks
coatings, 87
disinfection, 314
safety, 375, 421
Tap water sampling, 469
tapers, traffic control, 391, 393, 395, 396, 397
Temperature
coagulation, 197
disinfection, 221, 294, 302
sedimentation, 205
sols-contact clarification, 236, 238
Terminology, well pumps, 171
Test paper, pH, 452
Test tubes, 449
Testing
well pumps, 170–176
wells, 168
Thermometer, 450
Think safety, 363
Threat level categories, homeland defense, 552–555
Threshold odor, 514
Time of contact, disinfection, 221, 302
Titrate, 335
Titrate, amperometric, 454
Tongs, laboratory, 450, 462
Tools, 271
Topography, 27
Total chlorine, 223
Total Coliform Rule, 483
Also see the poster included with this manual and WATER TREATMENT PLANT OPERATION, Volume II, Chapter 22, “Drinking Water Regulations”
Total dissolved solids, 514
Toxic chemicals, 31
Toxic gases, 368, 463
Toxic materials, 460, 463
Toxicity, emergency response, 552
Traffic control, safety
ADA (Americans with Disabilities Act), 412
ADT (average daily traffic), 388
arrow panels, 408
barricades, 404, 406
bicycle, 412
channelizing devices, 404
clousures, street, 389
Traffic control, safety (continued) cones, 404, 407
control devices, 386, 397–409
control zones, 390–403
disabled persons, 412
drums, 404, 407
flagging, 410, 411
flashing yellow vehicle lights, 408
high-level flag tree warning devices, 408, 409
lighting devices, 408
PCMS (portable changeable message sign), 410
pedestrian, 412, 413, 416
persons with disabilities, 412
portable changeable message sign (PCMS), 410
regulations, street work, 389
routing traffic, 385–415
signs, 386, 387, 397, 409
speed limits, 414
street work, regulations, 389
tapers, 391, 393, 395, 396, 397
trenches, 416
tubular markers, 404, 407
uniform traffic control devices, 386
vertical panels, 407, 408
visibility, worker, 412
work zones, 414
worker considerations, 414
worker visibility, 412
zones, work, 414
Trailers, towing, 364
Training
course, 10, 269
operators, 269, 341
safety, 341, 363, 422
Transient noncommunity water system, 33
Transmissivity, 66
Transpiration, 27, 64
Turbidity
filtration, 215
units, 205, 512
Turbine-type pumps, 104–107, 114
Turnover, lake, 26
Types of wells, 147, 157
Typhoid, 26
Vacuum breaker valve, wells, 77, 79, 80, 87
Vacuum pump, 452
Valves
check, 82, 83, 84
chlorine, 326
solenoid, 82
vacuum breaker, 77, 79, 80, 87
well, 77, 79, 80, 82, 83, 84, 87, 88
Variable costs, 530
Variable displacement pumps, 104
Vent, wells, 77, 78, 79
Ventilation, safety, 368, 377, 422
Video inspection, wells, 101
Visibility, worker safety, 412
Viscosity, 26
Volatilization, 461
Volume charge, 541, 542
Volume of sample, 471
Volume over volume (V/V) test, 237
Volatility, 87
Volatilite liquids, 461
Volume charge, 541, 542
Volume of sample, 471
Volume over volume (V/V) test, 237
Volumetric flasks, 456
Volute-type pump, 104, 105
Vulnerability assessment, emergency response, 549
Waste backwash water, 215
Waste disposal, 463
Waste disposal sites, wells, 145
Wastewater facilities, wells, 26, 28, 145
Waste, 101
Water acid rain, 23
conservation, 23
costs, 23
evaporation, 25
groundwater, 24, 25, 27, 28, 34
hydrologic cycle, 24, 25, 63–65
importance, 23
irrigation runoff, 23
presence, 23
quality monitoring, 95, 101
rates, 23
seawater intrusion, 23, 25, 27, 67
sources, 24, 34
treatment, 33, 34
water quality problems, 33, 34, 102, 232
Water cycle, 24, 25, 63–65
Water hammer, 88
Water level measuring, wells, 77, 78, 79
Water mains, flushing, 125
Water quality biological, 30, 31, 101, 102
chemical, 30, 31, 101, 102
color, 30
crime, 101, 102
consumer demands, 33
inorganics, 31
monitoring changes, 102
control systems, 445
slow sand filters, 265
wells, 95, 101
odors, 31
organics, 31
physical, 30, 101, 102
problems, 33, 34, 102, 232
radioactivity, 30, 31
taste, 31
temperature, 31
turbidity, 30
Water rights appropriative, 24
prescriptive, 24
riparian, 24
Water supply systems description, 5–7
distribution systems, 7
layout, 6
operators, 5
sketch, 6
sources, 5
storage facilities, 5
treatment facilities, 7
Water table, 25, 27
Water treatment costs, 33
objectives, 33
water quality problems, 34
Water treatment plants clear well, 195
corrosion control, 195
disinfection, 195
diversion works, 195
filtration, 195
flocculation, 195
flow measurement, 195
groundwater, 196
hardness, 196
hazards, 273
high service pumps, 195
importance, 193
iron and manganese control, 196
layout, 194
maintenance, 271
O & M, 193
operator responsibility, 193, 196, 269
package plants, 195
pumps, 195
raw water storage, 193
settling, 195
sketch, 194
softening, 264, 266
storage, 195
surface waters, 193
Waterborne diseases, 220, 291
Water-lubricated pumps, 105, 107, 110, 114
Watershed, 29
Well casing vent, wells, 77
Wellhead protection, 69–74
Wells abandoning, 69, 180, 181, 378
acid treatment, 97–100
advantages, 63
adverse conditions, 92, 147
air blow test method, 169
air chargers, 88–91
air lines, 77, 79
air release valve, 77, 79, 80, 87
air rotary drilling, 153
annual gross seal, 162
bailing test method, 169
biofouling, 94
blowoff, 77, 80
bored wells, 149, 150
bowls, pump, 104, 156
cable-tool drilling, 149, 152, 156
caisson, 153
calculations, 115, 172
casing, 77, 156, 157
chlorine treatment, 100, 113–116, 307, 342
clogged screen, 92–102
collapse, 95
collapsed screen, 94
components, 156
Wells (continued)

- conductor casing, pages 78, 156, 157
- construction, pages 29, 156
- contaminated, page 114
- controls, pumps, pages 127–133
- corrosion, pages 93, 94
- diameter, page 158
- disinfection, pages 113–116, 307, 342
- distances to facilities, pages 144–146
- drawdown, pages 29, 78, 135, 171
- drilled wells, pages 149–155
- driller’s log, page 69
- driller’s report, pages 119, 120
- driven wells, pages 149, 151
- dug wells, pages 147, 148
- electrical supply, pumps, page 127
- evaluation, page 168
- explosive charges, page 95
- field testing of deposits, page 94
- flowmeters, page 85
- foot valve, pages 80, 82, 85
- gravel-envelope, pages 78, 156, 163, 164
- gravel-packed wells, pages 156, 157, 163, 164
- groundwater, pages 63, 65
- grout seal, page 162, 164
- hard-rock wells, pages 156, 157
- high-velocity jetting, pages 95, 97, 98
- hydraulic rotary drilling, pages 149, 153, 154
- hydrologic cycle, pages 24, 25, 63–65
- hydropneumatic tanks, pages 82, 85, 87, 90, 164–168
- incrustation, well screens, pages 92–100
- industrial facilities, page 145
- inspection, video, page 101
- intake, pages 158–164
- jetting, well screens, pages 95, 97, 98
- kelly, rotary drilling, page 155
- maintenance, pages 92–102
- operator responsibility, pages 67, 68, 77, 117, 170
- overdraft, page 66
- overpumping, page 92
- pedestal, pump, pages 77, 78, 79
- percussion drilling, pages 149, 152
- performance testing, page 168
- plugging, pages 69, 180, 378
- plugging, pages 95, 96
- pollution, page 63
- polyphosphates, page 100
- pressure relief valves, pages 88, 89
- pressure tanks, pages 82, 85, 87, 90, 92, 164–168
- pump, pages 82, 104–113, 127–133, 170–176
- pump bowls, page 104, 156
- pump pedestal, pages 77, 78, 79
- pump station, pages 82, 83
- pumping tests, page 169
- quality monitoring, page 102
- Ranney well, pages 153, 155
- recordkeeping, pages 69, 95, 117–124
- regulations, page 143
- rehabilitation, page 92
- repairs, page 95
- responsibility, operators, pages 67, 68, 77, 117, 170
- reverse circulation, well drilling, pages 153, 155
- rotary drilling, pages 149–153
- safe distances, pages 144–146
- safety, pages 374, 376, 377
- sampling tap, pages 77, 79, 80
- sand, pages 119, 126–127
- sand separator, pages 85, 86, 126
- sand trap, page 85, 86
- sanitary seal, pages 78, 163, 164
- screens, pages 92–102, 158–164
- seal, pages 78, 162, 163, 164
- sewers, location, page 145
- shallow collector wells, pages 150, 153, 155
- site selection, page 143
- solid waste disposal sites, page 145
- sounding tube, pages 77, 78, 79
- specific yield, page 66
- structure, page 156
- subsurface features, page 156
- surface features, pages 77–80
- surge suppressors, page 87
- surging, page 95
- testing, page 168
- troubleshooting, page 101
- types, pages 147, 157
- vacuum breaker valve, pages 77, 79, 80, 87
- valves, pages 77, 79, 80, 82, 83, 84, 87, 88
- vent, pages 77, 78, 79
- video inspection, page 101
- waste disposal sites, page 145
- wastewater facilities, pages 26, 28, 145
- water level measuring, pages 77, 78, 79
- water quality monitoring, pages 95, 101
- well casing vent, page 77
- wellhead protection, pages 69–74
- working pressure, pages 164, 166
- yield, page 66, 101
Wind, sedimentation, 205
Withdrawal rate of chlorine, 225, 321
Work zones, safety, 414
Worker considerations, safety, traffic control, 414
Worker visibility, 412
Working in streets, safety, 385–418
Also see Traffic control, safety
Working pressure, well pumps, 164, 166
Worksheets, laboratory, 459, 460
Wye strainer, 195

Y
Yield
safe, 27
sustained, 27
wells, 66, 101

Z
Zeolite, 267
Zone of saturation, 25, 27, 64, 65
Zones of settling, 203, 204, 205
Zones, work, 414

(NO LISTINGS)