

**Appendix E: Summary of Microbial Source
Tracking Studies in Southern California**

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| Study Period | County | Location | Study Group | Condition | Sampling Locations | Indicators/Markers Analyzed | Validated Markers | Human Marker Results | Sources Identified | Reference |
|--------------|-------------|-------------------|----------------|-------------|-----------------------|---|-------------------|---|--------------------------------------|---|
| 2003 - 2004 | San Diego | Mission Bay | MEC / Weston | Wet and Dry | Bay, MS4, Groundwater | General Bacteroides by PCR Human Bacteroides by PCR Ribotyping | No | Human markers detected in 9% of samples | Birds Human sources insignificant | 2004. MEC Analytical Systems, Weston Solutions Inc. Mission Bay Clean Beaches Initiative Bacterial Source Identification Study, Final Report. September 2004. |
| 2004 | Los Angeles | Ballona Creek | Noble / SCCWRP | Dry | Creek | FIB (E. coli and Enterococcus) Enterococcus by qPCR Human Bacteroides by PCR Enterovirus | No | Human markers detected in 86% of samples | None | 2006. Noble, RT. Multitiered Approach Using Quantitative PCR To Track Sources of Fecal Pollution Affecting Santa Monica Bay, California. Applied and Environmental Microbiology, 72 (2), February 2006. |
| 2005 - 2006 | Orange | Poche Beach | Weston | Dry | MS4, Channel | FIB (Fecal Coliform and Enterococci) General Bacteroides by qPCR Human Bacteroides by qPCR | No | Not Detected | None | 2006. Weston Solutions Inc. Prima Deshecha Canada Watershed: Poche Beach Bacterial Source Tracking Investigation, Abbreviated Report. November 2006. |
| 2007 | Los Angeles | Los Angeles River | CREST | Dry | River, MS4 | FIB (E. coli and Enterococcus) General Bacteroides by qPCR Human Bacteroides by qPCR (BacHum) Human Adenovirus | Yes | Human markers detected in 50% of storm drain samples (BacHum is validated, but is less specific than HF183) | None | 2008. Bambic, D. CREST Los Angeles River Bacteria Source Identification Study. November 2008. |
| 2007 - 2008 | Orange | Santa Ana River | CDM | Wet and Dry | River/Creek | FIB (E. coli and Fecal Coliform) Human Bacteroides by qPCR Dog and Cattle markers | No | Human markers detected in 16% of samples (11 of 13 sites) Dog and cattle markers | None | 2009. CDM. Middle Santa Ana River Bacterial Indicator TMDL Data Analysis Report. March |

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| | | | | | | | | also frequently detected | | 2009. |
| 2007 - 2009 | Orange | Doheny State Beach | SCCWRP | Dry | Ocean, Creek | FIB (Total/Fecal Coliform, Enterococcus) Enterococcus and E. coli by qPCR 5+ human markers by qPCR Phage, 5 viruses, and other bacteria | Yes | Human markers detected, but not correlated with illness Human marker detection rates not available | Sources not investigated | 2016. SCCWRP. Epidemiologic Evaluation of Multiple Alternate Microbial Water Quality Monitoring Indicators at Three California Beaches. Water Research 94, 371-381. |
| 2007 - 2010 | San Diego | Tecolote Creek | Weston | Wet and Dry | Creek, MS4 | FIB (Total/Fecal Coliform, Enterococcus) Human Bacteroides by qPCR | No | Human markers detected in 7 of 116 samples (5 of 77 during dry weather) | Homeless encampments | 2010. Weston Solutions, Inc. Tecolote Creek Microbial Source Tracking Summary Phases I, II, and III. June 2010. |
| 2008 | Los Angeles | Redondo Beach | City of Redondo Beach / LA County | Dry | Ocean, MS4, Runoff | FIB (Total Coliform, E. coli, and Enterococcus) General Bacteroides by qPCR Human Bacteroides by qPCR (HuBac) Human Adenovirus and Enterovirus | No | Human markers frequently detected in storm drain samples Human markers detected in 1 of 24 samples at 2 ocean sites | Birds and Kelp | 2009. Los Angeles County. Model Program for Bacterial Source Identification and Abatement Plan - Redondo Beach Pier Pilot Project, Final Report and Abatement Plan. December 2009. |
| 2008 - 2011 | San Diego | San Luis Rey River | MACTEC | Wet and Dry | River | FIB (E. coli and Enterococcus) General Bacteroides by qPCR HF183 and BacHum by qPCR Gull marker by qPCR and Enterovirus Community Analysis (TRFLP) | Yes | Human markers frequently detected during wet and dry weather with more frequent detection during wet weather | None | 2011. MACTEC; Noble, R.; Griffith, J.; Fuhrman, J. Lower San Luis Rey River Bacterial Source Identification Project. July 2011. |

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| 2009 | Los Angeles | Malibu Creek | UCLA | Wet and Dry | Ocean, Creek, Lagoon | FIB (Total Coliform, E. coli, and Enterococcus) HF183 SYBR by qPCR | No | Human markers detected in 5 of 80 samples (all in lagoon) | Sources not investigated | 2009. UCLA. 2009 Investigation of Spatial and Temporal Distribution of Human-specific Bacteroidales marker in Malibu Creek, Lagoon and Surfrider Beach. |
| 2009 | San Diego | San Diego River | Weston | Dry | River | FIB (Fecal Coliform and Enterococcus) General Bacteroides by qPCR Human Bacteroides by qPCR | No | No human markers detected during dry weather | None | 2009. Weston Solutions, Inc. San Diego River Source Tracking Investigation, Phase I Final Report Revision 1. December 2009. |
| 2009 - 2010 | Los Angeles | Malibu Lagoon | USGS | Dry | Ocean, Lagoon, Groundwater | FIB (Total Coliform, E. coli and Enterococcus) HF183 SYBR by qPCR Community Analysis (TRFLP and Phylochip) | No | Not Detected | None | 2012. USGS. Sources of Fecal Indicator Bacteria to Groundwater, Malibu Lagoon and the Near-shore Ocean, Malibu, California, USA. Annals of Environmental Science, 6, 35-86. |
| 2010 | Orange | Santa Ana River | UCI | Dry | River | FIB (E. coli and Enterococcus) Enterococcus by qPCR HF183 SYBR by qPCR | No | Human markers frequently detected in 2 of 9 river sites tested (59% and 25% detection) | None | 2010. Litton, RM et al. Evaluation of Chemical, Molecular, and Traditional Markers of Fecal Contamination in an Effluent Dominated Urban Stream. Environmental Science and Technology 44, 7369-7375. |
| 2010 | San Diego | San Diego River | Weston | Wet | River | FIB (Fecal Coliform and Enterococcus) General Bacteroides by qPCR Human | No | Human markers detected in 6 of 40 | None | 2010. Weston Solutions, Inc. San Diego River Source Tracking |

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| | | | | | | Bacteroides by qPCR | | samples | | Investigation, Phase II Final Report. June 2010. |
| 2010 - 2011 | Orange | Poche Beach | Weston | Dry | MS4, Groundwater | FIB (Total/Fecal Coliform and Enterococcus) General Bacteroides by qPCR HF183, dog, and gull markers by qPCR | Yes | Not Detected | Gulls and dogs (minor) | 2012. Weston Solutions, Inc. Poche Beach Bacterial Source Identification Study, Draft Report. March 2012. |
| 2010 - 2012 | San Diego | Tijuana River | Weston | Wet and Dry | River, MS4, Groundwater | FIB (Total/Fecal Coliform and Enterococcus) General Bacteroides by qPCR HF183 by qPCR and Enterovirus | Yes | Human markers detected in both dry and wet weather with most detections in wet weather runoff originating from Mexico | None | 2012. Weston Solutions, Inc. Tijuana River Bacterial Source Identification Study, Final Report. August 2012. |
| 2011 | Orange | Doheny State Beach | SCCWRP | Dry | MS4, Creek, Ocean, Groundwater | FIB (Total Coliform, E. coli and Enterococcus) Enterococcus by qPCR HF183 and HumM2 by qPCR | Yes | HF183 detected in 89% of storm drain and 54% of ocean samples HumM2 detected in 61% of storm drain and 13% of ocean samples HF183 and HumM2 also detected in Creek samples Only 1 groundwater detection of HumM2, none for HF183 | Rhodamine dye testing identified sanitary sewer leaks in bathrooms at the beach Birds a likely FIB source | 2015. SCCWRP. Use of Dye Tracers and qPCR to Identify Human Fecal Contamination at Doheny State Beach, Dana Point, CA. Technical Report 860. April 2015. |
| 2012 - 2014 | Los Angeles | Topanga Beach | UCLA | Wet and Dry | Ocean, Lagoon, Creek | FIB (Total Coliform, E. coli, and Enterococcus) HF183 and BacHum markers by qPCR Dog, gull, and horse markers | Yes | Human markers detected in 13% of ocean, 14% of lagoon samples Gull and dog markers frequently detected in ocean and lagoon | Gulls and dogs to the beach and lagoon | 2014. UCLA. Topanga Source ID Study FINAL Report Dec 2012 - August 2014. October 2014. |

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| 2012 - 2015 | Los Angeles | Inner Cabrillo Beach | Weston | Dry | Ocean, Sand, Sediment, Eelgrass | FIB (Total Coliform, E. coli and Enterococcus) Enterococcus by qPCR HF183, gull, and dog by qPCR | Yes | Human markers detected in <2% of inner beach samples Human markers detected in 11% open ocean samples Gull detected frequently at all sites, no dog detections | Birds/Gulls | 2015. Weston Solutions, Inc. Inner Cabrillo Beach Bacteria TMDL Update. CASQA Presentation. October 2015. |
| 2013 | San Diego | San Diego River | Geosyntec | Dry | MS4 | FIB (Fecal Coliform and Enterococcus) HF183 and HumM2 by qPCR BacCan dog marker by qPCR | Yes | Human markers quantified in 4 of 20 outfalls (1 of 4 verified) Dog marker found in 3 outfall samples | Homeless encampments Pet waste and urban wildlife | 2014. Geosyntec Consultants. Dry Weather Microbial Source Tracking Study Preliminary Findings Report, San Diego River Watershed. December 2014. |
| 2014 | San Diego | San Luis Rey River | Geosyntec | Dry | MS4 | FIB (Fecal Coliform and Enterococcus) HF183 and HumM2 by qPCR Dog, Ruminant, Cow, Horse, and Pig markers | Yes | Human markers detected in 4 of 14 outfalls Dog marker found in 4 outfall samples, pig and ruminant in one | Pet waste and urban wildlife No human sources identified | 2015. Geosyntec Consultants. Dry Weather Microbial Source Tracking Study Preliminary Findings Report, San Luis Rey Watershed. December 2015. |
| 2014 - 2015 | San Diego | Ocean Beach and Tourmaline Surfing Park | SCCWRP | Wet and Dry | Ocean, Creek/River, MS4 | FIB (Total/Fecal Coliform, Enterococcus) Enterococcus and HF183 by ddPCR Human Adenovirus and Norovirus Coliphage, Enterovirus, Salmonella, Campylobacter, Giardia, and Cryptosporidium | Yes | Human markers found in all source waters tested HF183 detected in 86% of San Diego River samples HF183 detected in 95% of Tourmaline Creek samples Norovirus, Adenovirus, Campylobacter, and | Sources not investigated | 2016. SCCWRP. Wet Weather Epidemiology Study. SCCWRP Commission presentation. March 2016. |

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| | | | | | | | | Salmonella also detected in river/creek samples | | |