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Traffic Signal Study
Phase I Final Report

Prepared for:

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Phase I Final Report

BACTS

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1.0 EXECUTIVE SUMMARY

The BACTS Traffic Signals Study was undertaken to develop a plan for reducing delay and congestion in selected commuter corridors, primarily through improvements in the synchronization, phasing plans, and timing patterns of existing traffic signals. The arterial corridors targeted for study included the coordinated signals systems on Union Street and Broadway in Bangor, the single-controller, dual-intersection system on Main Street in downtown Orono, and the single-controller, dual-intersection system on Center Street in downtown Old Town.

In January 2009, the BACTS Policy Committee decided to expand the study area to include all signalized intersections and signal systems in the BACTS urbanized area, with the goal of submitting a prioritized system-wide equipment acquisition plan for possible funding under the new federal infrastructure initiative. The recommendations from that study will be presented as the Phase II deliverable, consisting of the system-wide prioritized acquisition plan and cost estimates presented in spreadsheet format. The remainder of this report addresses only the findings from Phase I.

An inventory of existing traffic signal equipment at each Phase I intersection indicated that the Bangor corridors required only minor equipment upgrades: a few additional system detectors, repairs or adjustments to existing detectors, and troubleshooting to fix problems with faulty controller modules and inter-controller communications hardware. In fact, the Bangor controller inventory has always been capable of far more sophisticated operations than it was previously programmed to provide. Through this study, BACTS has been able to harness the full power of modern traffic controller technology to implement adaptive traffic-responsive operations in both the Broadway and Union Street commuter corridors, resulting in improved flows and reduced signal delays under all traffic conditions.

The Orono and Old Town corridors, on the other hand, were found to be operationally deficient and technologically constrained by their existing signal equipment. The dual-intersection, single-controller systems in both of these corridors introduce added delay through the use of hard-wired phase overlaps, as this is the only way to run all of the required movements from a single Multisonics controller. These older-manufacture controllers do not provide enough channels and programming capability to enable state-of-the-art operational improvements for vehicular and pedestrian traffic. Sewall was able to identify and implement some minor timing improvements for the Orono and Old Town intersections, but both systems will require significant new investment in both detection and controller equipment before any significant reductions in delay and congestion can be achieved.

A summary of recommendations and estimated costs for future traffic signals improvements to these corridors is provided at the conclusion of this report.

2.0 INTRODUCTION

In October 2005, BACTS commissioned the James W. Sewall Company (Sewall) to perform a traffic signals study. This study was undertaken to identify upgrades to existing signalized intersections that would help to reduce delay and peak-hour congestion in selected commuter corridors. As the biennial federal allocation has steadily declined relative to project costs and needs in the urbanized area over the past decade, the BACTS Policy Committee has been increasingly tasked with identifying ways to "do more with less." In this case, there was general recognition among committee members that operational upgrades to traffic signals, particularly in commuter corridors where the traffic flows tend to be more directional during the morning and evening peak hours, could help to delay or prevent the need for more expensive road widening projects in the future.

The BACTS Traffic Signals Study was conducted with the following objectives:

1. Identify existing deficiencies in the traffic signal control systems within the study area, and determine whether any of these deficiencies could be corrected at little or no additional cost to improve system operations.

2. Analyze recent volume and turning movement counts relative to existing timing and synchronization plans. Develop new optimized plans that will enable Bangor's modern controllers to operate in a traffic-responsive mode, rather than in the less flexible but commonly used time-of-day mode.

3. In coordination with municipal staff, implement new traffic plans and monitor their performance under all traffic conditions. Field-check and adjust each system as needed until satisfactory performance is achieved.

4. For the systems where Sewall has recommended investments in modernized signal control equipment, develop a prioritized acquisition plan for new equipment purchases that BACTS can use to scope projects for inclusion in future biennial transportation improvement programs (BTIPs). Identify and implement any interim improvements that can be accomplished at little or no cost.

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3.0 STUDY LIMITS

The following boundaries defined the study area for this project:

Bangor Union Street Corridor:

All signalized intersections between 14th Street and Griffin Road, including the master controller located at the Burger King entrance.

Bangor Broadway Corridor:

All signalized intersections between the I-95 northbound on-ramp and Grandview Avenue, including the master controller located at the Broadway Shopping Center entrance.

Orono Main Street Corridor:

Signalized intersections at Pine Street and Mill Street, operated by a single controller located near the corner of Main and Pine Streets.

Old Town Center Street Corridor:

Signalized intersections at Main Street and Water Street, operated by a single controller located on the corner of Center and Main Streets.

4.0 EXISTING CONDITIONS

Existing conditions and a detailed equipment inventory for all of the signalized intersections in the corridor study areas were documented in BACTS Traffic Signal Analysis: Technical Memorandum No.1, delivered to BACTS in August 2006. The general findings were that both Bangor coordinated signals systems were already working fairly well, and they could be improved greatly with just a few minor upgrades in system detection and communication equipment. Sewall's recommendations for short-term upgrades were implemented during the course of the BACTS Traffic Signal Study.

Prior to this study, the Bangor signal systems operated in a time-of-day mode, in which the master controller for each corridor is programmed to switch timing plans at a specific time each day to respond to predicted changes in traffic conditions. For example, a controller may be programmed to run a weekday morning peak hour plan from 6 a.m. to 9 a.m., a mid-day plan from 9 a.m. to 3 p.m., a weekday evening plan from 3 p.m. to 6 p.m., a nighttime plan from 6 p.m. to midnight, and a flashing-light program from midnight to 6:00 a.m. Weekend programs and special-events programs may also be provided. The time-of-day mode works well as long as corridor traffic patterns do not vary significantly from day to day and hour to hour. However, traffic engineering researchers have determined that peak hour volumes can vary as much as 20 percent on successive weekdays. A time-of-day system ignores these normal variations in traffic flow and directionality, and system operators must intervene to change the program manually if traffic becomes severely congested due to roadwork, crashes, bad weather, special events, and all other unforeseen or unusual factors. Time-of-day mode was the best option available for many years due to the limitations of older-technology controllers. However, the current generation of traffic controllers permits a more sophisticated traffic-responsive mode in which the controller automatically selects the most appropriate timing plan, based on real-time monitoring of traffic volumes and directionality of flow. The equipment in Bangor was assessed to be capable of traffic-responsive operations with only a few minor equipment upgrades, so these upgrades were the focus of Sewall's preliminary recommendations for the two Bangor corridors.

The equivalent to traffic-responsive operations for an isolated single-controller system, like those used in Orono and Old Town, are so-called "free" operations.

Free operations allow cycle lengths and phase lengths to vary (within programmable minimum and maximum parameters) in accordance with the real-time demand for all possible traffic movements, including pedestrians. The Orono and Old Town corridors were determined to be poor candidates at present for any significant operational improvements. The existing outdated controller technology is incompatible with advanced detection equipment and programming for more efficient, responsive dual-intersection control. The corridors in Old Town and Orono each consist of two signalized intersections that are so closely spaced that they can be operated from a single traffic controller. However, the existing Multisonics controllers even restrict the range of improvements that can be made by upgrading the detection equipment at each intersection, because the real-time volume and occupancy data provided by advanced detection systems cannot be processed by these older units. Therefore, Sewall was not able to make short-term recommendations other than to replace any malfunctioning detectors, and to implement some minor timing improvements to the existing actuated cycles. With an upgrade to Econolite ASC-3 controllers and video detection systems, both systems would benefit greatly from efficiencies and added capabilities in volume and occupancy detection, timing, and phase coordination while retaining the dual-intersection, single-controller approach. (Note: The Econolite model is recommended primarily to promote system compatibility throughout the BACTS area, as it has already been adopted as the equipment standard for Bangor and it is widely used in Brewer. The ASC-3 is the most advanced model currently available in the Econolite controller inventory, and with up to 16 uniquely assignable phase sequences per cycle, it is especially well-suited to dual-intersection, single-controller operation.)

5.0 SYSTEM IMPROVEMENTS AND RECOMMENDATIONS

5.1 BANGOR IMPROVEMENTS AND RECOMMENDATIONS

Sewall used Synchro and SimTraffic modeling software to develop and calibrate a traffic capacity and simulation model for both Union Street and Broadway. Current traffic counts were obtained from BACTS and in some cases from other consulting firms, as several commercial development projects added new trips to the Broadway corridor during the study period. For each of the two Bangor coordinated signals systems, the traffic models were used to develop 12 new traffic-responsive timing plans. Any of these 12 plans can be selected by the master controller at any time of day, depending on the detected traffic volumes and directionality within the corridor. Smoothing algorithms and a minimum plan-change interval of 15 minutes ensure that the plans are not changing constantly in response to transient fluctuations in volume and occupancy.

UNION STREET PLANS

CYCLE LENGTH	DETECTED TRAFFIC CONDITIONS		
70 seconds	Low – inbound flow	Low – balanced flow	Low – outbound flow
80 seconds	Low/med – inbound	Low/med – balanced	Low/med – outbound
90 seconds	Med/high – inbound	Med/high – balanced	Med/high – outbound
100 seconds	High – inbound	High – balanced	High – outbound

BROADWAY PLANS

CYCLE LENGTH	DETECTED TRAFFIC CONDITIONS		
80 seconds	Low – inbound flow	Low – balanced flow	Low – outbound flow
90 seconds	Low/med – inbound	Low/med – balanced	Low/med – outbound
100 seconds	Med/high – inbound	Med/high – balanced	Med/high – outbound
110 seconds	High – inbound	High – balanced	High – outbound

Appendix B provides a more detailed technical chart showing the names, cycle lengths, and Aries control system software addresses for each of these newly programmed plans in the controller memory banks, as a reference guide for system administrators and controller maintenance personnel.

While the traffic-responsive plans were being developed for each corridor, Sewall worked closely with BACTS, Bangor Public Works, and Econolite to troubleshoot and correct all identified deficiencies in system detection, controller functions, and interconnect communications to and from the master controller. In some cases, Bangor Public Works was able to provide spare equipment from their stockroom or reallocate previously purchased components. Other low-cost components were purchased off-the-shelf to ensure that the master controller in each corridor would receive all the information it needed to implement a fully traffic-responsive signal system.

As with all timing plans that are created using a computer-simulated modeling process, the traffic-responsive plans for the Union Street and Broadway corridors both required a break-in period of monitoring and adjustment to match real-world traffic conditions following implementation. The City of Bangor provided ample public notice prior to making the switch from time-of-day to traffic-responsive operation for the Broadway corridor, in order to prepare the general traveling public for changes to their expected traffic signal sequences. (Advance publicity was not needed for the changes on Union Street, since none of the existing signal phase sequences were altered as part of the traffic-responsive implementation.) Upon implementation there were some programming bugs to correct and not all of the initial public commentary for Broadway was positive. However, at this time both systems appear to be working well, and anecdotal observations indicate that through traffic is flowing more smoothly with fewer delays than before traffic-responsive operation was implemented. BACTS plans to conduct an “after” time-delay study in the spring of 2009, which will quantify the actual travel time reductions in each corridor since the “before” time-delay study was undertaken.

Sewall has two long-term recommendations for the Union Street and Broadway signal systems:

- Maintain the existing equipment configuration and system clocks in good working order, and
- Monitor to ensure that the traffic-responsive signal systems continue to efficiently handle travel demand up to the 85^{th} percentile annual daily traffic volume. At some future date, if traffic volumes in these corridors continue to increase, it may become necessary to reanalyze the traffic conditions and add timing plans (and possibly special-event or emergency evacuation plans) to each system’s traffic-responsive “toolbox” of available programs.

5.2 ORONO IMPROVEMENTS AND RECOMMENDATIONS

As described above, the Orono system consists of two closely spaced intersections on Main Street (Mill Street and Pine Street) that are controlled from a single older-manufacture Multisonics controller. Sewall used Synchro and SimTraffic modeling software to develop and calibrate a capacity and simulation model, using recent traffic counts provided by BACTS. Although no major system improvements could be made in the short term due to the technology limitations of the controller, Sewall engineers used the traffic modeling information to implement some minor timing improvements to address peak hour delays in downtown Orono.

A spreadsheet itemizing Sewall's longer-term recommendations for the Orono signal system is provided in Appendix A of this document. The recommendations include the purchase of a new Econolite ASC-3 controller, video detection for all approaches at both intersections, and a relocation of the existing controller box since it currently hinders sidewalk accessibility for pedestrian traffic and controller maintenance. The spreadsheet also includes estimated costs for providing an interconnected visual prompt for the school crossing guard at the unsignalized intersection at Goodridge Drive, located approximately 500 feet south of the signalized intersection at Pine Street. The crossing guard would be instructed to stop through traffic to cross pedestrians and vehicles only when the prompt lights up, corresponding to periods when through traffic is already stopped at the signals in downtown Orono. The current practice is to randomly stop through traffic at Goodridge Drive whenever pedestrians or vehicles arrive at the school crossing. The extended queues that develop on Orono's Main Street in both directions, particularly during the morning commute to the Orono Public Schools and the University of Maine, should be greatly reduced if the manually controlled crossing at Goodridge Drive is coordinated with the upstream signal operations at Pine Street and Mill Street.

5.3 OLD TOWN IMPROVEMENTS AND RECOMMENDATIONS

The Old Town signal system also consists of two closely spaced intersections on Center Street (Water Street and Main Street) that are controlled from a single older-manufacture Multisonics controller. Sewall used Synchro and SimTraffic modeling software to develop and calibrate a capacity and simulation model, using recent traffic counts provided by BACTS. Although no major system improvements could be made in Old Town over the short term due to the technology limitations of the controller, Sewall used the traffic modeling information to implement minor improvements to address peak hour delays in downtown Old Town.

A spreadsheet itemizing Sewall's longer-term recommendations for the Old Town signal system is provided in Appendix A. The recommendations include the purchase of a new Econolite ASC-3 controller, video detection for all approaches at both intersections, and a relocation of the existing controller box. The current location of the controller box presents a fixed-object hazard to vehicles, and it hinders sidewalk accessibility for pedestrian traffic and controller maintenance. It is located only a few feet behind the curb on Center Street, and displays multiple dings and dents where it has been hit by passing trucks and snowplow blades.

6.0 CONCLUSIONS

A traffic-responsive operational mode has been programmed and implemented for the existing coordinated signal systems on Union Street and Broadway in Bangor, and both systems appear to be functioning well at this time. Traffic-responsive operation reduces delays and congestion during both peak and in non-peak travel periods by allowing the controller to automatically select and switch to the most appropriate of 12 stored timing plans, based on continuous 15-minute monitoring of traffic volume and occupancy within the corridor. A traffic-responsive system represents the highest and best use of Bangor's existing traffic controller technology in these commuter corridors, and thus it provides additional value and return on investment on the equipment costs at each signalized intersection.

Significant operational improvements are not yet possible for the Old Town and Orono signal systems, due to outdated controller technology and system detection deficiencies. Some minor timing changes have helped to improve peak-hour flow in both corridors, but they will require new controller units (preferably in relocated controller boxes) and upgraded detection equipment before meaningful reductions in congestion and delay can be realized. A detailed list of required equipment purchases that would enable optimized free operations in these corridors, including conservative cost estimates for each component, are provided in Appendix A for use in compiling candidate projects for future BACTS biennial transportation improvement programs (BTIPs).

7.0 APPENDICES

7.1 APPENDIX A – PLAN AND COST ESTIMATE

BACTS SIGNAL IMPROVEMENT PLAN FOR ORONO and OLD TOWN
Installed Cost Estimate

ORONO, Pine Street and Mill Street at Main Street

	ITEM	COST
1	Replace and relocate existing controller with new 4 ring/16 phase controller in new 'P" Cabinet Relocate controller (recommend: southeast corner of Main & Pine)	$40,000
2	Install new video detection at all approaches to both intersections	$24,000
3	Install remote intersection monitor and phone drop	$3,000
4	Replace existing controller cabinet with small NEMA 4/5 cabinet (to be used as junction box only)	$1,000
5	Install new 4 inch conduit between existing controller location and new location	$2,000
6	Install new signal and detector cable as required	$2,500
7	Crossing guard indicator system (inclusive of cable and conduit from controller)	$5,000
	TOTAL	**$77,500**

OLD TOWN, Main Street and Water Street at Center Street

	ITEM	COST
1	Replace and relocate existing controller with new 4 ring/16 phase controller in new 'P" Cabinet Relocate controller (recommend: east side of Center St. between Main & Water)	$40,000
2	Install new video detection at all approaches to both intersections	$24,000
3	Install remote intersection monitor and phone drop	$3,000
4	Install new 2 and 3 inch conduit	$4,000
5	Install new signal and detector cable as required	$4,000
	TOTAL	**$75,000**

COMBINED TOTAL FOR ORONO AND OLD TOWN: $152,500

7.2 APPENDIX B – SYSTEM STRUCTURE

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BACTS SIGNAL SYSTEM STRUCTURE
by Michael R. Waugh, P.E.
James W. Sewall Company

Introduction

The new Union Street and Broadway signal system structure was developed by Senior Engineer Michael R. Waugh, P.E., of James W. Sewall Company, based on insights gained over four decades of hands-on programming work on traffic control systems. It conforms to the software standards of most modern system suppliers, so it is not specific to a single vendor or controller model. If this system structure could be consistently applied to coordinated signal systems in the BACTS metropolitan area, it would help to minimize confusion and possible errors in programming. A consistent system structure can streamline much of the workload for experienced system operators and outside consultants, and it also helps to flatten the learning curve for new traffic operations personnel. This technical appendix presents some general background information on the programming of traffic controllers for a coordinated system, plus very specific information on the numbering system and structure that was selected for the Union Street and Broadway coordinated systems. The document can serve as an instruction manual for signal system operators and their managers, not just for ongoing maintenance of the Union Street and Broadway systems, but as a reference guide to promote the use of a consistent system structure in coordinated signal systems throughout the BACTS area.

Signal Plan Structure

A signal plan is identified in the master controller by a one-up program identification number, and also by a three-digit operational code representing a combination of Cycle Length, Offset, and Split (COS). Thus a unique COS identifies each individual plan in the program memory. This structured numbering system makes it easy to instantly recognize the operational characteristics of each program. For example, if the plan in effect has a COS of 231, the operator understands that the system is operating in Cycle Length 2, Offset 3, and Split 1. In a modern controller, it is possible to assign COS numbers that communicate additional useful information to system operators.

The Econolite Aries system software and the signal plan structure in the master and local controllers allow plans to be entered with up to six different cycle lengths (referred to as "dials" in the Econolite programming vocabulary), up to five offsets, and up to four splits, for a total of 120 possible COS combinations -- although only 64 unique plans can be stored in the master controller, due to memory constraints. Since most roadways in BACTS achieve acceptable levels of service with system cycle lengths between 70 and 110 seconds, the proposed BACTS signal structure (already in effect on Broadway and Union Street) adopts the convention of assigning all 70-second cycle plans to Dial 1, all 80-second cycle plans to Dial 2, all 90-second cycle plans to Dial 3, all 100-second cycle plans to Dial 4, and all 110-second cycle plans to Dial 5. (Dial 6 in this system is reserved for future special-event programs, which typically require longer cycle lengths.) Using this numbering convention, a system operator can quickly determine the current signal cycle length at any time on Union Street or Broadway by running a status check and looking at the first digit of the COS number. (In our example from above, COS 231 starts with a "2," identifying it as an 80-second cycle plan.) The second digit in the COS identifier, the Offset number, can be used to identify the directionality of the traffic plan. In the proposed system structure, Offset 1 is assigned to all plans designed for predominantly inbound traffic flows, Offset 2 is used for plans with relatively balanced traffic distribution, and Offset 3 is used for predominantly outbound traffic plans. Offsets 4 and 5 are reserved for future assignment as needed. The third digit in the COS number represents the Split, and it has been left in its default setting of 1 (BACTS is unlikely to require the assignment of Splits 2 through 4, which are generally reserved within this system for special programs that address short-term but highly predictable daily traffic events, such as shift changes at a large factory). In the example of COS 231, a BACTS operator who understands the system structure will instantly recognize that the program currently in effect is an 80-second outbound plan. If the same operator later receives notification through Aries that the plan has switched over to COS 421, that simple 3-digit code communicates a shift to a 100-second, average-flow plan due to changing traffic conditions in the corridor. This system structure has already been provided for all of the new traffic programs developed by Sewall for the Broadway and Union Street corridors, and it would be a very simple data entry task to convert other BACTS coordinated signal systems over to the same structured identification system.

The following tables present a graphic display of the system structure as applied to the individual traffic plans for the Union Street and Broadway corridors. All of these plans have been programmed in accordance with the system structure and numbering conventions as described above. For easier visual identification, the traffic plans for each corridor have been color-coded in groups of five according to increasing cycle length. Note that COS numbers with Offsets 4 and 5 for each cycle length have been allocated within the program memory banks, but they remain largely unassigned at this time. These numbers can be used either for the development of additional plans for the given cycle length, or to correctly identify the cycle lengths of older signal plans that have been retained in the controller system memory. For example, COS numbers 241, 251, and 441 are currently assigned to the old traffic plans for Union Street. Should the City of Bangor determine that the old plans are no longer needed, these plans could be deleted and their COS identifiers would then become available for reassignment.

BACTS SIGNAL MODIFICATION
Union Street Timing Pattern Schedule

Pattern	Dial No.	Cycle (Sec).	COS	Directionality
1	1	70	111	Inbound
2	1	70	121	Average
3	1	70	131	Outbound
4	1	70	141	Not yet assigned
5	1	70	151	Not yet assigned
6	2	80	211	Inbound
7	2	80	221	Average
8	2	80	231	Outbound
9	2	80	241	Used for old stored plan #62
10	2	80	251	Used for old stored plan #63
11	3	90	311	Inbound
12	3	90	321	Average
13	3	90	331	Outbound
14	3	90	341	Not yet assigned
15	3	90	351	Not yet assigned
16	4	100	411	Inbound
17	4	100	421	Average
18	4	100	431	Outbound
19	4	100	441	Used for old stored plan #61
20	4	100	451	Not yet assigned
21-60	NOT USED			
61	4	100	441	Peak Old Plan
62	2	80	241	Old IB Off-Peak
63	2	80	251	Old OB Off-Peak
64	NOT USED			

BACTS SIGNAL MODIFICATION
Broadway Timing Pattern Schedule

Pattern	Dial No.	Cycle (Sec).	COS	Directionality
1*	1*	110*	111*	Old Plan*
2	1	70	121	Not Used
3	1	70	131	Not Used
4	1	70	141	Not Used
5	1	70	151	Not Used
6	2	80	211	Inbound
7	2	80	221	Average
8	2	80	231	Outbound
9	2	80	241	Not yet assigned
10	2	80	251	Not yet assigned
11	3	90	311	Inbound
12	3	90	321	Average
13	3	90	331	Outbound
14	3	90	341	Not yet assigned
15	3	90	351	Not yet assigned
16	4	100	411	Inbound
17	4	100	421	Average
18	4	100	431	Outbound
19	4	100	441	Not yet assigned
20	4	100	451	Not yet assigned
21	5	110	511	Inbound
22	5	110	521	Average
23	5	110	531	Outbound
24	5	110	541	Not yet assigned*
25	5	110	551	Not yet assigned
26-60	NOT USED			
61	6	140	611	Old peak IB
62-64	NOT USED			

*Note: According to the system structure conventions, the original Broadway signal plan (retained in the master controller at the request of the City of Bangor) should have been bumped out of the Dial 1 ring and reassigned as Plan 62, Dial 5, Cycle 110, COS 541. All of the old Union Street programs were reassigned in this fashion, so that Dial 1 could be allocated to the new Union Street 70-second cycle plans in accordance with the numbering system. However, since a 70-second cycle was determined to be too short for efficient signal coordination on Broadway, there was no urgent reason to dislodge the old Broadway traffic plan from its existing position on Dial 1 as COS 111. Eventually, however, this program should be reassigned as Program #62 with the correct COS identifier (assuming the City of Bangor still wishes to retain it) in order to maintain system integrity. The 140-second plan identified on the Broadway table as #61, COS 611, was developed by Michael R. Waugh, P.E. to handle unusually high traffic volumes when the Kenduskeag Bridge construction work on I-95 shunted interstate traffic onto a cross-town detour route via Broadway. This plan is correctly identified in accordance with the system structure.

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