Water Quality Monitoring Strategies for the Indian River, Sitka, Alaska

By Edward G. Neal and Edward H. Moran

Administrative Report
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Contents

Figures

Tables

Conversion Factors

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)

Area		
acre	0.4047	hectare (ha)
square mile (mi^2)	2.590	square kilometer (km^2)
Flow rate		
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:
°F=(1.8×°C)+32
Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as follows:
°C=(°F-32)/1.8
Specific conductance is given in microsiemens per centimeter at 25 degrees Celsius (µS/cm at 25 °C).
Concentrations of chemical constituents in water are given either in milligrams per liter (mg/L) or micrograms per liter (µg/L).

NOTE TO USGS USERS: Use of hectare (ha) as an alternative name for square hectometer (hm^2) is restricted to the measurement of small land or water areas. Use of liter (L) as a special name for cubic decimeter (dm^3) is restricted to the measurement of liquids and gases. No prefix other than milli should be used with liter.

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Abstract

The Indian River Basin, near Sitka Alaska, drains an area of 12.3 square miles and is an important natural resource of Sitka National Historic Park. Currently the watershed faces increasing development on tracts of private land upstream of the park that could affect the water quality and aquatic habitat of Indian River. The National Park Service requested technical assistance from the U.S. Geological Survey to develop monitoring strategies for the Indian River. The approach was to review existing literature on development and associated impacts to water-quality and aquatic-habitat parameters on river basins with similar climatic and hydrologic characteristics to the Indian River. Previous work evaluating the water-quality and aquatic habitat of the Indian River also was reviewed in order to develop monitoring strategies that would aid the National Park Service in detecting changes in streamflow, water quality, and aquatic habitat of the Indian River and its downstream tributaries. In addition, remotely sensed data were utilized to estimate the amount of impervious surface within the Indian River basin.

Introduction

The Indian River is in southeast Alaska, near the town of Sitka and drains an area of 12.3 square miles (mi^2) (fig. 1). Sitka National Historical Park (SNHP) is located near the mouth of the Indian River and preserves historically and culturally significant sites and artifacts related to the 1804 Battle of Sitka, the Russian-American period in Alaska, and the Alaska Native people of southeast Alaska. Indian River is an important natural resource in SNHP and provides a critical link to understanding the cultural history and events that took place in the 1800s. The SNHP is concerned that existing and continued development may degrade the water quality and aquatic habitat of the Indian River and that past land use practices already may have altered habitat in the distal reaches.

Previous work funded by the National Park Service/U.S.Geological Survey (USGS) Water-Quality Partnership Program analyzed discharge, water-chemistry, bed-sediment, and biological data and indicated that thus far Indian River has suffered minimal effects from development (Neal and others, 2004). Additional work providing baseline information useful to future monitoring studies on the Indian River includes an inventory and assessment of conditions and impairments of water resources in the coastal region of Sitka, Alaska (Eckert and others, 2006). An aquatic resource survey conducted by

Paustian and Hardy (1995) assessed aquatic resource conditions and trends within SNHP. Instream flow investigations were previously undertaken by Nadeau and Lyons (1987). Shannon and Wilson Inc. (written commun., 1995) conducted an environmental site assessment at a former asphalt plant within the SNHP. The USGS collected streamflow data on the Indian River from August 1980 through September 1993 and from October 1998 through September 2005 (USGS, 1981-2006).

Until recently, urban development within the Indian River watershed has been limited to small areas in the lower reaches. City and Borough of Sitka (CBS) lands adjacent to the river recently have been rezoned from public to residential. Housing areas with large amounts of impervious surfaces have been developed and an additional 180 acres of private land has been marketed for further development. Additional reaches upstream of the Park may be developed in the future. In the Pacific Northwest, development has been widely identified as a major contributor to water-quality and aquatic-habitat degradation (Gregory and Bisson, 1997). A short list of common problems associated with development include loss of habitat diversity, increases in impervious surfaces, pollution, siltation associated with increased erosion, loss of riparian vegetation, and diversions creating fish passage barriers.

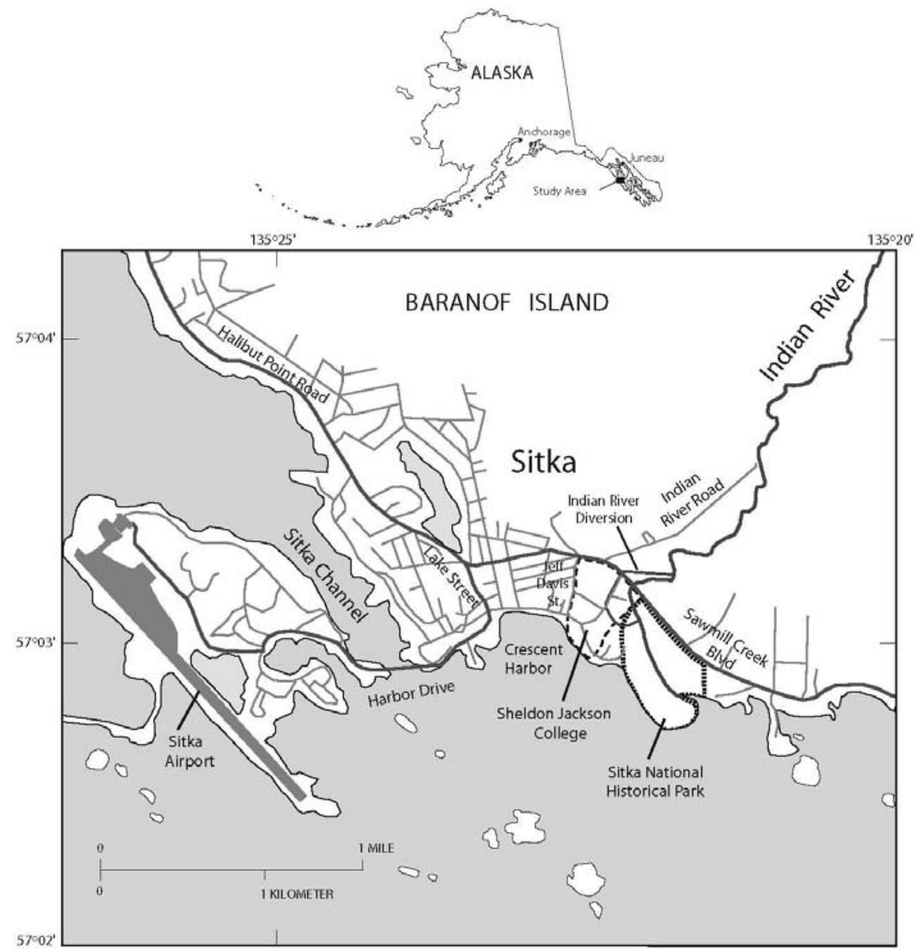

Figure 1. Location of Sitka and the Indian River.

Acknowledgment

The authors thank Geoffrey Smith of the National Park Service who assisted with the development of the monitoring strategy.

Purpose and Scope

The purpose of this report is to provide an overview of monitoring strategies that SNHP can use to detect changes in streamflow, water quality, and aquatic habitat of the Indian River and its downstream tributaries. The scope of this report is limited to an examination of remotely sensed data available in 2007 and a review of literature examining impacts of urban and residential development on water quality and aquatic habitat of other Pacific Northwest streams, particularly as they relate to salmon ecology. Monitoring strategies for atmospheric deposition of mercury and persistent organic pollutants potentially of concern to Alaska and SNHP are beyond the scope of this report. The report suggests sampling and monitoring strategies for different components of the watershed that aim to identify future impacts on the water quality and aquatic habitat of the Indian River drainage.

Potential Threats to Water Quality and Aquatic Habitat of the Indian River

While examining the degradation of anadromous salmon habitat in the Pacific Northwest, Gregory and Bisson (1997) found that modification of aquatic habitats typically affects one or more of six elemental components of stream ecosystems: channel structure, hydrology, sediment input, environmental factors, riparian forests, and exogenous materials. Site visits to the Indian River combined with a review of literature pertaining to urbanization and habitat degradation in the Pacific Northwest aided in identifying potential threats to the water quality and aquatic habitat of the Indian River.

Diversions and Instream Flow

A primary issue of concern on the Indian River is maintenance of adequate levels of instream flow (Eckert and others, 2006). Low flow negatively affects suitable habitat for salmon spawning, incubation, and rearing (Nadeau and Lyons, 1987). At SNHP maintaining adequate instream flows is also important for salmon viewing and sport fishing. Low flows in the river occur naturally and as a result of diversions by Sheldon Jackson College (SJC) and occasionally CBS. Flow diversion by SJC and CBS periodically conflict with water rights reserved by the Alaska Department of Fish and Game (ADFG) for instream flows to protect salmon habitat in the Indian River. Streamflow investigations conducted by the USGS in 2001 and 2002 indicated ADFG flow reservations were not met for 106 and 172 days, respectively (Neal and others, 2004). Diversions were responsible for reduction in flows below ADFG reservations for a total of 140 of the 278 days.

Urbanization

Impervious surfaces and contaminants

Development within a watershed typically results in an increase in impervious surfaces, which can influence stream ecology through changes in channel structure, hydrology, sediment input, water chemistry, and riparian habitat of a stream. A recent study (Ourso and Frenzel, 2003) conducted in Alaska shows changes in stream basin variables including riparian habitat, instream habitat, macroinvertebrate populations, and water and sediment chemistry are correlated with impervious area as low as 5 percent, much lower than previous literature suggests. Among the greatest changes urbanization can produce in stream environments is an increase in both frequency and magnitude of peak discharges. The rapid surface-water runoff during storms results from increases in impermeable surfaces such as streets, parking lots, and roofs (Leopold, 1968; Hollis, 1975). Currently, the amount of developed area within the basin is small (figs. 2-4); however, continued development in the Indian River watershed may result in an increase in frequency and magnitude of peak discharges, particularly within the tributaries located in the lower reaches. Increases in magnitude and frequency of peak discharges have been shown to have negative effects on salmon and stream ecosystems including scouring of redds (Quinn, 2005), reductions in primary and secondary productivity (Anderson, 1992; Borchardt, 1993), depletion of large woody debris (Culp, 1988; Collins and Montgomery, 2002), and accelerated erosion of stream banks (Cristner and Harr, 1982; Berris and Harr, 1987).

Increases in developed areas and impervious surfaces also may create influxes of contaminants such as hydrocarbons, heavy metals, or other toxic substances. Recent studies conducted by the USGS (Van Meter and others, 2006) have identified parking lot or asphalt sealcoat as a major and previously unrecognized source of polycyclic aromatic hydrocarbon (PAHs) contamination. PAHs are a group of organic contaminants that form from the incomplete combustion of hydrocarbons such as gasoline. Several PAHs are suspected human carcinogens and are toxic to aquatic life. Numerous studies have illustrated the toxicity of parts per billion exposures to developing Pacific herring embryos (Carls and others, 1999), and pink salmon (Marty and others, 1997; Heintz and others, 1999). Recent work by Heintz (in press) suggests that exposure to PAH compounds found in storm-water runoff may reduce pink salmon productivity in urbanized streams and estuaries.

In addition to potentially harmful PAH compounds, Brabetto and Booth (2003) have shown that toxic concentrations of copper and zinc were reached in many asphalt runoff samples in the Pacific Northwest. Furthermore, Baldwin and others (2003) found that short-term influxes of dissolved copper to streams may interfere with olfactory-mediated behaviors critical to the survival of salmon. Copper is a major toxic metal in storm water and is correlated with the intensity of vehicular traffic (Makepeace and others, 1995).

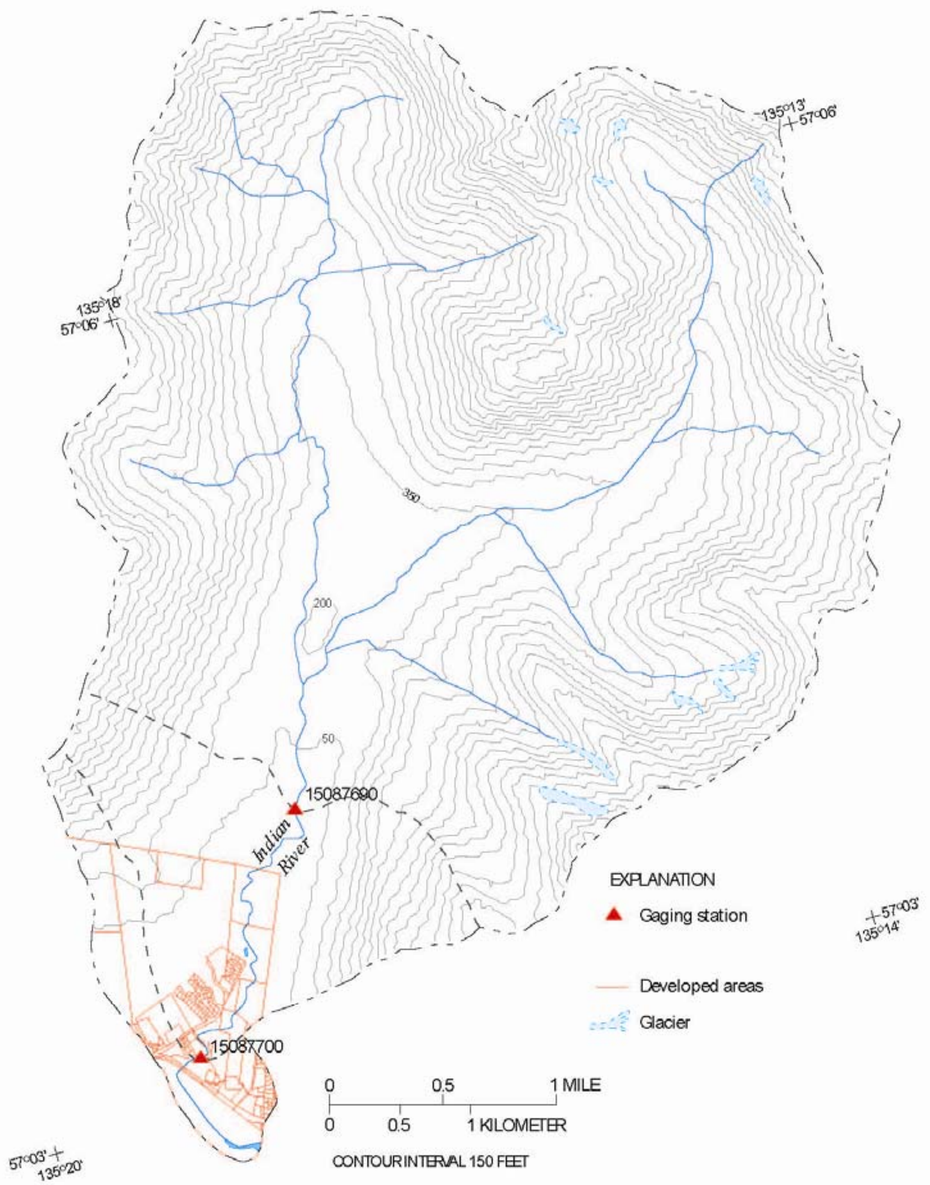

Figure 2. Indian River watershed.

Habitat loss and alteration

In the Pacific Northwest alterations of aquatic habitat associated with urbanization are more severe than habitat alterations attributed to agricultural, range, or forested land use (Booth, 1991). Obvious direct effects of urbanization on aquatic habitat include the loss of habitat or connectivity through development activities such as filling wetlands, encroachment into riparian areas and flood plains; and channel modifications including channelization, crossings, and culverts. Indirect effects of urbanization include channel incision, loss of channel complexity, changes in channel width-to-depth ratios, erosion, and increases in fine sediments (Lucchetti and Fuerstenberg, 1993). Disruption of natural drainage patterns due to road construction, poorly designed culverts, and stream crossings combined with a reduction of ground-water recharge due to increases in impervious surfaces can also reduce baseflows in critical rearing habitats (Leopold, 1968).

In streams like the Indian River, the incremental modification or loss of flood-plain, side-channel, or tributary habitat and riparian forests through development practices may adversely impact salmon spawning and rearing habitat in subtle ways that can be difficult to measure. Due to remote locations, small size or ephemeral nature of these habitat types, many have not been surveyed and are not included in the ADFG catalog of important habitat for anadromous fish (Johnson and Weiss, 2006). The maintenance of healthy salmon runs in SNHP is important because spawning salmon have significant impacts on both terrestrial and freshwater aquatic ecosystems. When salmon migrate from the ocean to their native stream to spawn, they transport nutrients and energy from the marine environment to freshwater and terrestrial ecosystems (Gende and others, 2002).

Indian River asphalt site

From 1957-1961 an asphalt plant was in operation near the mouth of the Indian River on the northeast bank (fig. 3). Soils from the 0.75 acre site, contaminated with weathered diesel- and asphalt-range organics, have been eroding into the river and estuary since at least 1990 (Shannon & Wilson Inc., written commun., 1995). The bank of the Indian River has eroded at the site exposing debris including drums, miscellaneous equipment, metal debris and chunks of asphalt, all of which were evident during a site visit in April 2007. In the early 1990s, employees of the NPS and Alaska Department of Environmental Conservation reported the persistence of an oily sheen originating from the bank at the abandoned asphalt plant (Shannon & Wilson Inc., written commun., 1995). There have been no further reports of a sheen following erosive storm events of the early 1990s.

Following the recommendation of Shannon and Wilson Inc., the NPS has taken no remedial action. A monitoring program initiated by the NPS from 2002-2005 resulted in no detections of contaminants (Geoffrey Smith, NPS, oral commun., 2007). Although the erosion of contaminated soils appears to have abated since the mid-1990s the potential exists for future erosion of these soils. Periodic monitoring of this site may be useful in identifying future erosion of potentially contaminated soils.

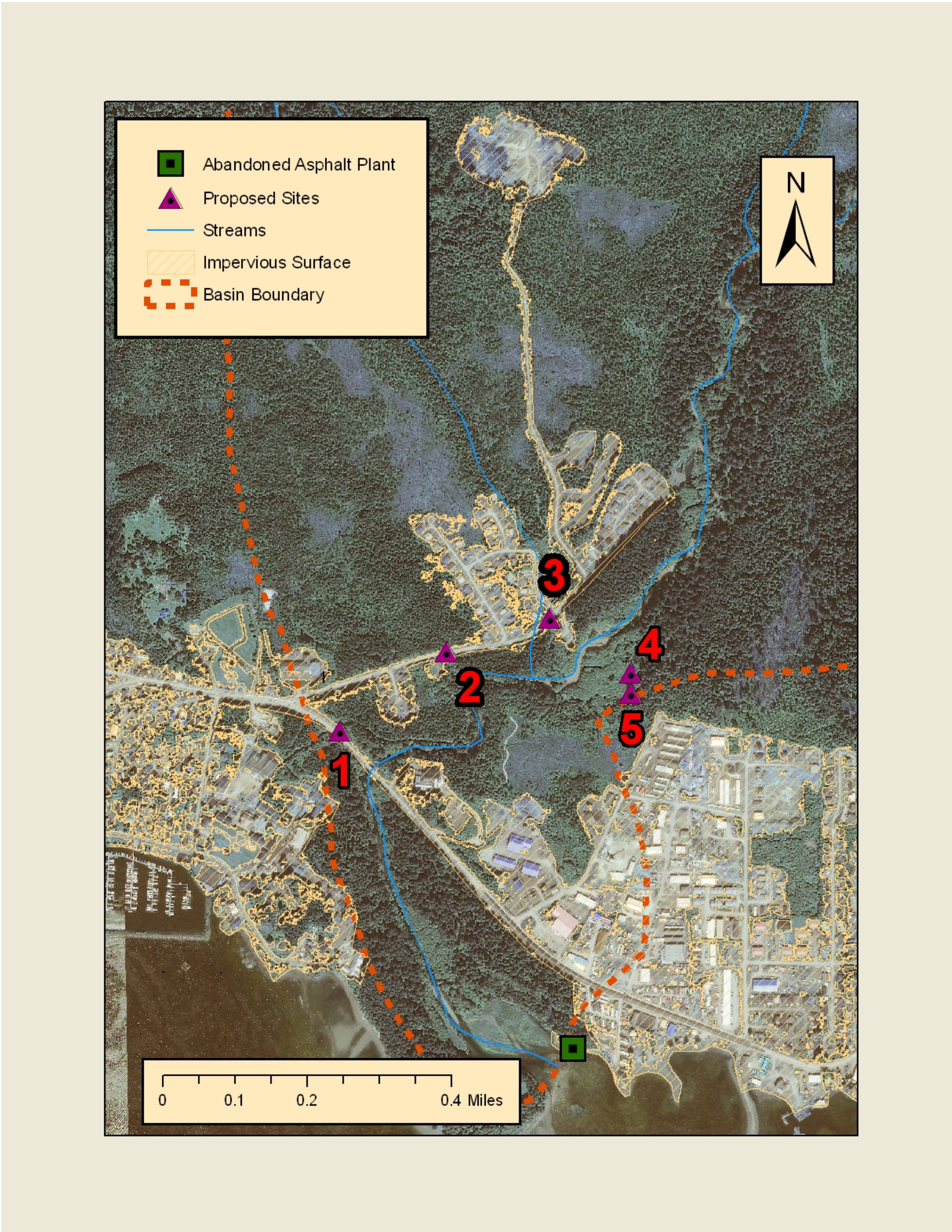

Figure 3. Satellite imagery of the lower Indian River showing basin boundary, estimated impervious area, and proposed monitoring sites at five tributary streams.

Methods

Estimations of the urban-impervious areas in the Indian River basin were made using 2005 IKONOS satellite imagery. Impervious-surface area was calculated by reducing the 4-band multispectral image to a single image. The reduced single images were then used to classify each pixel as either impervious or not impervious. Automated misclassified impervious-surface pixels, such as water-surfaces and shadowed areas, were manually removed from the final product through visual inspection of the 4-band image.

Small tributaries flowing through areas with residential development or zoned for future development were identified in the field, and points near their confluences with the Indian River were mapped with a handheld global positioning system. Many, but not all of the smaller tributaries within the region zoned for development were identifiable using remotely sensed data. Monitoring strategies were developed based on field visits, examination of maps and remotely sensed data, previous monitoring conducted on the Indian River and review of literature pertaining to urbanization and aquatic habitat degradation.

Urban Areas and Impervious Surfaces

The total length of all channels in the Indian River watershed was estimated from satellite imagery as 34 mi, however, not all channels were identifiable using maps and remotely sensed data. All urban development within the Indian River basin is in the lower 7 percent of the basin and includes 0.12 mi^2 of urban-impervious area as estimated from satellite imagery (figs. 3 and 4). Although the amount of impervious surface is just 1 percent of the Indian River basin, most of that exists in the lower part of the watershed (fig. 3).

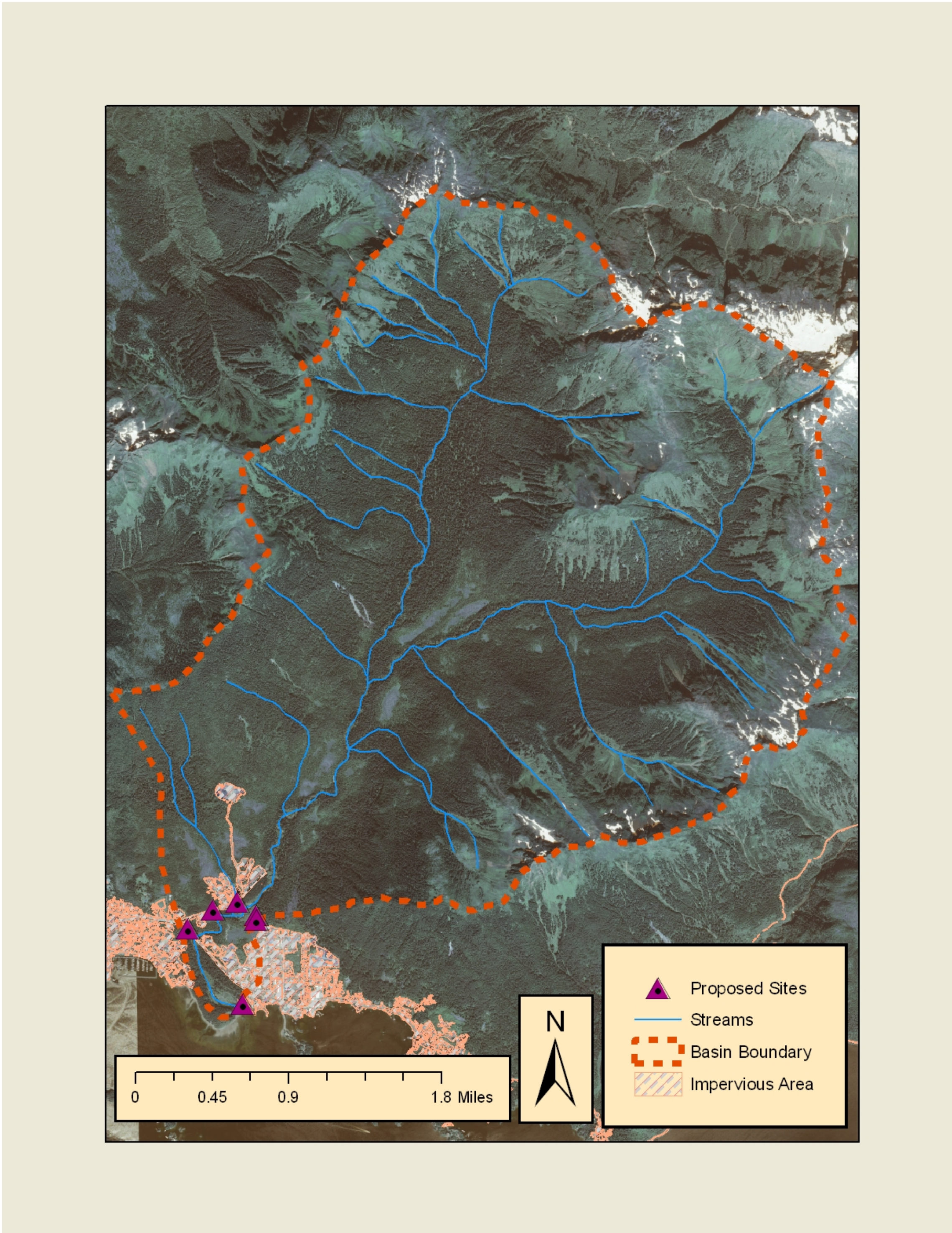

Figure 4. Satellite image of the Indian River watershed showing basin boundary and estimated impervious area.

Monitoring Strategies

The following sections outline suggested monitoring strategies for different components of the Indian River drainage including tributaries, storm-water return flow, and the Indian River main stem. The strategies do not include sampling or monitoring protocols, but rather list parameters or conditions that should be monitored to detect changes in the water chemistry, streamflow, and aquatic habitat.

Tributary Streams

Tributary streams one, two, and three (fig. 3) should be monitored to establish baseline conditions. During the site visit on April 19, 2007 fish were present in these streams, although species were not identified. Tributaries two and three were identified as fish-bearing streams (coho salmon rearing habitat) by Johnson and Weiss (2006). Stream discharges for tributaries one and two were estimated at 1 ft^3/s, discharge in tributary three was estimated as less than 0.4 ft^3/s, which indicates that it may be intermittent. Diversions and drainage associated with road building and development have the potential to alter drainage patterns and dynamics in these three tributaries. Because all three tributaries flow adjacent to or are crossed by existing roadways, there is a potential for an increase in the delivery of fine sediment. Where tributary three flows adjacent to the roadway, riparian vegetation has been cut down by what appeared to be routine roadside maintenance. Although tributaries were not mapped in their entireties and their associated drainage networks were not determined, they appeared to flow through regions zoned for future development and through currently developed areas.

Two additional small tributaries (four and five, fig. 3) also were identified during the site visit in 2007. They both enter the left (east) bank of the Indian River through a flood plain side channel. These tributaries are not identified by ADFG as anadromous fish habitat although fish were present in tributary four (fig. 3). Discharges in tributaries four and five were estimated at less than 0.4 ft^3/s suggesting that flow may be intermittent.

Suggested Monitoring

Streamflow

It is unknown if the tributaries discussed in the previous section flow perennially or, if so, their upstream extent of perennial flow. Streamflow in tributaries 1-3 should be gaged or systematically monitored near their confluences with the Indian River to establish flow dynamics of these systems. If continuous recording gages cannot be operated, crest-stage gages would aid in determining flood frequency and magnitude in these tributaries. During periods of low flow, it also may be of value to establish the upstream extent of perennial discharge. Flow data associated with these tributaries will be useful in determining their function with respect to rearing habitat for juvenile salmon.

Water Quality

Water samples from the tributaries identified in figure 3 should be sampled for nutrients, field parameters (temperature, pH, dissolved-oxygen concentration, conductivity and alkalinity), suspended-sediment concentration, fecal coliform bacteria, dissolved copper, zinc, water hardness, and PAHs.

Samples should be collected such that the water chemistry is defined seasonally and during periods of high and low discharges. Trace elements and organic compounds in bed materials also should be sampled to determine existing conditions.

Under ideal conditions both discharge monitoring and water-chemistry sampling of the tributaries would have been conducted prior to development within their basins in order to determine baseline conditions. It would be prudent to conduct samples on these tributaries as soon as possible to establish reference conditions prior to additional development. Additional monitoring should be conducted every 5-10 years. However, monitoring frequency may need to be increased if problems are identified after sampling is initiated or following additional development within the drainages.

Aquatic Habitat

The presence of anadromous fish, or the extent of their range within each tributary, should be determined with the use of small nets or minnow traps baited with salmon eggs. The habitat conditions should be well documented within the stream reaches that support anadromous fish. Habitat conditions could be readily documented using monumented photo points, video recordings, or both. It would be preferable to monitor both the presence of anadromous fish and habitat conditions seasonally (i.e., during spring, summer, winter, and fall).

Stormwater Discharge

During the field reconnaissance visit in April 2007 discharges in stormwater drainage systems were minimal or dry making it difficult to determine which stormwater systems would be suitable for sampling. It should be noted that a stormwater detention facility was in place at the downstream end of one of the developments located upstream of SNHP and immediately adjacent to tributary 3 (fig. 3). The detention facility consisted of a detention pond to allow for the settling of particulates downstream of the developed area. Ideally all stormwater flows would be sampled during runoff events. These sites should be further investigated during storms to determine their relative contributions to stormwater runoff, and to refine monitoring strategies.

Suggested Monitoring

Stormwater return flows should be measured for discharge and sampled for dissolved copper, zinc, and PAHs as identified by Van meter and others (2006) and for nutrients, field parameters, and suspended sediments. Samples should be collected during periods of stormwater runoff.

Indian River

In 2001 and 2002, the USGS conducted extensive monitoring of the Indian River near the gaging station Indian River at Sitka (station 15087700) and Indian River near Sitka (station 15087690) (fig. 2). Results of this study suggest that at the time development within the drainage had not detectably affected water chemistry, bed-sediment chemistry, or benthic algae and macroinvertebrate communities

(Neal and others, 2004). The results of this previous investigation should be used as a baseline for future monitoring activities on the mainstem Indian River.

Suggested Monitoring

Streamflow

Streamflow should be continuously monitored upstream and downstream of existing diversion structures (station nos. 15087690 and 15087695, fig. 2) to allow for temporal analysis of the impacts of diversions on instream flows within SNHP. Work by Neal and others (2004) has shown flow diversions upstream of SNHP commonly result in flows below reservation levels established by ADFG. Continuous monitoring of discharges would also aid in definition of changes in the frequency and magnitude of peak flows.

Water Quality

Physical, chemical, and biological water-quality parameters summarized in Neal and others (2004) should be monitored over a range of discharges at 5-10 year intervals at the downstream site 15087700 (fig. 2). Results of subsequent monitoring can be compared directly to previously established baseline conditions. If significant differences in monitoring parameters are detected it may be of use to repeat sampling at site 15087690 (fig. 2) to determine if similar changes occurred within the undeveloped reach. In addition to analytes investigated previously, water-quality samples should be analyzed for dissolved copper, zinc, and PAHs as these constituents have recently been identified in stormwater runoff in developed areas and were not examined in prior studies. Because pollutants from developed areas are known to accumulate on impervious surfaces between rainfall events (Roesner, 1982), samples analyzed for PAHs and dissolved copper and zinc should be collected at the start of storms to determine it they are present in pulsed events.

Sampling/Monitoring Protocols

The primary objective when collecting samples or monitoring data is to obtain data representative of the system being studied. Sampling equipment, collection, and processing techniques for different constituents typically vary with the type of sample being collected. Incorrect sampling methods can result in data that are not representative of the system being evaluated. Furthermore, if the sample is contaminated or degraded prior to analysis, the resulting data is less valuable and study results may be uncertain. Compliance with documented and technically approved sample collection and processing protocols will aid in ensuring the quality of the environmental samples and data. Although the selection of environmental monitoring protocols is beyond the scope of this report, table 1 provides a summary of protocol utilized by the USGS to collect environmental data pertaining to water chemistry and aquatic habitat. Also listed are recommended methods for conducting biological assessments appropriate for the Indian River.

Table 1. List of suggested references detailing protocols for the collection of water-quality samples, biological assessments, stream physical characteristics, streambed sediment samples, and selected physical properties

Surface-water sampling	Suggested references
Equipment selection	Horowitz and others, 1994; Lane and others, 2003
Sample collection	Horowitz and others, 1994; Wilde and others, 2004; Edwards and Glysson, 1999; Ward and Harr, eds., 1990
Cleaning sampling and processing equipment	Wilde, 2004
Field measurements: temperature, dissolved-oxygen concentration, specific conductance, pH and alkalinity	Wilde, ed., variously dated
Biological Samples	
Benthic invertebrates	Cuffney and others, 1993; Rinella and others, 1995; ENRI, 1999a
Algae	Porter and others, 1993; ENRI, 1999b
Stream habitat and physical characteristics	Meador, Hupp, and others, 1993; Fitzpatrick and others,1998
Fecal indicator bacteria	Myers and Wilde, eds., 2003
Sediment samples	
Suspended sediment	Edwards and Glysson, 1999
Streambed/bottom sediment	Shelton and Capel, 1994; Radtke, 1997

Summary

This report provides suggested monitoring strategies that would aid Sitka National Historic Park in detecting changes in streamflow, water quality, and the aquatic habitat of the Indian River and its tributaries within areas zoned for development. The approach used to develop the monitoring strategies was to review existing literature on urban development and associated impacts to water-quality and aquatic-habitat parameters on river basins with similar climatic and hydrologic characteristics to the Indian River. Site visits and the review of previous studies of the Indian River aided in refining the monitoring strategies. The proposed strategies assume optimum monitoring capabilities.

All urban development within the Indian River basin occurs within the lower 7 percent of the basin, and includes 0.12 square miles of impervious area as estimated from satellite imagery. Future monitoring of the Indian River should focus on the lower seven percent of the drainage, as the watershed upstream is undisturbed.

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